Modelling the energy demand for transport in Sub-Saharan Africa: World Energy Outlook as a Case Study

by

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Master of Science Thesis TRITA-ITM-EX 2019:653

KTH Industrial Engineering and Management
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Abstract

Energy demand projections are essential tools that enable policymakers, engineers, scientists, stakeholders and investors to assess the future energy needs of a country and understand the technical, economic, social and environmental costs associated with meeting this demand. Such tools become further indispensable in the case of developing countries, where past consumption trends alone cannot indicate the trajectory of their future energy demand.

Transport is one of the largest consumers of energy among all the end-use sectors. In 2018, it accounted for almost 29% of the total final consumption (TFC) of energy and 65% of oil consumption in the world [1]. A key ingredient for economic growth, mobility is indispensable for access to employment, education, health care and other services and operating industrial and trade activities. This report describes an energy demand model of the transport sector for selected countries in Sub-Saharan Africa. The countries modelled are Angola, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, South Africa and Tanzania. With the exception of South Africa, the transport sector in the focus countries is largely underdeveloped and outdated.

Road transport dominates the energy demand for transport in the region today and this trend is projected to continue to 2040. The ownership of cars increases rapidly, especially in cities, but this growth starts from very low levels as the region is home to countries with the lowest ownership rates in the world. As in the case of emerging Asian economies, the fleet of two- and three-wheelers grows

faster than that of cars and a significant share of this growth comes from rural areas. Aviation is the largest non-road consumer of energy and this continues to 2040 as a consequence of rising GDP and rapid urbanisation. Rail and navigation lag behind current global levels but are projected to develop significantly to aid in achieving the industrialisation goals set out by the African Agenda 2063.

In its current state, the sector faces major challenges like inadequate and poorly maintained infrastructure, dealing with increasing traffic congestion in cities, large-scale imports of second-hand vehicles with poor emission standards that affect air quality in cities, lack of safe and formally operated public transportation systems and insufficient consideration for the different mobility needs of women. Sound policymaking and investments in infrastructure have the potential to overcome or significantly reduce the severity of most of these challenges in the future.

Key-words

Energy demand projections, modelling, transport, infrastructure, Sub-Saharan Africa, road, rail, aviation, navigation, oil consumption, population, GDP, growth, urbanisation, air quality, sustainability, policies, development

Sammanfattning

Energibehovsprognoser är grundläggande verktyg som möjliggör för beslutsfattare, ingenjörer, forskare, intressenter och andelsägare att bedöma framtida energibehov för ett land och förstå de tekniska, ekonomiska och de miljömässiga kostnaderna förknippade med att möta detta behov. Dessa verktyg är än mer oumbärliga i fallet för utvecklingsländer, där tidigare förbrukningstrender enskilt inte kan indikera den framtida utvecklingen av energibehoven.

Transport är en av de största förbrukarna av energi utav alla slutanvändningssektorer. Under 2018 stod den för nästan 29% av den totala slutförbrukningen (TFC) av energi och 65% av oljekonsumtionen i världen[1]. Som en nyckelingrediens för ekonomisk tillväxt är rörlighet oumbärligt för åtkomst till anställning, hälsovård och andra tjänster och drift av industri och handelsaktiviteter. Den här rapporten beskriver en energibehovsmodell av transportsektorn för utvalda länder i subsahariska Afrika. Länderna som har modellerats är Angola, Elfenbenskusten, Demokratiska Republiken Kongo, Etiopien, Ghana,Kenya, Mozambique, Nigeria, Senegal, Sydafrika och Tanzania. Undantaget Sydafrika så är transportsektorn i de utvalda länderna i stora delar underutvecklad och föråldrad.

Vägtransporter dominerar energibehoven för transport i regionen idag och den här trenden förväntas pågå fram till 2040. Ägandet av bilar ökar kraftigt, framförallt i städer, men den här tillväxten sker från väldigt låga nivåer då länderna i regionen tillhör den grupp länder med lägst ägande i världen. Som är fallet med växande ekonomier i Asien, så växer flottan av två- och

trehjulingar snabbare än den för bilar och en signifikant andel av den tillväxten sker i lantliga områden. Flyg är den största förbrukaren utanför vägarna vilket förväntas fortsätta fram till 2040 som en konsekvens av växande BNP och snabb urbanisering. Järnväg och sjöfart släpar efter aktuella globala nivåer men förväntas att utvecklas signifikant för att uppfylla industrialiseringsmålen som finns uppsatta av African Agenda 2063.

I det aktuella stadiet, så möter sektorn stora utmaningar som otillräcklig och dåligt underhållen infrastruktur, ökade trafikstockningar i städer, storskalig import av andrahandsfordon med dåliga utsläppsstandarder som påverkar luftkvaliteten i städerna, avsaknad av säker och officiellt driven kollektivtrafik samt otillräcklig hänsynstagande för kvinnors transportbehov. Sunt beslutsfattande och investerande har potentialen att övervinna eller signifikant reducera allvaret av de flesta av dessa utmaningar inför framtiden.

Nyckelord

Energibehovsprognoser, modellering, transport, infrastruktur, subsahariska Afrika, väg, järnväg, luftfart, sjöfart, oljekonsumtion, befolkning, BNP, tillväxt, urbanisering, luftkvalitet, hållbarhet, politik, utveckling

Modelling the energy demand for transport in Sub-Saharan Africa: World Energy Outlook as a Case Study

Master Thesis Report

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Abstract

Energy demand projections are essential tools that enable policymakers, engineers, scientists, stakeholders and investors to assess the future energy needs of a country and understand the technical, economic, social and environmental costs associated with meeting this demand. Such tools become further indispensable in the case of developing countries, where past consumption trends alone cannot indicate the trajectory of their future energy demand.

Transport is one of the largest consumers of energy among all the end-use sectors. In 2018, it accounted for almost 29% of the total final consumption (TFC) of energy and 65% of oil consumption in the world [1]. A key ingredient for economic growth, mobility is indispensable for access to employment, education, health care and other services and operating industrial and trade activities. This report describes an energy demand model of the transport sector for selected countries in Sub-Saharan Africa. The countries modelled are Angola, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, South Africa and Tanzania. With the exception of South Africa, the transport sector in the focus countries is largely underdeveloped and outdated.

Road transport dominates the energy demand for transport in the region today and this trend is projected to continue to 2040. The ownership of cars increases rapidly, especially in cities, but this growth starts from very low levels as the region is home to countries with the lowest ownership rates in the world. As in the case of emerging Asian economies, the fleet of two- and three-wheelers grows faster than that of cars and a significant share of this growth comes from rural areas. Aviation is the largest non-road consumer of energy and this continues to 2040 as a consequence of rising GDP and rapid urbanisation. Rail and navigation lag behind current global levels but are projected to develop significantly to aid in achieving the industrialisation goals set out by the African Agenda 2063.

In its current state, the sector faces major challenges like inadequate and poorly maintained infrastructure, dealing with increasing traffic congestion in cities, large-scale imports of second-hand vehicles with poor emission standards that affect air quality in cities, lack of safe and formally operated public transportation systems and insufficient consideration for the different mobility needs of women. Sound policymaking and investments in infrastructure have the potential to overcome or significantly reduce the severity of most of these challenges in the future.

Acknowledgements

I feel a sense of sincere gratitude towards Laura Cozzi for giving me this great opportunity to work on my Master thesis project in the prestigious World Energy Outlook team, at the International Energy Agency in Paris. Her encouragement and support to young and aspiring students is exceptionally kind.

I need to give a special mention to Dr. Stéphanie Bouckaert, for guiding me throughout my internship and helping me take the smallest but first step towards realising my dream of contributing to the field of energy and sustainability.

I received a tremendous amount of practical and scientific aid from my mentor and friend, Apostolos Petropoulos, and I would like to convey my deepest gratitude to him for the time and effort that he spent on guiding and assisting me.

I cannot forget to mention here that Dr. Francesco Fuso-Nerini, who is also the academic supervisor of my thesis internship, played a pivotal role in nurturing my interest to join the field. I thank him for his kind support, motivation and insightful lectures on energy demand modelling.

I sincerely appreciate and cherish the help and advice that I received from all the colleagues of the WEO team and beyond – Paul Hugues, Yasmine Arsalane, Dr. Andreas Schröder, Zakia Adam, Arthur Contejean, Davide d'Ambrosio, Wilfred Yu, Adam Baylin-Stern, Timothy Goodson, Olivia Chen, Ali Al-Saffar, Brent Wanner, Claudia Pavarini, Daniel Crow, Tae-Yoon Kim, Timur Gül, Jacob Teter, Jacopo Tattini, Sacha Scheffer, Thibaut Abergel, Michela Cappannelli, Connor Donovan, Leonie Staas, Jianguo Liu, Daeyoung Kim, Marcela Ruiz de Chavez and Haoua Coulibaly – each of whom supported me in their own unique way.

I must also thank my entire department and Prof. Mohammad-Reza Fakhraie, along with everyone at the student services office in KTH for making my move from Stockholm to Paris a lot more comfortable and simple. A final but very important mention is owed to Teresa Coon, Marina Dos Santos and Eleni Tsoukala at the IEA, who work relentlessly to make every endeavour of the WEO team a success.

Paris, September 2019

Contents

List of tables

List of figures

Glossary

AC	Africa Case
AEO	Africa Energy Outlook (of World Energy Outlook 2019)
AFD	French Development Agency
AfDB	African Development Bank
AU	African Union
BRT	Bus Rapid Transit
CPS	Current Policies Scenario
DR Congo	Democratic Republic of the Congo
EV	electric vehicle
GDP	gross domestic product
GFEI	Global Fuel Economy Initiative
GIZ	(German) Society for International Cooperation
HFT	heavy freight truck
IEA	International Energy Agency
IMF	International Monetary Fund
ITDP	Institute for Transportation and Development Policy
ITF	International Transport Forum
KWh	kilowatt-hour
LCV	light commercial vehicle
LPG	liquefied petroleum gas
mb/d	million barrels per day
MFT	medium freight truck
Mtoe	mega tonnes of oil equivalent
OECD	Organisation for Economic Cooperation and Development
PLDV	personal light duty vehicle (passenger car)
SDG	United Nations Sustainable Development Goals
SDS	Sustainable Development Scenario
STEPS	Stated (Energy) Policies Scenario
SSA	Sub-Saharan Africa
TFC	Total Final Consumption
TPED	Total Primary Energy Demand
UNEP	United Nations Environment Programme
USD	US dollar
WB	World Bank
WEM	World Energy Model
WEO	World Energy Outlook

1 Introduction

This report describes the detailed approach adopted to complete a project undertaken at the International Energy Agency. The goal of the project was to create a simplified energy demand projection model for the transport sector in eleven major economies of Sub-Saharan Africa. The countries studied and analysed are: Angola, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, South Africa, Senegal and Tanzania.

In this chapter, we begin with a brief introduction to the World Energy Outlook, the key modelling scenarios and indicators, the relevance of studying energy trends in Africa and the evolution of energy demand in the region.

1.1 World Energy Outlook

The World Energy Outlook (WEO) is based on objective data and dispassionate analysis; it provides critical analysis and insights on trends in energy demand and supply, and what they mean for energy security, environmental protection and economic development.

The WEO is produced by the Energy Demand Outlooks Division, under Laura Cozzi, and the Energy Supply Outlooks Division, under Tim Gould, in the IEA's Directorate of Sustainability, Technology and Outlooks (STO). Each publication undergoes an extensive peer review process by leading international experts in the relevant fields from governments, industry, research institutions and other organisations.

The first WEO was published in 1977 and it has been an annual publication since 1998. The detailed projections are generated by the World Energy Model (WEM), a large-scale simulation tool, developed at the IEA over a period of more than 20 years that is designed to replicate how energy markets function. It covers the whole energy system, allowing for a range of analytical perspectives from global aggregates to elements of detail, such as the prospects for a particular technology or the outlook for end-user prices in a specific country or region.

The WEO uses a scenario-based approach to highlight the key choices, consequences and contingencies that lie ahead, and to illustrate how the course of the energy system might be affected by changing some of the key variables, chief among them the energy policies adopted by governments around the world.

The Sustainable Development Scenario, introduced in 2017, examines what it would take to achieve the main energy-related components of the "2030 Agenda for Sustainable Development" adopted in 2015 by member states of the United Nations. The three goals are: to achieve universal energy access to modern energy by 2030; to take urgent action to combat climate change; and to reduce dramatically the pollutant emissions that cause poor air quality.

The geographical reach of the analysis has expanded considerably. Since 2005, this has involved an annual in-depth country or regional focus. The thematic reach of the analysis has also grown. The annual 'fuel focus' was added in 2008 and has since covered all the major fuels and technologies, including energy efficiency. Access to modern energy has become a signature issue, with systematic monitoring of the numbers of the global population without basic energy services, together with analysis of the policies, technologies and investment required to close this gap.

1.2 Energy modelling: WEM scenarios and indicators

Since 1993, the International Energy Agency (IEA) has provided medium- to long-term energy projections using the World Energy Model (WEM). The model is a large-scale simulation model designed to replicate how energy markets function and is the principal tool used to generate detailed sector-by-sector and region-by-region projections for the *World Energy Outlook* (*WEO*) scenarios. Updated every year and developed over many years, the model consists of three main modules: final energy consumption (covering residential, services, transport, agriculture, industry and non-energy use); energy transformation including power generation and heat, refinery and other transformation; and energy supply. Outputs from the model include energy flows by fuel, investment needs and costs, CO_2 emissions and end-user pricing.

The WEM is a very data-intensive model covering the entire global energy system. Much of the data on energy supply, transformation and demand, as well as energy prices is obtained from the IEA's own databases of energy and economic statistics [2]. Additional data from a wide range of external sources is also used.

1.2.1 Scenarios

The *World Energy Outlook* makes use of a scenario-based approach to examine future energy trends relying on the WEM. For the *World Energy Outlook 2019 (WEO 2019),* detailed projections for three scenarios are modelled: the Stated Policies Scenario, the Current Policies Scenario and the Sustainable Development Scenario. For the upcoming special focus publication, *Africa Energy Outlook 2019* [1], the scenarios modelled are the Stated Policies Scenario and the Africa Case.

The scenarios differ with respect to what is assumed about future government policies related to the energy sector.

The ***Stated Policies Scenario*** (STEPS) is the central scenario for both WEO and AEO. It is identical to the former *New Policies Scenario* (NPS) and takes into account policies that are in place as of mid-2019 and those which have already been announced ("stated"), but does not speculate on how these might evolve in the future. The Stated Policies Scenario is more than "business-as-usual"; it incorporates some far-reaching commitments, including most NDCs, aspirations to achieve full energy access in a few years and, more recently, to reach net zero emissions in some countries and sectors. These ambitions are not automatically incorporated into the scenario: full implementation cannot be taken for granted, so the prospects and timing for their realisation are based upon an assessment of the relevant regulatory, market, infrastructure and financial constraints.

The ***Sustainable Development Scenario*** (SDS), introduced for the first time in the *WEO-2017*, is an essential counterpart to the Stated Policies Scenario. It sets out the major changes that would be required to reach the key energy-related goals of the United Nations Sustainable Development Agenda. Its three key pillars are: an early peak and rapid subsequent reductions in emissions, in line with the Paris Agreement (SDG 13), universal access to modern energy by 2030, including electricity and clean cooking (SDG 7) and a dramatic reduction in energy-related air pollution and the associated impacts on public health (SDG 3.9).

The ***Africa Case*** (AC), introduced in 2019 for the special focus on 11 major economies in Sub-Saharan Africa, combines features of the WEO's Sustainable Development Scenario along with the specific economic aspirations of these countries as underlined in the Agenda 2063 [3]. It describes a pathway to the achievement of universal access to modern energy services in the African continent by 2030, including not only access to electricity but also clean cooking. It is different from the Sustainable Development Scenario in that it is modelled on far more ambitious GDP projections as the backbone for a rapidly urbanising and industrialising, prosperous Africa. Table 1.1 lists the key features of the three scenarios.

	Stated Policies Scenario	Sustainable Development Scenario	Africa Case
Definitions	Existing policies are maintained and recently announced commitments and plans, including those yet to be formally adopted, are implemented in a cautious manner.	An integrated scenario specifying a pathway aiming at: ensuring universal access to affordable, reliable, sustainable and modern energy services by 2030 (SDG 7); substantially reducing air pollution (SDG 3.9); and taking effective action to combat climate change (SDG 13).	Designed and built on the premise of Agenda 2063. It takes into account each country's own vision for economic growth, while achieving the energy goals of the Sustainable Development Scenario.
Objectives	To provide a benchmark to assess the potential achievements (and limitations) of recent developments in energy and climate policy.	To demonstrate a plausible path to concurrently achieve universal energy access, set a path towards meeting the objectives of the Paris Agreement on climate change and significantly reduce air pollution.	To present a viable pathway for attaining inclusive and sustainable economic growth and development for a prosperous Africa, achieving both higher GDP growth and universal access to electricity and clean cooking.

Table 1.1: Summary of the definitions and objectives of the three WEM modelling scenarios referenced in the Africa Energy Outlook

1.2.2 Population assumptions

Rates of population growth for each WEM region are based on the medium-fertility variant projections contained in the United Nations Population Division report [4]. In WEO 2019, world population is projected to grow by 0.9% per year on average, from 7.6 billion in 2018 to 9.2 billion in 2040. Global population growth slows over the projection period, in line with past trends: from 1.2% per year between 2000 and 2018 to 1.0% between 2018 and 2026.

The trends are quite different in the African continent where the total population grows 2.2% annually over the projection period reaching 2.1 billion in 2040. This annual growth is even larger at 2.5% in developing Sub-Saharan Africa, with a significant share of this growth occurring in urban areas that see an annual average rise of 3.8% while adding over 500 million people to urban dwellings between 2018 and 2040.

1.2.3 Macroeconomic assumptions

Economic growth assumptions for the short to medium term are based largely on those prepared by the OECD, IMF and World Bank. Over the long term, growth in each WEM region is assumed to converge to an annual long-term rate. This is dependent on demographic and productivity trends, macroeconomic conditions and the pace of technological change.

In the Stated Policies Scenario, Africa's GDP grows at an average annual rate of 4.3% during the projection period to 2040. While North Africa and South Africa are currently the most developed regions in the continent, majority of the projected economic growth comes from the burgeoning potential of developing Sub-Saharan Africa that grows at an annual rate of 5%

over the same period. Tables 1.2 and 1.3 show the annual GDP growth for the different regions according to the assumptions of the Stated Policies Scenario.

Stated Policies Scenario	Compound average annual growth rate			
	2000-18	2018-25	2025-40	2018-40
North Africa	3.5%	4.3%	3.3%	3.6%
South Africa	2.7%	1.7%	2.8%	2.5%
Developing Sub-Saharan Africa	5.4%	4.2%	5.4%	5.0%
Africa	**4.3%**	**4.0%**	**4.4%**	**4.3%**

Table 1.2: Projected annual average GDP growth rates in North Africa, South Africa and developing Sub-Saharan Africa in the Stated Policies Scenario

Stated Policies Scenario	Compound average annual growth rate			
	2000-18	2018-25	2025-40	2018-40
Angola	5.8%	2.8%	3.5%	3.3%
DR Congo	5.3%	4.6%	5.9%	5.5%
Côte d'Ivoire	3.6%	6.8%	4.6%	5.3%
Ethiopia	9.0%	7.2%	6.1%	6.5%
Ghana	6.3%	5.1%	3.3%	3.9%
Kenya	4.8%	6.0%	5.9%	5.9%
Mozambique	7.1%	4.7%	6.6%	6.0%
Nigeria	6.3%	2.6%	3.7%	3.4%
Senegal	4.6%	8.9%	5.4%	6.5%
Tanzania	6.5%	4.6%	6.1%	5.6%

Table 1.3: Projected annual average GDP growth rates in 10 major economies of Sub-Saharan Africa in the Stated Policies Scenario

However, with currently stated policies, investment flows and technology trends, the outcome of the Stated Policies Scenario falls short of realising the full potential of Africa's energy-rich resource endowments and fulfilling the aspirations of a young and growing African population. If Africa is to satisfy its own economic aspirations and transform into a global powerhouse of the future, a substantial reshaping of the region's energy sector will be required. The confluence of demographics, falling costs of renewable energy technologies and ample domestic resources present Africa with a unique opportunity to be the first region to industrialise while building a sustainable economy.

In 2015, the Heads of State and Governments of the African Union (AU) adopted Agenda 2063 [3], a modern interpretation of Pan-Africanism, spelling out its vision for "an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena". Closely linked to the Sustainable Development Goals, it is an ambitious vision and one which will require significant political will and a sustained implementation framework if its goals are to be realised.

The essence of Agenda 2063 is the creation of a new Africa, a modern continent that is integrated, prosperous and at peace. It builds on previous Pan-African initiatives but is distinct in many respects: it sets out clear goals implementation plans and targets alongside elements of accountability; it identifies key flagship programmes as well as monitoring and review mechanisms; and, a clear resource mobilisation strategy. While Agenda 2063 sets out a comprehensive and ambitious blueprint for Africa, its success rests on overcoming a series of challenges. Most important among these are the lack of resources for its implementation alongside the need to develop government capacities, transparency and intra-African co-ordination institutional reform.

The GDP projections for the Africa Case are built on the premise of Agenda 2063, and take into account each country's own vision for economic growth, based on regional economic blueprints, energy master plans and Nationally Determined Contributions. It presents a viable pathway for attaining inclusive and sustainable economic growth and development. In the Africa Case, the continent's GDP grows at an average annual rate of 6.1% during the projection period to 2040 with developing Sub-Saharan Africa maximising its economic growth at an average yearly rate of 7.3%. Tables 1.4 and 1.5 show the annual GDP growth rate for the different regions according to the assumptions of the Africa Case.

Africa Case	Compound average annual growth rate			
	2000-18	2018-25	2025-40	2018-40
North Africa	3.5%	4.7%	4.8%	4.8%
South Africa	2.7%	3.2%	3.3%	3.3%
Developing Sub-Saharan Africa	5.4%	7.4%	7.3%	7.3%
Africa	**4.3%**	**6.0%**	**6.2%**	**6.1%**

Table 1.4: Projected annual average GDP growth rates in North Africa, South Africa and developing Sub-Saharan Africa in the Africa Case

Africa Case	Compound average annual growth rate			
	2000-18	2018-25	2025-40	2018-40
Angola	5.8%	3.9%	6.0%	5.3%
DR Congo	5.3%	8.1%	8.9%	8.7%
Côte d'Ivoire	3.6%	7.7%	8.0%	7.9%
Ethiopia	9.0%	8.8%	9.0%	8.9%
Ghana	6.3%	6.7%	6.1%	6.3%
Kenya	4.8%	7.3%	9.8%	9.0%
Mozambique	7.1%	7.6%	8.4%	8.1%
Nigeria	6.3%	5.8%	5.2%	5.3%
Senegal	4.6%	9.4%	8.3%	8.7%
Tanzania	6.5%	8.1%	9.8%	9.3%

Table 1.5: Projected annual average GDP growth rates in 10 major economies of Sub-Saharan Africa in the Africa Case

1.2.4 Historical energy balances

To project the future energy demand of any country to a degree of certainty, it is pivotal to have access to the historical energy consumption data of the country. The historical energy balances for every country, which act as essential inputs for the World Energy Model, are obtained from the Energy Data Centre. The Energy Data Centre (EDC) of the IEA Secretariat works closely with national administrations to collect a variety of energy statistics and compile energy balances on an annual basis for both OECD and non-OECD countries.

For non-OECD countries, data are compiled in close collaboration with the country administrations, other international organisations such as UNECE, OLADE, APERC, UNSD, FAO, and draws upon the work of the United Nations in the field of global energy statistics.

1.3 Why Sub-Saharan Africa?

Five years after a special report on Africa in the *WEO-2014* series, the IEA decided to update and expand its analysis of the energy outlook for the continent in the new *WEO-2019* report. The swift return to Africa as a focus region for the *World Energy Outlook* is a result of several factors.

Africa accounts for a disproportionately low share of the world’s energy demand and high share of population without access to electricity (Figure 1.1). The in-depth study presents selected energy data and projections for all of Africa, but much of the focus of the analysis and discussion is on Sub-Saharan Africa. The Sub-Saharan energy landscape is very diverse, including large populations without access to modern energy, but also a wide variety of national circumstances, resource endowments, cultures and prospects. This is why the geographical granularity was greatly improved since 2014. Eleven of the largest economies in Sub-Saharan Africa are assessed and analysed separately. These focus countries are Angola, Côte d’Ivoire, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Mozambique, Nigeria, Senegal, South Africa and Tanzania.

Sub-Saharan Africa is home to some of the world’s fastest growing economies, a wide range of natural resources and a young, rapidly urbanising workforce. There has also been steady progress in metrics such as economic growth, income per capita and life expectancy. While the region is home to a growing share of the global energy-poor, new renewable energy technologies alongside innovative digital technologies and finance tools halted the growth of people without access to electricity in 2016, giving new impetus to reach "reliable and sustainable energy for all" by 2030.

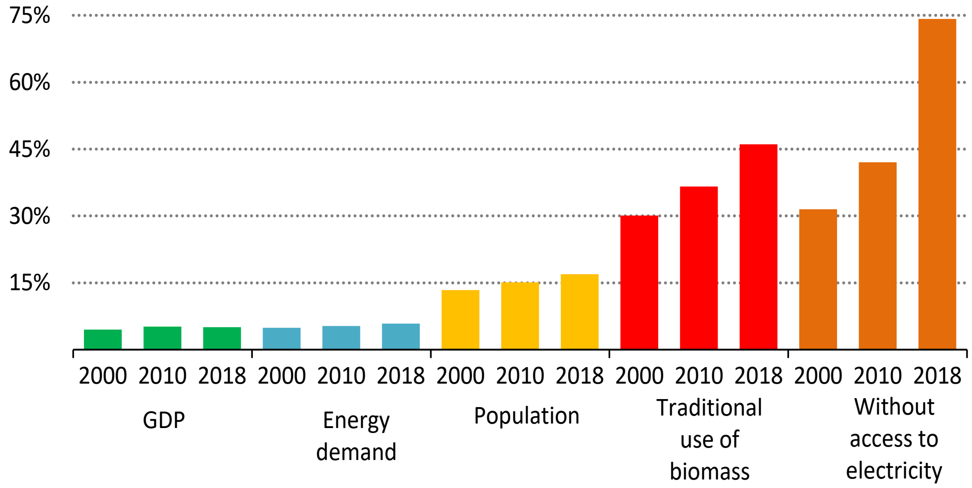

Figure 1.1: Africa's share of selected global indicators. Africa accounts for a disproportionately low share of global GDP and high share of global population without access to electricity [1]

Many of the minerals essential to modern energy transitions are also found in large amounts in Africa, including one-fifth of the world's uranium resources and large amounts of the strategic metals and minerals, like 90% of world cobalt reserves in DR Congo, serving as important components of batteries needed for the electric vehicle revolution.

1.4 Evolution of energy demand in Africa

In recent decades, African energy demand has been driven by the growing needs of North Africa, Nigeria, and South Africa. In 2017, primary energy demand in Africa was 815 million tonnes of oil equivalent (Mtoe), of which North Africa (24%), Nigeria (18%), and South Africa (16%) accounted for more than half despite making up only 35% of the population [1]. Nonetheless, average energy consumption per capita in most African countries is well below the world average of around 2 tonnes-of-oil equivalent per capita (Figure 1.2). The highest per capita consumption comes from South Africa and Nigeria at 2.32 and 0.8 toe/capita respectively – most other countries have a consumption of around 0.5, and the lowest, Senegal is 0.3. In most countries, a large part of energy consumption per capita consists of the relatively inefficient use of solid biomass.

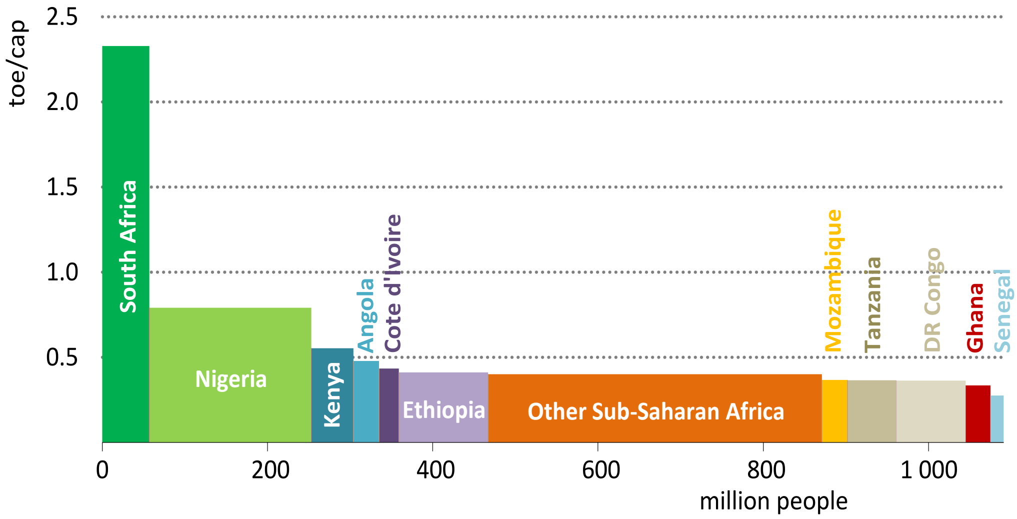

Figure 1.2: Per capita energy consumption and population in 2018 for selected countries in Africa. Average per capita energy consumption in Africa is far below the global average. [1]

The rate of growth in energy demand has slowed significantly in recent years and is low compared to GDP growth (Figure 1.3). Between 2000 and 2010, energy demand increased at an annual average rate of 3.4%, but this slowed to 2.7% from 2010 to 2018. There are also very strong regional variations. Countries such as the Democratic Republic of the Congo (Africa’s fourth most populous country) have seen their primary energy demand almost double between 2010 to 2018, whereas others such as Côte d’Ivoire, Ghana and Mozambique have witnessed only a gradual increase or even a decline in energy demand. The fall in demand does not mean energy services have declined. In fact, the opposite is true: in the case of both Mozambique and Côte d’Ivoire, the push towards LPG for cooking has resulted in a decline in solid biomass use, a substitution that also accounts for a large gain in efficiency.

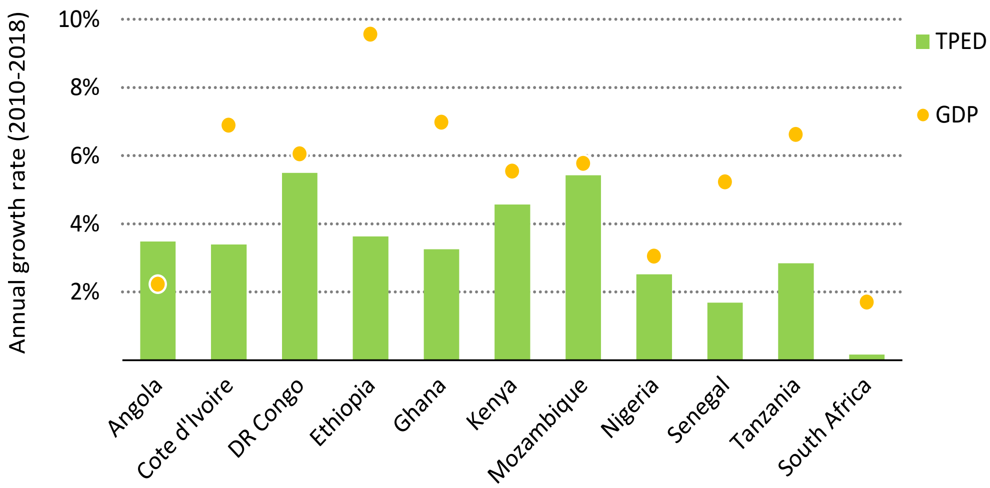

Figure 1.3: Annual growth rates of total primary energy demand (TPED) and GDP for selected African countries between 2010 and 2018 [1]

Fossil fuels currently represent almost 40% of the overall energy mix in Sub-Saharan Africa and more than half of the total African energy mix. Oil consumption stands at almost four million barrels per day (mb/d). The transport sector accounts for most oil use (around 60%) but it is also consumed as diesel for back-up generators and within households in the form of kerosene or LPG for lighting and cooking, and for industry [1].

2 Transport situation in Africa

Mobility is a key ingredient for economic growth: mobility for access to employment, education, health care and other services. Mobility of raw materials and goods is also crucial for smooth operations of industry, transport of agricultural produce and trade between different regions. Transport services have the power to drive development. The more the world urbanises, the more important it becomes to have adequate access to efficient, safe and sustainable transport solutions.

Certain studies on transport in Africa provide some useful insights on the topic. A study by GIZ analyses mitigation options for GHG emissions from the transport sector in Kenya [5] and finds that in the absence of fuel economy improvements in the imported second-hand vehicles and a shift from road to rail, emissions from road transport are set to rise dramatically to 2050. Yet another study on Kenya undertaken by GIZ looks into the characteristics of in-service road vehicle fleets [6] in major cities of the country. Their calculations showed that the average age of cars in Kenya is more than 12 years, with 9% of the fleet being over 20 years old. Research developed by the Addis Ababa Institute of Technology, UNEP and GFEI on Ethiopia's transport sector states that GHG emissions of passenger cars will increase from 2.5 million tonnes in 2010 to 13.1 million tonnes of CO_2 equivalent in 2030 and emphasises the need for fuel efficiency [7]. Further studies on Côte d'Ivoire [8] and Senegal [9] similarly discuss the importance of vehicle fleet age and fuel economy. Nevertheless, there exists a noticeable research gap in modelling the overall transport energy demand of the region. South Africa is the only country in Sub-Saharan Africa with a study published by the University of Cape Town in 2012 to quantify the energy needs of the transport sector [10]. It projects that transport energy demand in South Africa will double by 2050 under a "business as usual" scenario and this increase can be constrained to less than 30% in an alternative case that assumes annualised 2% improvement in fuel economy across all vehicle categories [10]. Moreover, all studies found on the topic highlight the urgent need for better data collection in the region as well as for the sector, which is currently the major limitation for more elegant modelling and research in the field. Transport is a sector that has an enormous scope for improving the social and economic situation in Africa and an assessment of its future energy needs is crucial.

About 60% of the continent's population lacks access to modern transport infrastructure [11] and the high cost of transportation is reported to increase the cost of goods traded between

African countries by 30 to 40% [12]. The sector currently faces a severe challenge on the continent, both in terms of infrastructure and regulations. These challenges can be overcome through a holistic approaching that combines sound policies and boosted investments.

In many parts of Africa, ownership of cars remains a luxury, while ownership of two-and three-wheelers is comparatively higher. The number of light-duty vehicles is increasing in many countries as incomes rise but the efficiency of the vehicle fleet is low as many of these are imported second-hand from Europe and Asia. Public transport is also less developed in many places but it could be pivotal to boost the economic and social welfare in the world's most rapidly urbanising region. Rail networks are scarce, and historically, many were built to meet the needs of extractive industries rather than as a way to provide passenger services. Instead, in many parts of the continent, households rely on informally operated, unsafe buses and minibuses to travel within or between cities. Providing safer and faster alternatives for transporting large numbers of people simultaneously and linking the rural/agricultural production areas to big commercial centres would be among the many benefits of investing in these modes of mass transport.

This chapter gives an overview of the current transport situation on the continent.

2.1 Road transport

Roads dominate the transport sector in most African countries, accounting for 80-90% of total passenger and freight traffic [13]. Although an estimated 200 billion USD of trade in Africa depends on road transport, the density of road network, per person as well as per square kilometre of land area, is far lower than in other regions of the world. Moreover, lack of proper and regular maintenance and upgrades results in degradation of road surfaces. Only 0.8 million kilometres out of the total 2.8 million kilometres of road networks in Sub-Saharan Africa are paved. Out of the total paved roads, only around half are in good condition. Compared to 101 kilometres per 10, 000 people in the European Union, the road to population ratio in Sub-Saharan Africa is only 27 kilometres per 10, 000 people [12]. Africa has an average of 204 km of roads per 1,000 square km; of which only one quarter are paved [14]. Thus, the density of national roads in Africa lags far behind the world average of 944 km per 1,000 square km, of which more than half are paved. Regionally, North Africa and South Africa fare much better than the rest of the continent.

The absence of transport to connect rural areas to cities also leads to loss of agricultural revenue, a sector that employs a sizeable fraction of the African population. Studies have shown that more than half of the untapped potential for cultivation in Sub-Saharan Africa is located more than six hours from a major market, and less than 40% of rural Africans live within two kilometres of an all-season road—by far the lowest level of rural accessibility in the developing world [15].

Road transport is also a major contributor to outdoor air pollution in Africa. A pre-dominantly second hand, ageing and growing vehicle fleet imported from Japan and Europe, poor fuel quality, absence of strict and uniform emission standards and rapid, improperly planned urban growth all contribute to increasingly choked cities. The average age of commercial road vehicles (buses and trucks) in Africa is 20 years, compared to 8 to 12 years in other emerging economies and less than 10 years for developed countries [16]. Improving public transport systems through sound policymaking, proper urban planning and capacity building, could reduce the number of smaller, less efficient vehicles on the road. Nevertheless, improving fuel quality, particularly to reduce sulphur content, is a necessary step towards the use of improved vehicle technologies that reduce tailpipe pollution.

2.2 Railways

Most of the railway lines in Africa were constructed for resource extraction and transport by the colonising nations in order to connect mines and other natural resources to ports. While this stitauation remains largely unchanged in most of Sub-Saharan Africa, South Africa is an exception. The South African rail system has been modernised through dedicated investments and the country now has the best rail infrastructure on the continent according to the United States Department of Commerce [17], including the upgraded famous luxury *Blue Train* for tourists and new projects like the Tambo Springs Intermodal Terminal [18] for freight transport set to be fully commissioned by 2022 in the pipeline. However, the sector has not seen such development in the rest of the region and still struggles with outdated rail infrastructure.

The total rail network size for Africa as a whole is 82,000 km [19], 84% of which are operational, with the remainder closed due to war damage, natural disasters or lack of maintenance and funds.

Passenger services account for around 20% of rail traffic. Financial studies have reported that railways that carry less than 1 million net tonnes of freight annually do not generate sufficient revenue to finance the capital costs of the infrastructure [20]. With the exception of South Africa and the North African countries, there are currently very few African countries that have the requisite volume of freight traffic. In 2016, Africa's share in total global tonne-kilometres of freight transported was just 2%.

This situation could quickly change with the rapid shift in the continent's demographics and increasing GDP. Rising urbanisation and industrialisation in the region will pose new transportation challenges which are better suited for railways. Africa, being home to a variety of natural resources and minerals could use railways to transport large volumes of goods.

2.3 Aviation

Air passenger transport demand has been growing steadily in Africa. In 2015, African airlines carried 79.5 million passengers, representing 2.2% of the global air passenger transport, up by 1.8% from 2014. 48.3 million passengers were carried on international routes, while 31.2 million were carried on domestic routes in 2015. Air freight carried by African airlines increased to 817,000 tonnes from 777,000 tonnes during the same year. African airlines represented 1.6% of total global freight carried in 2015 [12].

Although air transport in Africa is growing strongly, but from a very low level. It lags far behind other developing regions and is expensive with patchy connections. Though Africa has over 4,000 airports and airfields [16], a significant number of them do not meet International Civil Aviation Organization (ICAO) standards and recommended practices. Only 25% of these airports have paved runways. Intra-African air transport growth has been subdued to a large extent due to underdeveloped infrastructure and partly due to the lack of a proper liberalisation policy among African nations.

The International Air Transport Association (IATA) reports that though the share of Africa in global aviation industry remains relatively small, it employs 6.9 million people and contributes 80 billion USD to the African economy [21].

2.4 Navigation

Maritime transport is fundamental to international trade, accounting for over 90% of the global international trade transits through ports. It is even more dominant in Africa where 92 to 97% of international trade depends on ports [16]. However, poor maintenance and inefficient operations also plague this mode of transport in the continent.

Africa has 90 major ports, which handle only 6% of global maritime traffic. Of these, only six ports, three in Egypt and three in South Africa, account for 50% of Africa's total shipping traffic.

Africa's port productivity is low compared to the world average, estimated to be about 30% of the global level. Dwell time for vessels at a port is an important indicator of efficiency of port operations and the average dwell time recorded at a number of major ports in Africa is about 11 days, which is three times as long as the average dwell times at ports in other developing regions. Dar-es-Salaam, one of the major ports in East Africa, has a recorded dwell time of 15 days [16]. Efficient management and better maintenance of equipment could effectively reduce the dwell time and boost income from international trade significantly.

3 Methodology

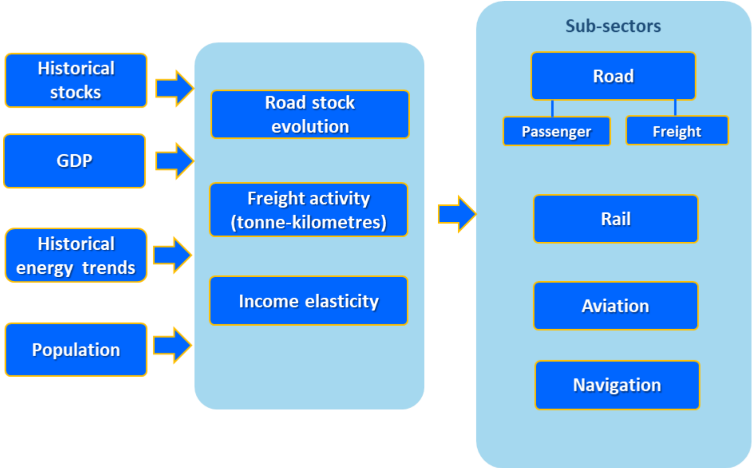

Figure 3.1: Schematic representation of the transport module of the Africa Model for WEO 2019.

The transport module of the WEM consists of several sub-models to clearly describe energy demand behaviour in road transport, rail, aviation and navigation. The model methodology presented in this chapter was developed during the course of the thesis internship. The Africa Model for transport (Figure 3.1) was built using a very similar overall structure as the WEM but by making certain simplifications to accommodate for the lower availability of detailed data for this region as compared to OECD countries. While the WEM treats Sub-Saharan Africa (except South Africa) as one aggregated region of 49 countries, the Africa Model projects the demand for the 10 major economies individually and aggregates the remaining 39 countries as one region.

Given the significantly larger share of road transport in the total transport energy demand, road transport was modelled with a fully bottom-up approach, accounting for the evolution of individual parameters like stocks, fleet composition, mileage and fuel economy, that affect energy demand over time. As non-road modes have a much smaller contribution to total energy demand and the detailed data available for their stocks and infrastructure in Africa is scarce, these modes were modelled using a top-down regression based on the year-on-year GDP per capita growth in each country.

3.1 Road transport

Road transport is further subdivided into passenger and freight transport. Passenger vehicles include personal light duty vehicles (PLDVs/passenger cars), two- and three-wheelers and buses. Freight vehicles include light commercial vehicles (LCVs), medium freight trucks

(MFTs) and heavy freight trucks (HFTs). The following subsections describe the methodology used to project the energy demand arising from the two categories of road transport.

The sub-category of road transport was modelled with higher granularity in the Africa Model than it is done in the WEM in the way that it was further divided into rural and urban road transport. This was done with the goal of later analysing the effect of the rapid urbanisation currently underway in Sub-Saharan Africa.

While the historical stock numbers (in thousands) are different for each country, the Africa Model is coupled with the WEM to get feedback for parameters such as the fleet composition by fuel, the fuel economy (in litres per 100 kilometre) and mileage (in kilometre) for each vehicle and fuel type. These parameters are assumed to be the same in all focus countries except South Africa. The fuel economies and mileages were adjusted for urban and rural cases by using suitable multiplication factors. In the fleet composition, it was assumed that the demand for electricity for transport in Africa comes predominantly from urban areas.

3.1.1 Passenger vehicles

The number of passenger cars (PLDVs) and two- and three-wheelers per urban and rural household as well as the mean number of people per urban and rural household were obtained from a database of the USAID [22] and used to calculate the total urban and rural shares of these vehicles. For buses, it was assumed that mini-buses operate in urban areas and long distance buses contribute mainly to the energy demand of rural areas. The resulting split between urban and rural vehicles was applied to the detailed vehicle fleet stocks drawn from the IEA Mobility Model (MoMo) [23] to obtain the historical stock numbers of each vehicle type in urban and rural areas for every country of the Africa Model. The future projections of these stocks was done in the same way as in the WEM by starting with an S-shaped Gompertz function. This method gives the vehicle ownership based on income (IEA GDP assumptions through to 2040) and two variables: the saturation level (the assumed maximum vehicle ownership of a country/region) and the speed at which the saturation level is reached. The equation used is:

$$V_t = y\, e^{a e^{b (GDP/capita)_t}} \qquad \text{-------- (1)}$$

where V is the vehicle ownership (expressed as number of vehicles per 1000 people), t is the year for which the value is being calculated, y is the saturation level (expressed as number of vehicles per 1000 people), a and b are negative parameters defining the shape of the function, i.e. the speed of reaching the saturation level. The saturation level is drawn from bibliography and is based on several country/region-specific factors such as population density, urbanisation and infrastructure development. Projected vehicle stocks are then benchmarked against several real-life considerations and developments. The resulting vehicle stock projections could therefore differ from those that would be derived solely by the use of the Gompertz function.

The final energy demand, for each vehicle type and each fuel, was then calculated as a product of the total time series of the stocks, fuel economy, mileage and fleet composition from the base year to the end of the projection period according to equation 2.

$$E_{roadpass_{fuel}} = stock\ X\ \ fleet\ composition_{fuel}\ X\ \ fuel\ economy_{fuel}\ X\ mileage_{fuel} \text{ -------- } (2)$$

3.1.2 Freight vehicles

Freight vehicles can be broadly classified into light-commercial vehicles (less than 3.5 tonnes), trucks (between 3.5 and 16 tonnes) and heavy trucks (above 16 tonnes). The urban and rural split of stocks for LCVs was assumed to be the same as that for PLDVs, while medium and heavy trucks were assumed to contribute mainly to rural areas. The projected activity levels (in million tonne-kilometres or Mtkm) were calculated using equation 3 given below. Subsequently, the freight fleet required to serve the projected activity levels were estimated using a linear regression between the projections of GDP and the freight activity.

$$Activity = stock\ X\ mileage\ X\ occupancy\ factor \qquad \text{-------- } (3)$$

The occupancy factor (in tonnes) is an indication of the average number of tonnes of goods that can be transported by each type of vehicle.

3.2 Non-road transport

Due to scarcity of available data for non-road modes and their relatively small share in the overall transport energy demand compared to road transport, a simpler econometric approach was adopted for their energy demand projections. The key variables used here were the historical energy demand for the aviation, rail and navigation modes in each country and the effect of income elasticity approximated by the GDP per capita. While historical energy balances provide the demand until the base year, the equation 4 was to used to project the demand beyond the base year:

$$E_{non-road_t} = \left\{E_{non-road_{t-1}} X \left[\frac{\left(\frac{GDP}{capita}\right)_t}{\left(\frac{GDP}{capita}\right)_{t-1}} - 1\right] X \in +1\right\} X \; e \qquad \text{-------- (4)}$$

Where $E_{non-road}$ is the energy demand for the relevant non-road mode, t is the year for which the value is being calculated, $\in$ is the elasticity factor that determines how quickly the the energy demand grows for a given growth in GDP per capita between two consecutive years and e is the efficiency improvements of the relevant non-road mode.

3.2.1 Rail

The current railway infrastructure in Africa was pre-dominantly built during the colonial years and is generally in a poor state of maintenance. However, several new projects are expected (see Annex I) to change this situation and result in a rise in the importance of rail transport both for passengers and freight, especially for trade within different African nations. The elasticity factor based on historical trends and bibliography for rail in equation 4 is:

$$\in = 0.3 \;\; in\ Stated\ Policies\ Scenario$$

$$\in = 0.5\ for\ selected\ countries\ (Annex\ I)\ in\ Africa\ Case$$

3.2.2 Aviation

From historical data, aviation is the largest and fastest growing consumer of energy among the three non-road modes of transport in the eleven focus countries. Rapid urbanisation across the continent and globally observed transportation trends indicate that aviation would likely maintain its position as the most significant consumer of energy in non-road transport. To reflect this, aviation grows more rapidly with GDP per capita compared to rail and navigation. The elasticity factor assessed from historical trends for aviation in equation 4 is:

$$\in = 0.5 \;\; in\ Stated\ Policies\ Scenario\ and\ Africa\ Case$$

3.2.3 Navigation

Most of the international trade from Africa is documented to occur through shipping and navigation. There has been a constant effort over recent years to build new ports and infrastructure to boost the African economy further. The elasticity factor assessed from historical trends for navigation in equation 4 is:

$$\in = 0.2 \;\; in\ Stated\ Policies\ Scenario$$

$$\in = 0.3\ for\ selected\ countries\ (Annex\ I)\;\; in\ Africa\ Case$$

4 Results

This chapter presents the results obtained through the modelling of transport energy demand for the focus countries. Section 4.1 briefly explains how the road vehicle stocks evolve with time in the two scenarios, while section 4.2 lists and elaborates all the key features of the projected transport energy demand to 2040. All results presented below exclude South Africa, except where specified.

4.1 Road stock evolution

The growth of road vehicle stocks were individually modelled by different vehicle categories in order to enable a detailed bottom-up projection for road energy demand, which claims the largest chunk of total transport energy demand in Africa.

4.1.1 Road passenger vehicles

PLDVs see an average annual growth rate of 5.6% in the Stated Policies Scenario and 7% in the Africa Case during the projection period in the region. In 2018, Nigeria had by far the largest fleet of over 2.6 million personal cars and Tanzania and Ethiopia had the smallest at under 150,000. The highest annual growth rates are projected for Côte d'Ivoire, Ethiopia, Mozambique, Tanzania and DR Congo although Tanzania, Ethiopia and Mozambique start this growth from very low levels. In both scenarios, Nigeria grows below the regional average rate at 3.9% (in STEPS) and 5.8% (in AC) per year but continues to possess the single largest fleet in 2040 at over 6 million and almost 9.2 million cars in the respective cases. Figure 4.1 illustrates the share of each country in the projected total PLDV stocks of the region in 2040 in the Stated Policies Scenario.

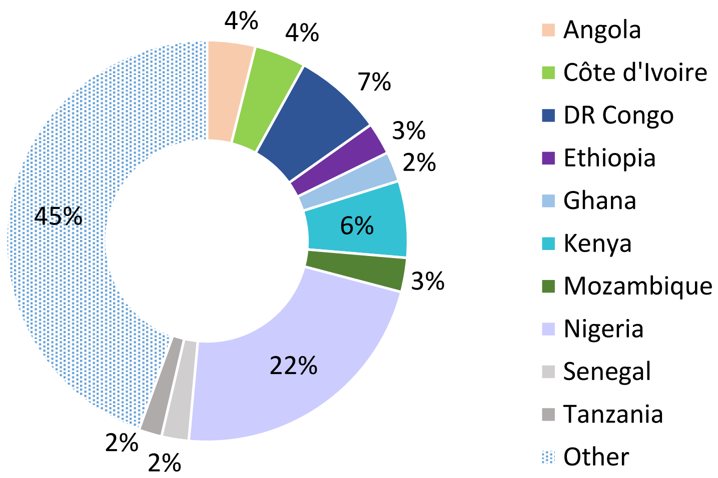

Figure 4.1: Share of each focus country, excluding South Africa, in the total car stocks of Sub-Saharan Africa by 2040 in the Stated Policies Scenario ("Other" includes 39 countries)

Two- and three-wheelers grow at 4.8% annually in the Stated Policies Scenario and 6.2% in the Africa Case. Nigeria and Senegal were at two ends of the spectrum in 2018, with stocks of almost 8 million and only 37,000 respectively. Kenya, Ghana, Tanzania, Ethiopia, Côte d'Ivoire and DR Congo show significant growth till 2040. By 2040, Nigeria is projected to have almost 15 million and over 21 million two- and three-wheelers in the Stated Policies Scenario and Africa Case respectively. Among the remaining countries, Kenya stands out for being a leading market for this vehicle category with stocks of almost 2.6 million and over 3.3 million by 2040 in the two scenarios.

Buses start from a much lower level (refer to Section 6.4) in all countries and grow at 4.9% in the Stated Policies Scenario and 5.1% in the Africa Case for the whole region. Nigeria is projected to have a fleet of 4.3 million and 5.9 million buses by 2040 in the two scenarios respectively. DR Congo, Angola and Senegal have the smallest stock of buses throughout the projection period, not even reaching 50,000 buses by 2040 in the Stated Policies Scenario.

4.1.2 Road freight vehicles

Till 2040, LCV stocks in the region grow at an average annual rate of 3.4% in the Stated Policies Scenario and 4.9% in the Africa Case. Heavy (HFT) and medium trucks (MFT), which are significant consumers of diesel in Sub-Saharan Africa, grow annually at 3.8% and 3.4% in the Stated Policies Scenario and 5% and 4.6% in the Africa Case.

4.2 Energy demand evolution

This sub-section first displays the results for total energy demand projections by transport mode, country and fuel and then, presents the specific demand for oil products for transport in Sub-Saharan Africa.

4.2.1 Total energy demand

In 2018, the total energy demand for transport in the focus countries (excluding South Africa) was 51.1 Mtoe, of which road transport accounted for 97.2%. In the Stated Policies Scenario, the total transport energy demand increases at an average annual rate of 3.4% to reach 105.5 Mtoe by 2040, with road transport again accounting for the largest chunk at 97.4%. In the Africa Case with higher GDP projections, the total demand grows at a faster pace of 4.2% per year to reach 128.1 Mtoe by 2040, with road transport alone being responsible for almost 125 Mtoe. While the absolute numbers increase in the Africa Case, the balance between the share of road and non-road modes still remains strongly tilted towards road transport.

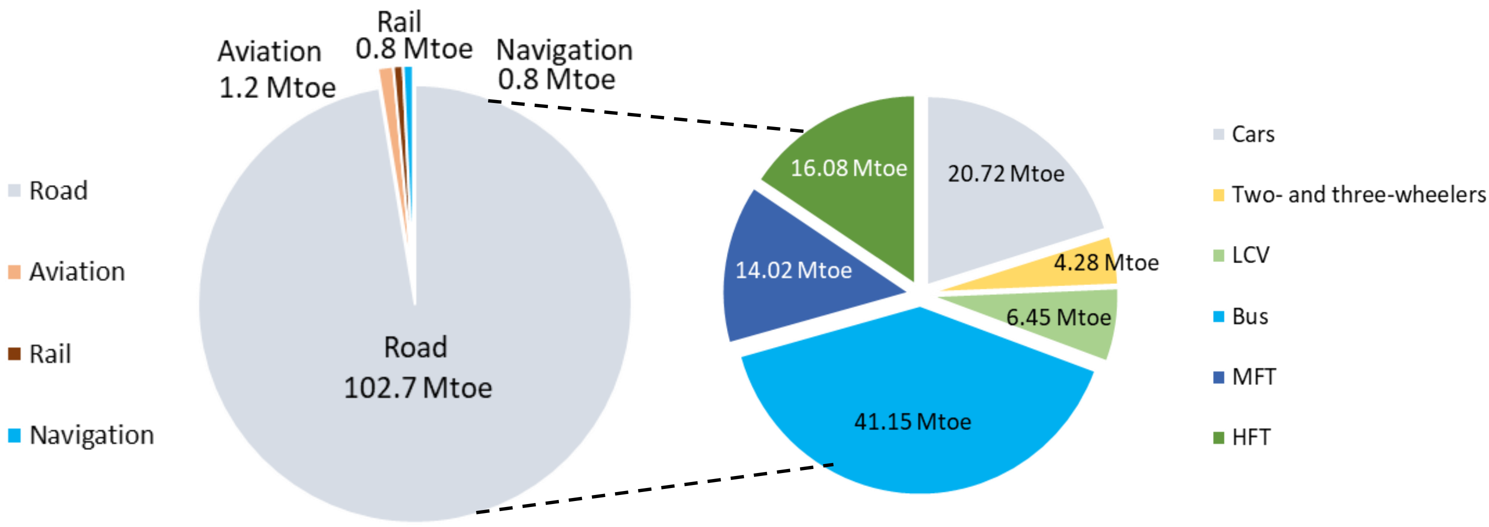

Figure 4.2: Total energy demand (in Mtoe) by transport mode (left) and the breakdown of demand from different vehicle categories of road transport (right) in 2040 in the Stated Policies Scenario.

Taking a closer look at road transport (Figure 4.2), cars and buses together account for over 60% of road transport demand by 2040 in the Stated Policies Scenario. Despite consuming far less energy per vehicle than cars, at just over 4 Mtoe, the large stock of two- and three-wheelers in the region stand for 4.2% of the demand. Heavy and medium trucks account for around 29% of total demand, while light commercial vehicles take up just over 6%.

The total energy demand (in Mtoe) for all transport modes in the focus countries today and the increase in demand till 2040 for the Stated Policies Scenario and the Africa Case are illustrated in Figure 4.3. Nigeria was and is projected to remain the single largest consumer of energy for the transport sector, owing to its much larger stock size across all vehicle categories. In 2018, Nigeria's transport sector consumed almost 10 times as much energy as that of Tanzania and almost 18 times that of Senegal. With Nigeria's demand steadily stabilising and the stocks and demand in other countries growing significantly, this gap slowly closes over the projection period. By 2040, Nigeria's consumption is projected to be 6 times that of Tanzania's and less than 14 times that of Senegal's.

In the Stated Policies Scenario, Kenya, Ghana, Côte d'Ivoire, Mozambique, Senegal, Tanzania and Ethiopia all show remarkable growth in transport energy demand, more than doubling their 2018 consumption levels by 2040. Further in the Africa Case, Kenya's demand increases by a factor of 2.8 over its 2018 consumption levels, while Ghana and Tanzania are projected to consume more than 3.5 times as much energy for transport in this scenario as they did in 2018.

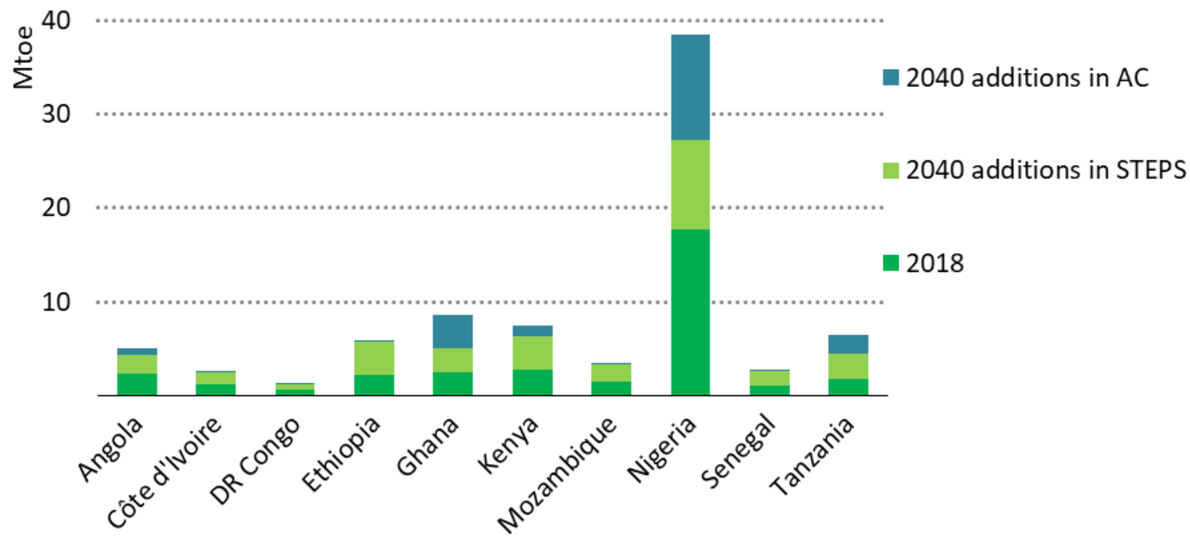

Figure 4.3: Total transport energy demand (in Mtoe) by country in 2018 and 2040 in the Stated Policies Scenario and Africa Case.

In 2018, transport in Sub-Saharan Africa was entirely fuelled by oil products, a mix of gasoline and diesel. Oil still remains the main fuel in the Stated Policies Scenario to 2040, accounting for 103.6 Mtoe of the total 105.5 Mtoe energy demand for transport, while natural gas and biofuels increase their shares in the mix to 1% each. In the Africa Case, which assumes a higher penetration of alternative fuels like the Sustainable Development Scenario, oil makes up almost 95% of the total 128 Mtoe energy demand for transport, while natural gas increases to 3.2%, biofuels to 1.3% and electricity to 1%.

4.2.2 Oil demand

As in the rest of the world, transport is a major consumer of oil in Sub-Saharan Africa. In 2018, transport accounted for 64% of the total final fossil fuel (oil) consumption across all end use sectors in the region (Figure 4.4). By 2040, oil demand for transport is projected to double in the Stated Policies Scenario and increase 2.5 times in the Africa Case.

Splitting the oil demand for road transport into gasoline and diesel, where passenger vehicles in Africa are pre-dominantly fuelled by gasoline and freight vehicles by diesel, the share of gasoline in 2018 was 56%. By 2040, the gasoline share drops to 53% to account for the increase in freight vehicles in the Stated Policies Scenario, but rises to 61% in the Africa Case where the more ambitious GDP projections lead to a much faster increase in the stocks of passenger cars and motorcycles

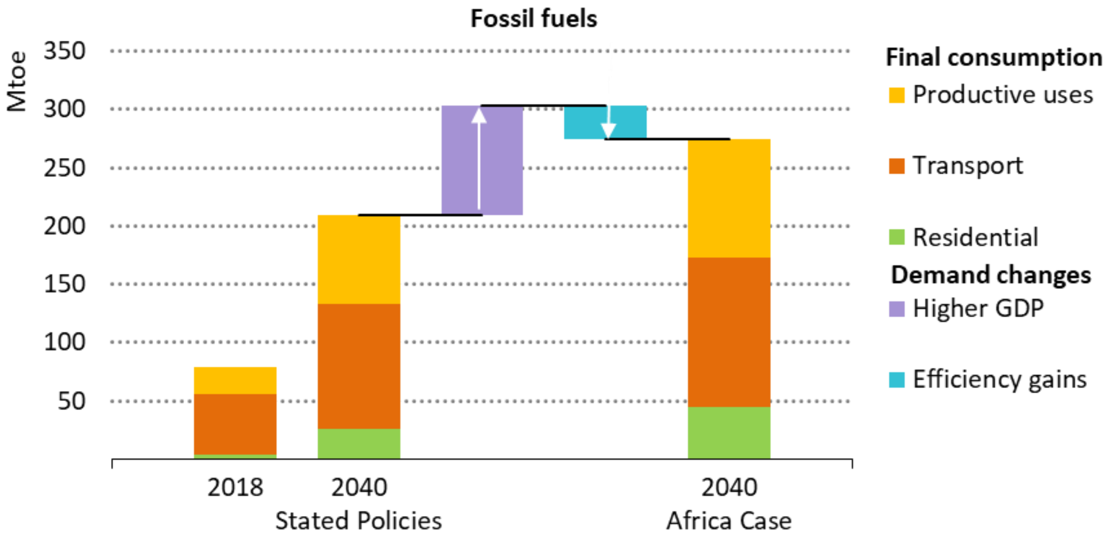

Figure 4.4: Total demand for fossil fuels (in Mtoe) from all end use sectors by 2040 in the Stated Policies Scenario and Africa Case. Demand increases between the two cases due to higher GDP and the increase is partially offset by efficiency gains. [1]

Though its share in the total demand across sectors reduces to 51% and 47% in the two scenarios but transport still remains the most significant consumer of oil in the region. Figure 4.4 illustrates the share of each end use sector in total oil consumption today and the projected demand by 2040 in the two scenarios. Table 4.1 gives the evolution of total oil demand for transport in the region for the two scenarios in million barrels per day (mb/d). Although a higher GDP increases the demand for oil in the Africa Case, the improved fuel economy standards compared to the Stated Policies Scenario offset a part of that rise in demand to 2040 (see Section 5.2).

Oil demand for transport (mb/d)	historical		projected	
	2010	2018	2030	2040
	0.69	1.06		
Stated Policies Scenario			1.55	2.15
Africa Case			1.89	2.54

Table 4.1: Evolution of oil demand (in mb/d) for the transport sector (excluding South Africa) in the Stated Policies Scenario and Africa Case.

5 Analysis

This chapter discusses and analyses the noteworthy features observed in the results of the transport sector projection for Sub-Saharan Africa.

5.1 Room for growth

Sub-Saharan Africa has a smaller passenger car stock than Australia, whose population is around 90% smaller. In 2018, at 115 per 1 000 people, South Africa's car ownership rate was four-times the African average [1], but stands at less than half the average for developing countries globally (while in Ethiopia the ownership of vehicles is around 2 per 1000 people).

The room for growth in the continent with the world's smallest per capita vehicle ownership rates is understandably massive and in all scenarios, there is a large expansion of the passenger car and two- and three-wheeler stocks in the period to 2040. In the Stated Policies Scenario, the car stock triples, to reach 25 million. This is still relatively small, with average ownership levels of 16 per 1000 inhabitants being equivalent to only 60% of the ownership rate in India today. Factoring in an accelerated rate of economic growth, as in the Africa Case, the vehicle stock reaches more than 50 million by 2040. Figure 5.1 compares the ownership of personal passenger vehicles in the ten African countries today with the average ownership of other developing economies. Even under the assumptions of the Africa Case, most of the focus countries do not reach 50% of today's average ownership levels of other developing economies by 2040.

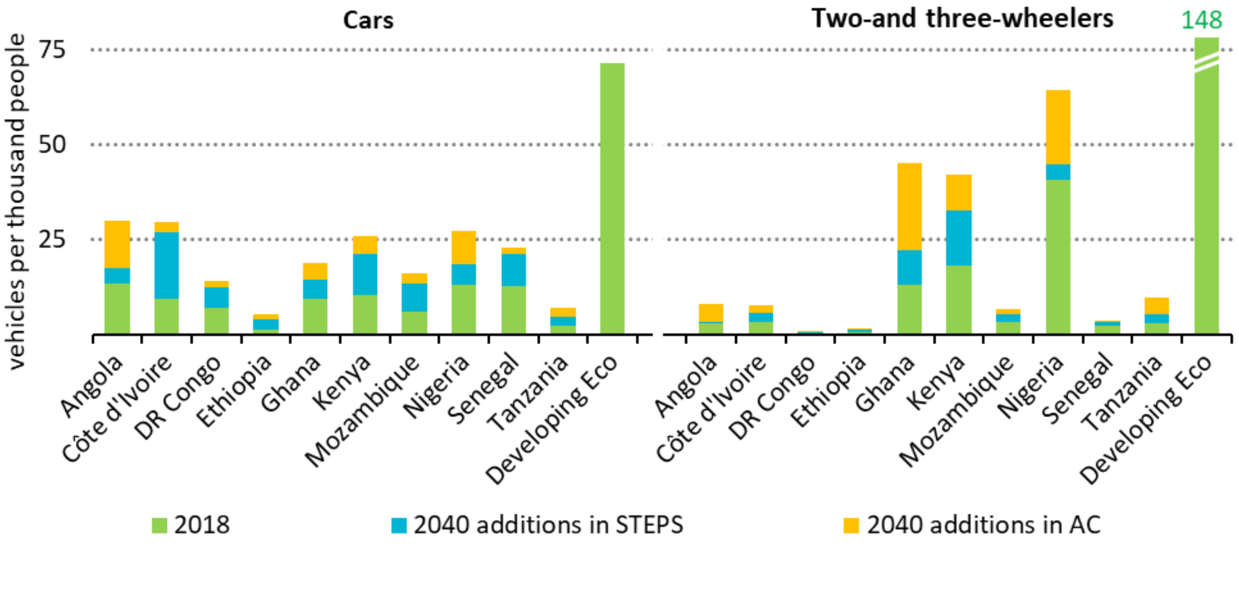

Figure 5.1: Ownership levels (in vehicles per thousand people) by country for cars and two- and three-wheelers till 2040 in the Stated Policies Scenario and Africa Case, compared to the average ownership in developing economies in 2018. [1]

5.2 Gains from efficiency and electrification in the Africa Case

The increase in road transport demand fuels a significant increase in oil use in Africa. Under the assumptions of the Stated Policies Scenario, oil demand increases from just over one million barrels per day today to reach almost 2.15 million barrels per day by 2040. Demand is slightly higher in the Africa Case, at 2.54 million barrels per day (Figure 5.2), but this accounts for almost 8.5 million additional cars, with the increased efficiency of the fleet in effect negating the consumption of 410 kilo barrels per day in 2040.

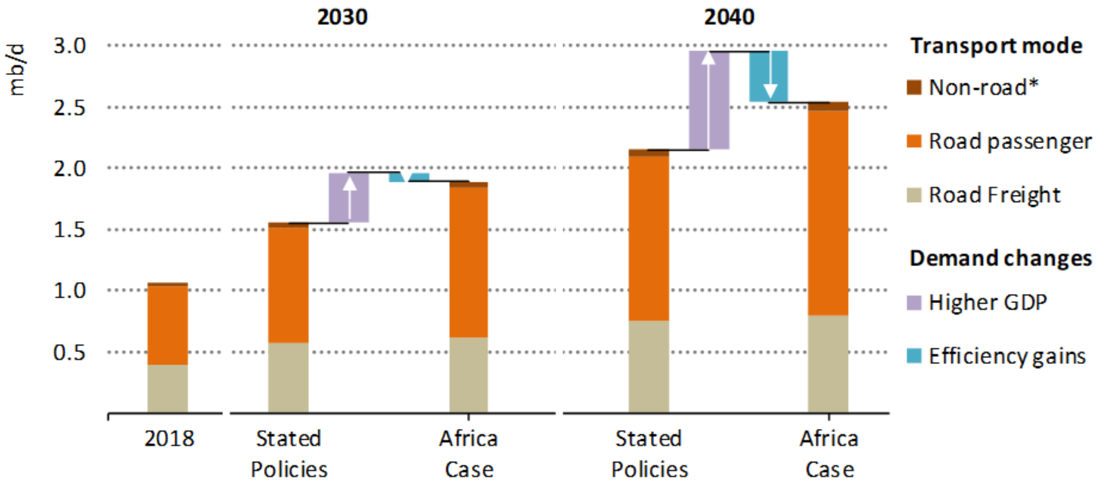

Figure 5.2: Total oil demand (in mb/d) for transport in Sub-Saharan Africa, excluding South Africa, in 2018, 2030 and 2040 in the Stated Policies Scenario and Africa Case. * Non-road aggregates rail, aviation and navigation [1]

The electrification of transport struggles to get started in the Stated Policies Scenario, reaching only 0.5% of transport energy demand, mainly due to the absence of policy measures supporting the electric vehicles (EVs). Progress is faster in the Africa Case, with a greater shift towards EVs, nonetheless, electric cars account for only 0.2% of cars on the road in 2040, while the share is 18% electric from for two and three wheelers. This translates to 65,000 fewer cars and 10.7 million fewer two- and three-wheelers that are fuelled by oil. Conditions for the electrification of transport are more favourable in urban areas with existing grid connections, as a result, the majority of EV uptake in Africa is concentrated in cities (see Section 6.2), with 29% of the urban two-and-three wheeler fleet electrified by 2040. By 2040, electricity demand for transport reaches 15 TWh in the Africa Case, two times higher than the Stated Policies Scenario but still only 1% of total transport energy demand Electricity demand growth by region.

5.3 Mobility and urbanisation

The urban African population is growing rapidly, increasing by 260 million (+90%) since 2000. The share of the population living in cities now exceeds 43%, up eight percentage points in this time [1]. A key driver for this movement is that urban centres play an outsized role in economic output – in Sub-Saharan Africa, 143 cities generate around $500 billion, or half the region's GDP. 600 million people will be moving to, or be born in, African cities by 2040. Although urbanisation trends have been observed globally, the magnitude of the transformation currently re-shaping African demographics has never been seen in any other region of the world, and is expected to be twice as large as the projected urbanisation rate of India in the next two decades.

There is a large discrepancy between transport demand in cities and rural areas. The 6.5 million passenger cars in cities in Sub-Saharan Africa (excluding South Africa), represent almost 80% of the total car stock of the region. This number grows at 6% annually in the Stated Policies Scenario, approaching 23 million cars and bringing the share of urban areas to 85% of the total car stock by 2040. The same number grows at more than 7% annually in the Africa Case with the ambitions for a more prosperous economy increasing the urban car stock to more than 30 million. In contrast, rural areas contribute to 51% of the current stock of 15 million two- and three-wheelers in the region. Growing robustly in both the Stated Policies Scenario and the Africa Case, the rural share of two- and three- wheelers continues to account for a sizeable 42% of the total stocks of these light vehicles to 2040, dropping slightly to accommodate the trend of rapidly increasing urbanisation in these countries.

In the Africa Case, fuel economy improvements save 4.7 Mtoe of energy demand coming from cars in urban areas, much higher than the 0.8 Mtoe saved in rural areas due to the proportionately larger stock of cars in cities and poorer road conditions in rural areas. Savings from two- and three-wheelers are not as significant because their stocks grow faster than the improvements in their fuel economy characteristics. Figure 5.3 shows the energy demand from urban and rural areas for cars and two- and three-wheelers in the Stated Policies Scenario and Africa Case.

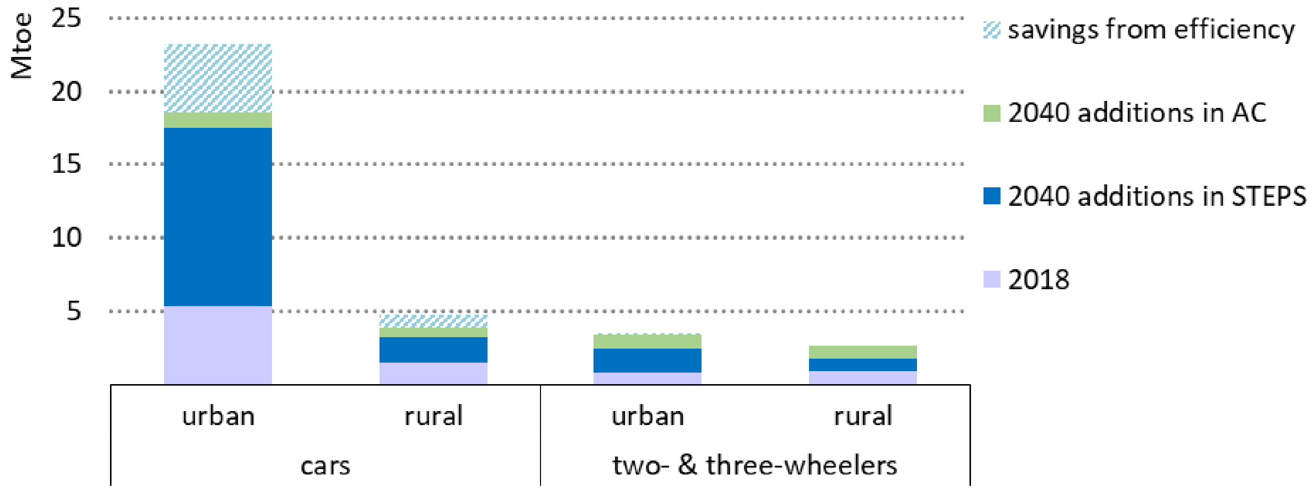

Figure 5.3: Total energy demand (in Mtoe) for cars and two- and three-wheelers in urban and rural areas by 2040 in the Stated Policies Scenario and Africa Case.

6 Conclusions and policy recommendations

Although there are many blindspots and uncertainties when it comes to projecting the future energy demand of the African continent, given the diverse needs and various stages of development of every country, the massive opportunity for growth across the region is apparent. This room for growth is particularly substantial in Sub-Saharan Africa, where most countries except South Africa and Nigeria are ranked among the smallest consumers of energy per capita.

Modernisation of the transport sector has the potential to solve many social, economic and environmental challenges facing the region today. Access to modern, efficient and safe transport could improve access to employment opportunities, education and healthcare, thereby, boosting overall productivity and wellbeing of the society. Additionally, transport is the key factor that enables trade between countries and continents and economic losses due to inefficient transport systems can be avoided by improved planning and sound policies.

While road transport accounts for the greatest share of transport energy demand in Africa, the continent is still home to countries, like Ethiopia, Tanzania, Mozambique and DR Congo, with some of the lowest car ownership rates in the world. The scope to grow is evident and total car stocks increase significantly, particularly in urban areas, till 2040 in both modelling scenarios to reach a percentage of today's ownership levels of developing Asian countries. Two- and three wheelers that are popular in many developing countries due to their affordability, are already growing rapidly in both rural and urban Africa and this rise is expected to continue as mobility needs will increase with population. As envisaged in Agenda 2063, the industrialisation of Africa will become a priority and with that, the role of freight transport, shipping and railways will gain prominence. Aviation is the largest consumer of energy among non-road modes and would be expected to continue growing as a result of rapid urbanisation.

The following sub-sections outline the various areas in which sound policies, improved infrastructure and entreperneurial endeavours could significantly improve the current transport situation in Africa. They deal with the concerns surrounding second-hand, polluting vehicles, the opportunity to electrify light passenger vehicles, the potential for biofuels as low-carbon transport fuels, the increasingly important role of public transport in fast-growing cities and the mobility challenges facing African women.

6.1 Emission and fuel economy standards

Beyond just the number of additional vehicles on the road, the condition of the fleet will, in large part, determine the future of energy consumption in the transport sector. Air pollution is already blighting several of Africa's largest cities, and with some of the lowest vehicle ownership rates in the world, it is evident that this problem cannot solely be attributed to the number of cars on the road, but also to the quality of the vehicles sold in many countries. Up to 80% of personal cars in Africa are second-hand cars imported, with little to no restrictions [24], from Japan and Europe with poor emissions standards that no longer satisfy the legislation of the source countries [1]. The situation is not much better for sales of new cars where only Nigeria (Euro 3) and South Africa (below Euro 3) have any emissions standards in place [25], and the Euro 3 standard was superseded in Europe some 15 years ago (Table 6.1). Countries in the East Africa region have recently agreed to adopt sub-regionally harmonised Euro IV/4 equivalent standards for new vehicles [24].

Country	Current emission standards for new vehicles	Regulation on import of second hand vehicles
Angola	N/A	3 year age limit on second hand imported cars
Côte d'Ivoire	N/A	no import restrictions, incremental tax on vehicles older than 10 years
DR Congo	N/A	10 year age limit on second hand imported cars
Ghana	N/A	no import restrictions, graduated penalty for vehicles older than 5 years
Kenya	N/A	8 year age limit on second hand imported cars with a proposal to reduce it to 5 years under process
Mozambique	N/A	5 year age limit on second hand imported cars
Nigeria	Euro 3	15 year age limit on second hand imported cars
Senegal	N/A	8 year age limit on second hand imported cars
South Africa	Below Euro 3	import of second hand cars is banned
Tanzania	N/A	vehicle import tax

Table 6.1: Emissions standards imposed on new and second hand vehicles in Africa [24] [25]

Average fuel economy of cars on road in Sub-Saharan Africa is at 8.4 l/100 km, less efficient than the average of 7.4 l/100 km in North African countries and much less efficient than the European Union average of 6.9 l/100 km [1]. Among several possible solutions, the most practical would be to ensure a uniform age limit on imported cars across all African countries and restricting the import of cars that do not meet the minimum fuel economy and emission standards in their source country. Fuel quality specifications are also being introduced and can herald great benefits. The East African region harmonised their fuel quality, setting sulphur limits for petrol of 150 ppm, and for diesel of 50 ppm [26] [27]. This was implemented in 2016 and has resulted in a ten-fold improvement on previous fuel quality standards.

6.2 Electrification and low-carbon fuels

The limited projected electrification of transport (see Section 5.2) is a result of the high power requirements to charge electric vehicles, relative to other uses. Designing the extension of electricity access with the electrification of transport in mind would significantly increase costs of achieving universal access. Supply reliability concerns and the costs of electric vehicles also hinder EV uptake. Policy instruments could effectively diminish the magnitude of these obstacles.

Africa is one of the fastest growing markets for two- and three-wheelers, this is partially driven by the increasing number of cheap second-hand motorcycle imports from Asia. The rapid motorisation trend in Africa means that the number of registered motorcycles surpasses private cars. However, unlike Asia, this trend in Africa is largely informal and unregulated, and in Africa, this trend has not been accompanied by alternative measures such as electric mobility, a sure way to transition to low-carbon transport to mitigate emissions.

Given the high population, economic growth and urbanisation rates, coupled with still low mobility access in most parts of rural and urban areas in Africa, electric mobility could be a leap-frog solution for what is set to be a growing vehicle fleet. Furthermore, two- and three-wheeler ownership and use are increasing in rural areas in Africa where distances travelled are greater and fuel quality much less reliable. Nevertheless, most African countries lack a policy framework to foster uptake of electric mobility. Electric two-wheelers have low additional purchase cost (400- 650 dollars) relative to an ICE scooter, mainly due to the small battery capacity (1.5 to 4 kWh) and low power needs [28]. This higher upfront cost could be offset by the decrease in operating and maintenance costs. Depending on the travelled distances and the fossil fuel prices, the payback period could be between two to three years.

Within this conversation, the impact of a large-scale electrification of transport on the electricty grids in Sub-Saharan Africa cannot be overlooked. Studies on the load curves in this region are very limited, but they show that peak demand normally occurs in the evenings [29] when lighting and appliances are most commonly used. It would be fair to assume that the same behaviour would be observed for EV charging, further increasing peak demand during the evening hours. Since electricity demand in much of Africa is constrained by available supply [30], such an increase in peak demand would need to be carefully modelled (Chapter 7).

Besides light vehicles, electricity and low-carbon fuels could play a role in reducing emissions from other modes of transport in the future too. Electrification of railways, use of hydrogen for shipping and biofuels for aviation are trends being observed in many developed countries. Increased industrialisation would require (long-distance) transport of raw and finished goods, leading to an increased demand for freight vehicles, rail, navigation and aviation. The new African Continental Free Trade Agreement will also require improved connectivity between the countries from regions of production to major commercial centres and ports. A transcontinental railway is in the works and plans to connect shipping ports in West and East Africa by reportedly linking more than 10 countries including Angola, Democratic Republic of the Congo, Zambia, Tanzania and Kenya [31]. Such projects are expected to support the economic development of landlocked African nations and enhance trading and mining activities in the region significantly [32]. Although decarbonisation of these modes is far more challenging and capital-intensive than electrifying light two- and three-wheeler vehicles, new infrastructure projects in Africa could choose this path in the future.

6.3 Potential for biofuels

Biofuels account for less than 0.1% of transport energy use in Africa today, yet from this small base there is strong potential for growth. 2018 already saw an important expansion in the market, with year on year growth of 5% [1], mainly led by South Africa, responsible for around one third of the growth, and Nigeria.

The potential for production of advanced biofuels in many African countries is enormous, thanks to the size of the continent's agricultural sector. Increasing biofuel production from the transformation of agricultural waste is most sustainable if based on the intensification of crop production and livestock grazing on existing agricultural lands, rather than the extension of crop and grazing lands [33][34]. Relying on intensification rather than extension reduces negative environmental impacts such as deforestation and land use change, and their associated GHG emissions. East Africa alone is estimated to have the potential to produce over 100 million tonnes of agricultural residues per year [35], which could be converted into advanced biofuels like ethanol and bio-butanol. Realisation of this potential will depend on whether using this resource for biofuels production can compete with other uses, such as direct combustion or even electricity generation. Many countries have announced mandates for boosting the use of biofuels in the transport sector, with the most popular mandates being ethanol blending rates of 5% or 10% (E5 and E10). It is important to note that most of these mandates exist but have not yet been enforced. Table 6.2 lists the major African economies against their intended biofuel blending targets and mandates. In both the Stated Policies Scenario and the Africa Case, biofuels represent only a small share of total fuel consumption for the road transport sector, at 1.5% and 2.5% of the overall fuel consumption of the sector. The evolution of the biofuels market in the Africa Case should take into account the potential supply of agricultural residues in key African countries.

Country	Mandate*	Target*	Potential from agriculture residues
Angola	Ethanol 10		11%
Ethiopia	Ethanol 5	Ethanol 10	
Ghana		Replace 10% of fossil fuels by 2020 and 20% by 2030	
Kenya		Ethanol 5, Ethanol 10	5%
Mozambique	Ethanol 10		1%
Nigeria	Biodiesel/Ethanol 2	Ethanol 10	
Tanzania			4%

Table 6.2: Biofuel blending mandates for transport in Africa [36] [37] [38] [39] [40] [41] [42].

Notes: The numbers in the table are referring to the blending ratios of each type of biofuel. *The distinction between mandate and target is related to the policy framework strictness and the mechanisms that are in place to enforce these shares.

6.4 Planning for the future: the importance of public tranport

Among the 532 cities of more than one million inhabitants across the world today, 66 are in Africa [43]. 85% of the inhabitants of these cities live in areas denser than Paris (Figure 6.1). Cities will be responsible for around 60% of buildings and transport energy demand growth in the period to 2040 in Africa [1], and the growth of cities will play a central role in the energy picture going forward. To meet the demands of Africa's growing urban population, cities will have to develop and expand at an unprecedented rate — what these cities look like, and how they are planned, will have far-reaching implications. Strong policy ambitions, long-term investments and sound urban planning will be needed to harness energy-efficient and low-carbon opportunities for urbanisation, densification and the rise of medium-sized cities.

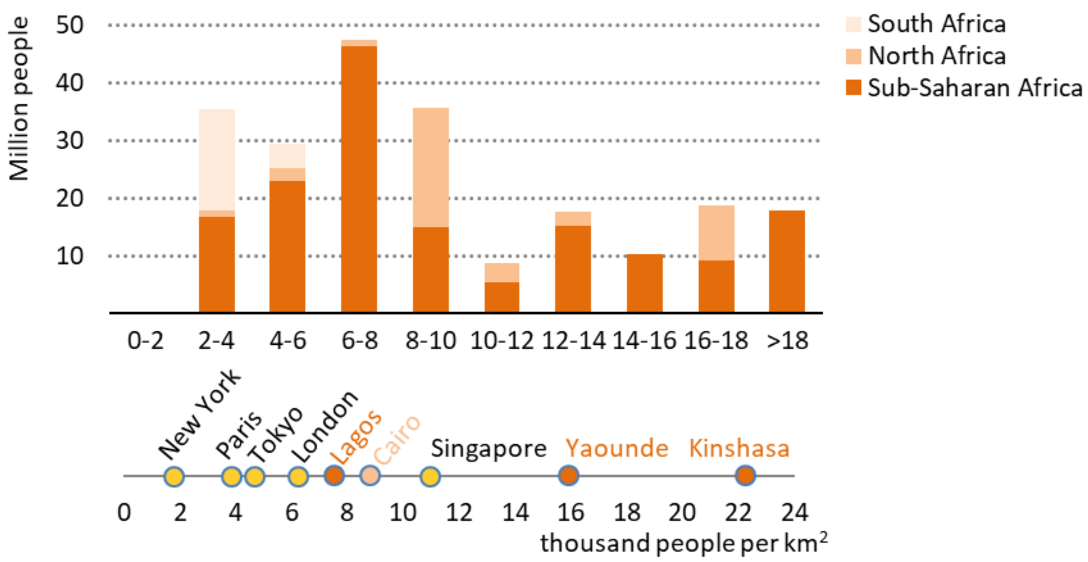

Figure 6.1: Population density in global cities of more than one million inhabitants [1]

The compactness of cities (Figure 6.1) usually makes public transit more viable. In particular, bus rapid transit systems require low shares of public subsidies since moderate capital investment can sustain a large passenger throughput. Urban areas in Africa suffer from traffic congestion, driven not only by increasing needs for transportation services but also by sub-optimal modal choices motivated by numerous factors including imports of second-hand vehicles, lack of dedicated walking or cycling tracks and free/cheap parking spaces in fast-growing African metropoles. A lack of sound urban planning also leads to multiple externalities such as longer travel times, increasing CO_2 and local pollutant emissions.

Providing the infrastructure and promoting rules of the road that encourage public and non-motorised transit is essential to making urban growth sustainable in Africa. New mobility models such as dedicated rapid bus transit corridors could be promoted, expanded, maintained and extended to other big cities. Providing safer and faster alternatives for transporting large numbers of people simultaneously and linking the rural production areas to big commercial centres would be first among the many benefits of investing in these modes of mass transport. The drive to build the needed infrastructure is embedded in the Agenda 2063 [3]. Success stories to inspire further development of public transport have been observed in some cities across the region.

Dar es Salaam in Tanzania, growing at an unprecedented rate of half a million each year, is projected to become a megacity by the year 2035 and be home to more than 70 million inhabitants by 2100 [44]. Most of the expansion occurred via sprawling outside the city, which meant that people were required to travel very long distances. After years of struggling with an outdated transportation system, that was overcrowded and extremely time-consuming, the city has introduced a new bus rapid transit (BRT) system which has cut average travel times from the city centre to the terminus from 2 hours each way to 45 minutes [45]. This high-quality transit system of dedicated bus lanes offering fast, comfortable, and cost-effective services at metro-level capacities, recognised by the ITDP as Africa's only "gold standard" BRT rating [46], can serve as an exemplary model for such systems in other cities. A similar initiative built in 2009 in South Africa is called the *Rea Vaya* or "We are going" bus system [47]. It runs on low sulphur diesel and operates on predetermined routes in separated traffic lanes, significantly slashing the time spent in traveling through the congested streets of Johannesburg. The system is reported to have saved the country around 900 million USD so far by reducing travel time, improving road safety and cutting down on carbon emissions according to the World Resources Institute [48]. In 2019, Ethiopia signed a deal to receive 300 million USD from the Korean government for the construction of a BRT system in the capital city of Addis Ababa [49]. Urban planning and city structure matter equally. Planning that leads to a mix of land uses – residential, commercial and industrial – will contribute to reducing overall transport needs while promoting sustainable mobility patterns such as walking, cycling or mass transit.

6.5 Linking gender and mobility in Africa

While improving urban transportation is a great challenge facing the ever-expanding cities of Sub-Saharan Africa, the discussion on transport must not exclude mobility options for women in both urban and rural communities. In cities, several factors such as financial constraints, cultural norms prioritising asset allocation to men and security concerns notably limit access to transportation for women. Even in rural areas, women and children are more vulnerable to the negative impacts of the lack of transportation options. Long distance walks to fetch water or wood for fuel, access to healthcare facilities and schools are all major obstacles in the daily lives of women. The effects of the situation range in severity from loss of productive time to reduced literacy rates, risking personal safety and increased mortality rates. Proper transport planning would need to consider the different mobility needs of women and men throughout the day and seek to solve problems related to women’s safety.

In Sub-Saharan Africa, maternal mortality and morbidity rates continue to be high [50] [51]. Although there are many factors in addition to obstetric causes that contribute to the high mortality rate, a major cause is the delay in reaching emergency care [50]. Emergency and routine medical check-up for the elderly, children and women is critical to achieving most of the sustainable development goals, specifically; SDG 3 on healthy lives and wellbeing, yet this is a challenge for the rural populations in Sub-Saharan Africa where healthcare and other essential services remain inaccessible.

Light, and preferably electrified for air pollution and health concerns, two/three wheelers could be the game changer for mobility of both urban and rural women in Africa. An increasingly popular concept in large, developing countries such as China and India, these modes of transport could have a great potential for improving rural lives in Africa. Some entrepreneurial ventures have also embarked on the quest to solve the rural mobility crisis [52] by involving women in the production of light two/three wheelers [53]. Such ventures not only provide employment opportunities and skills training to women, but also a safe and sustainable mode of transport in cities or in rural areas for carrying children or light agricultural goods, water or fuel wood.

7 Limitations and future work

The major limitation, found during the course of this thesis and in several published studies, in any modelling or research work based on Sub-Saharan Africa is the scarcity of useful, reliable and recent data. In the absence of this, several assumptions need to be made. Such assumptions need to then be validated by experts and local researchers, adding a layer of complexity to the task. Nevertheless, continued efforts to conduct and publish research in this field would only improve the quality of future work.

The prospects further research based on the premise of this thesis are many. Liaising with local researchers to precisely quantify the potential and impact of large-scale biofuel production; evaluating the impact of electrification of transport on the grids in Sub-Saharan Africa (Section 6.2) and studying the role of demand side response [54] and smart charging systems to potentially offset this impact; and analysing the health benefits of modal shifts from personal cars to safe public transport or trains in terms of air pollution reduction.

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Annex I

A.1 Planned transport infrastructure projects

The following table lists the top transport infrastructure projects planned till 2040 in Africa. Their effect on the transport energy demand in the focus countries has been catiously implemented in the IEA WEO 2019 Africa Outlook projections [1]

Beneficiary countries	Project Type	Project Stage	In Service Date	Source of Finance	Amount (USD)
East Africa					
Zambia, Malawi, **DR Congo**, Burundi, Rwanda and Uganda	Maritime Port	Implementation	2020	Public	384 million
South Sudan and Uganda	Road	Technical Design Study	Unknown	Public-private partnership	68 million
Kenya and South Sudan	Road	Implementation	Unknown	Multi-donor	420 million
Southern Africa					
Botswana, **DR Congo**, Malawi, Namibia, **Tanzania**, Zambia, Zimbabwe	Road	Implementation	2022	Public	674 million
West Africa					
Senegal and Mali	Railway	Feasibility Study	2022	Public	3 billion
Burkina Faso and **Côte d'Ivoire**	Road and Railway	Feasibility Study	Unknown	Public	600 millon
Togo, **Nigeria**, Niger, Mali, **Ghana**, **Côte d'Ivoire**, Burkina Faso and Benin	Road	Implementation	2040	Public	68 million
Central Africa					
Cameroon, **DR Congo**, Gabon and Congo	Road and Railway	Initiation	Unknown	Public	1.65 billion