MODELLING THE URBAN ENERGY FUTURE OF SUB-SAHARAN AFRICA

WORKING PAPER

SUSTAINABLE ENERGY AFRICA

SAMSET
Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions

TABLE OF CONTENTS

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MODELLING THE URBAN ENERGY FUTURE OF SUB-SAHARAN AFRICA

SUMMARY

This working paper presents the results of a modelling exercise undertaken to assess the future urban energy demand of Sub-Saharan Africa. Because of limited data on specifically urban energy use for the sub-region (even in data sources as comprehensive as the International Energy Agency's Africa Energy Outlook 2014), the results should be seen as provisional. The exercise nevertheless points to some significant trends:

- The future energy demand of Sub-Saharan Africa is likely to be substantially urban, with the urban share of total demand rising to over 75% by 2040.
- Energy-related carbon emissions from urban areas are likely to rise by 280% between now and 2040, increasing urban sub-Saharan Africa's contribution to the global total from just over 1% to 4%.
- Universal access to modern energy and energy efficiency implementation, as proposed in the Sustainable Energy for All goals, could reduce energy demand by 17% by 2040.
- Implementing Sustainable Energy for All goals is expected to reduce energy-related carbon emissions by 20% off the Business-as-Usual trajectory by 2040.

The overall implication suggested by this work is that a focus on energy demand and supply at a local level may become increasingly important, and that a more detailed understanding of energy use characteristics and trends, as well as approaches toward a more sustainable energy future, is necessary at an urban scale.

CONTEXT

Global energy demand is continuing to grow and much of this growth is in urban areas. Over 50% of the world's population currently lives in urban areas, yet these areas are responsible for approximately 75% of energy use. As these urban populations continue to grow, there will be a large impact on global energy demand and the resultant carbon emissions (GEA 2012).

Sub-Saharan Africa currently has 13% of the world's population but is only responsible for 4% of its energy demand – and much of this demand is from traditional biomass fuels (IEA 2014). Because of this relatively low energy demand per capita, and the fact that much of it is from biomass, sub-Saharan Africa is typically considered a relatively small contributor to future global energy demand and carbon emissions (IEA 2014).

Much of Africa is still early in its development trajectory and population growth is projected to be high, especially in sub-Saharan Africa. Much of this growth is set to occur in urban areas, and although there are reports that look at total energy growth, little is known about the increase in energy demand in specifically urban areas and how this relates to energy demand in the sub-continent and globally. National energy policies in sub-Saharan Africa often focus on rural areas and the energy supply sub-sector. Yet with the population growth in urban areas, and resulting national energy profile changes, the emphasis may need to shift towards our towns and cities.

OVERVIEW OF THE MODELING EXERCISE

STRUCTURE OF MODEL

Long-range Energy Alternatives Planning system (LEAP) version 2015.0.8.0 was used to create the sub-Saharan urban energy model. LEAP models both energy demand and supply, and data were collected for both. Energy demand was divided into four sectors, namely; residential, commercial, industrial and transport. Each of these were then further divided into sub-sectors, partially depending on the availability of data for that sector.

The supply-side sector modelled both electricity generation transformation and charcoal processing from wood. The proportions of each electricity supply technology (IEA 2014) were used to calculate installed capacity based on the modelled demand requirements. Charcoal processing was modelled based on a conversion efficiency of 10% (Knöpfle 2004). The modelling of transformation (from crude to final product) of liquid fuels was not considered useful for the purposes of this exercise, and such fuels were treated as final products in the model.

PAUCITY OF DATA

Reliable and detailed energy data specific to urban areas is difficult to find for all sectors and end-uses. This is the single largest challenge in modelling the urban energy future of sub-Saharan Africa. However, in spite of this paucity of data, general trends and proportions of energy demand, currently and into the future, can be adequately estimated to inform strategic thinking.

A full breakdown of the data used and assumptions made in the LEAP model can be found in the *Modelling the Urban Energy Future of sub-Saharan Africa Technical Report* (SEA 2015b).

GROWTH RATES

Two factors were used to increase demand to 2040 in the LEAP model, namely Gross Domestic Product (GDP) and urban population growth. The average urban population growth rate for all sub-Saharan African countries (CIA 2015), was used to increase demand in the residential sector. A GDP growth rate of 5.1%, reflecting average national economic growth (IEA 2014), was applied to all other sectors (this may be conservative, as some sources indicate city economic growth to be as much as 1% higher).

SCENARIOS

At the heart of the scenarios included in the LEAP model is the United Nation's Sustainable Energy for All targets for 2040, corresponding to the energy-related global Sustainable Development Goals. Sustainable Energy for All has three interlinked targets—ensuring universal access to modern energy services, doubling the global rate of improvement in energy efficiency, and doubling the share of renewable energy in the world's energy mix. Each of these targets were modelled as separate scenarios and then combined into a single scenario that reflected the Sustainable Energy for All scenario. Below is an outline of each of the scenarios. For more a more detailed list of interventions in each scenario, see the modelling technical report (SEA 2015b).

Universal Access – This scenario focuses on moving household energy use from traditional biomass-based fuels to more modern, cleaner energy sources such as electricity and liquefied petroleum gas (LPG). It therefore only affects energy use in the residential sector with wood and charcoal use for cooking moving to electricity and LPG.

Energy Efficiency – Efficiency gains can be found in almost all sectors and end-uses. In the residential sector, the Energy Efficiency scenario reflects more efficient electricity use into the future (note that results are cumulative on top of the Universal Access scenario). In the commercial and industrial sectors, energy efficiency gains were implemented for all end-uses based on best practice assumptions. To model efficiency in the transport sector, the proportion of passenger kilometres attributed to public transport were maintained (and slightly increased) into the future and the energy intensity of freight vehicles was improved over time. Essentially, this reflects a situation where, despite rapid urbanisation, the current relatively high proportions of public transport are maintained into the future rather than the less efficient alternative, which is an increasing shift to private vehicles.

Renewable Energy – This scenario doubles the share of renewable energy in the energy mix by 2040. Since large hydro-electric plants are not always considered renewable (depending if they are associated with large dams), only a portion of the currently installed hydro-electric capacity was treated as 'renewable'.

Sustainable Energy for All (SE4All) – This scenario combines the Universal Access, Energy Efficiency and Renewable Energy scenarios to show cumulative impact.

Business-As-Usual (BAU) – In this scenario, current trends and GDP and population relationships with energy demand are assumed to remain relatively unchanged. This is a 'do nothing different' scenario, and forms a projection baseline to assess the impact of interventions in other scenarios.

RESULTS

CURRENT PICTURE

The energy demand in sub-Saharan urban Africa is dominated by industry and transport, which together account for approximately 74% of total energy demand. Consequently, energy demand by fuel is dominated by transport fuels (petrol and diesel) and electricity. Wood and charcoal together account for 29% of the energy demand, showing that even urban areas of the sub-continent are still heavily reliant on these traditional fuel sources.

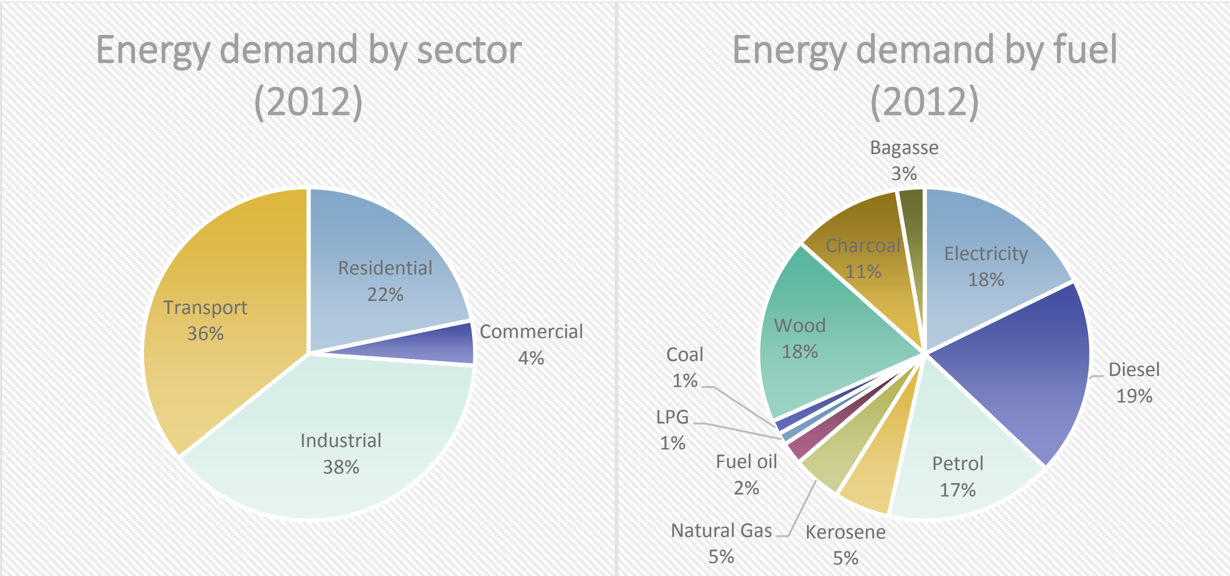

Figure 1: Urban sub-Saharan energy demand by sector and by fuel

Carbon emissions by sector are also dominated by transport and industry, while the residential sector is only responsible for 15% of emissions but 22% of demand. This is due to the fact that this sector relies heavily on fuels such as wood and charcoal. By fuel type, the vast majority of emissions are generated from diesel, petrol and electricity, with electricity being the most carbon intensive.

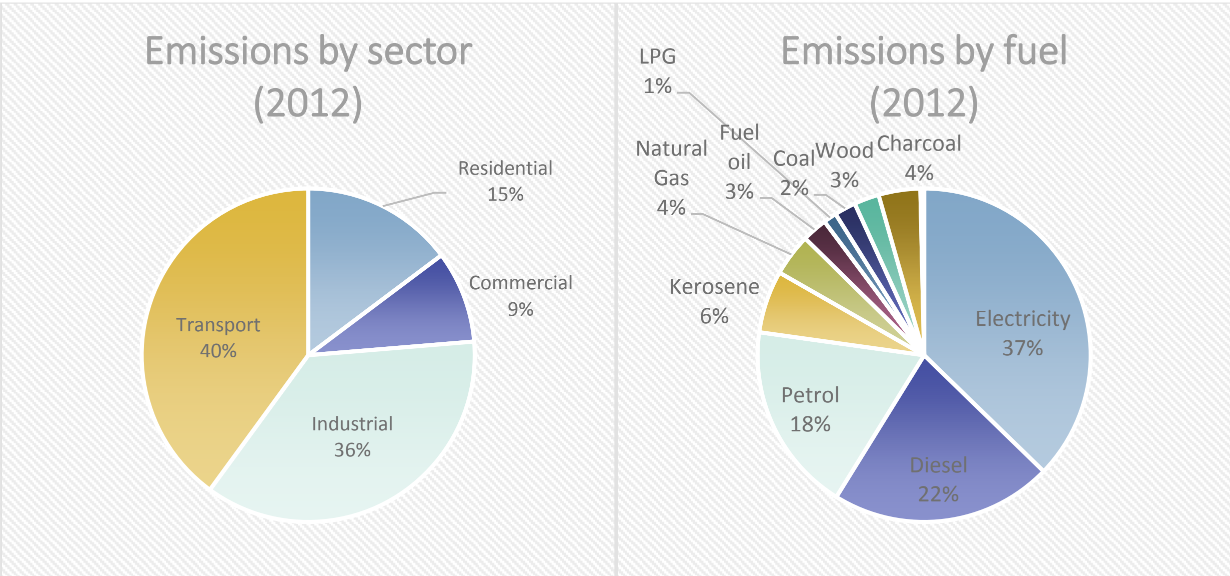

Figure 2: Urban sub-Saharan carbon emissions by sector and by fuel

The vast majority (87%) of energy demand in the residential sector is for cooking, with much of this being supplied by charcoal and wood. Only 19% of the energy demand in the residential sector is estimated to come from modern fuels (electricity and LPG).

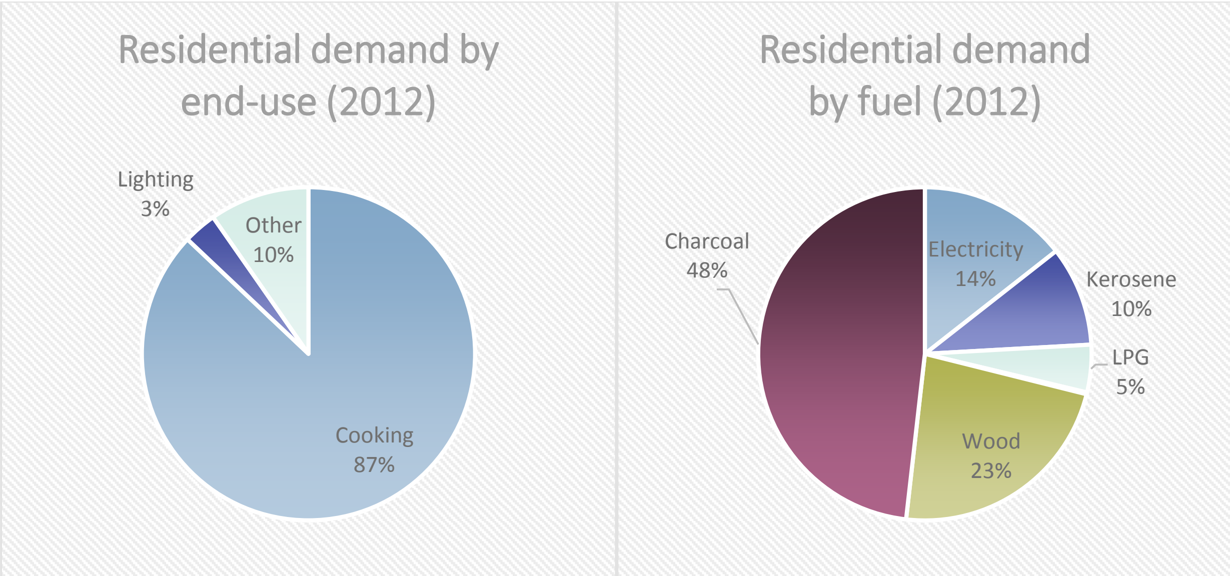

Figure 3: Urban sub-Saharan residential energy demand by end-use and by fuel

LOOKING FORWARD

Projecting the current demand forward under Business-as-Usual conditions shows that urban energy demand in sub-Saharan Africa doubles around 2025 and increases fourfold by 2040 if current GDP and population growth rates are maintained[1]. The majority of this growth in demand is within the transport and industrial sectors. Although not shown below, the carbon emissions per sector generally reflect that of the demand, with only a slight change in relative proportions due to the residential sector being responsible for fewer emissions than its proportion of total energy demand.

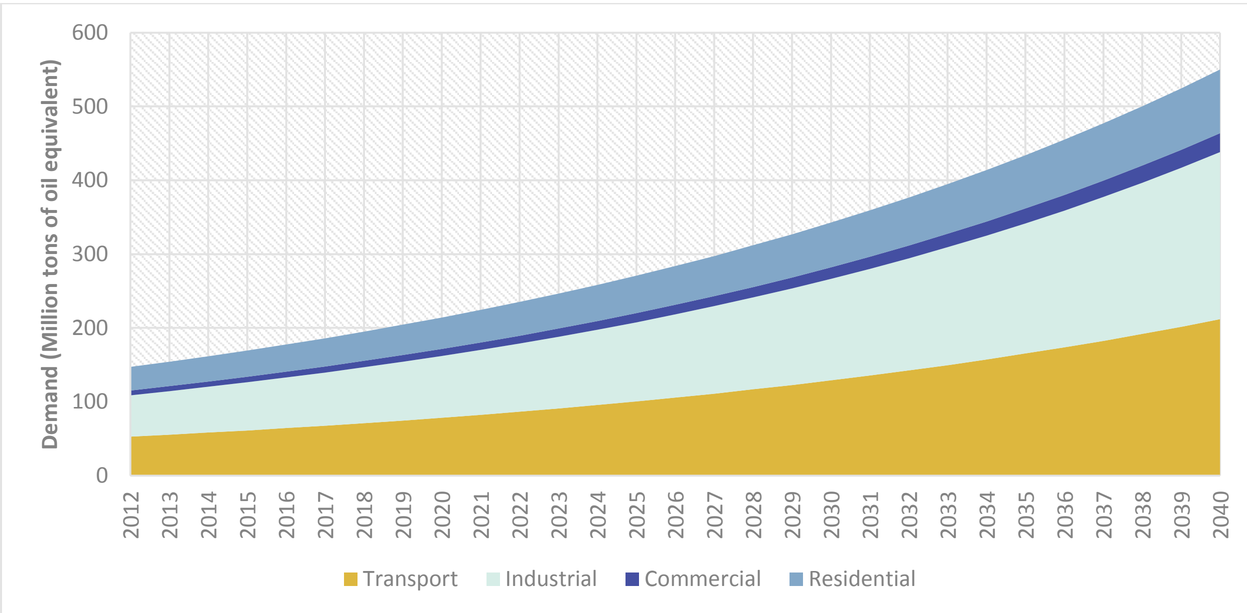

Figure 4: Urban sub-Saharan energy demand over time – Business-as-Usual scenario

[1] The relationship between urban energy demand and national GDP is assumed to be relatively steady. This is effectively taking a middle path between, on the one hand the proposal by the IEA (2014) that economies may become less energy intensive, and on the other hand the fact that economic growth in urban areas is expected to be higher than national average growth.

The large role transport energy is expected to have into the future is of particular significance. Transport systems in larger sub-Saharan African cities, while high in public transport modal split, are already often very congested with associated social and economic costs. There is currently little to suggest that Business-as-Usual transport energy trends, with associated deterioration in system efficiency, will not be the future urban reality.

The International Energy Agency's Africa Energy Outlook (IEA 2014) projected energy demand for sub-Saharan Africa (rural and urban) from the year 2000 to 2040. This was compared to the urban demand from the LEAP model to show the proportion of total energy demand attributed to urban areas. In the LEAP base year, 2012, the urban sub-Saharan energy demand is approximately 35% of the total sub-Saharan Africa demand estimated by the IEA. This is close to the current urban population proportion. Urban energy demand grows faster than total sub-continent demand in all scenarios, driven by high urbanisation rates and urban economic activity. For the Business-as-Usual scenario, urban energy demand in 2025 is approximately 50% of total demand and 76% by 2040. Urban population will be around 40% of the total in 2025 and 50% in 2040, pointing to an increasing energy intensity of urban areas into the future.

The two scenarios that affect energy demand, Universal Access and Energy Efficiency, both reduce the total energy demand of urban sub-Saharan Africa from the Business-as-Usual scenario. With the Universal Access scenario reducing 2040 demand by approximately 10% (modern energy is more efficient) and the Energy Efficiency scenario reducing 2040 demand by approximately 17% (cumulative on top of the Universal Access scenario).

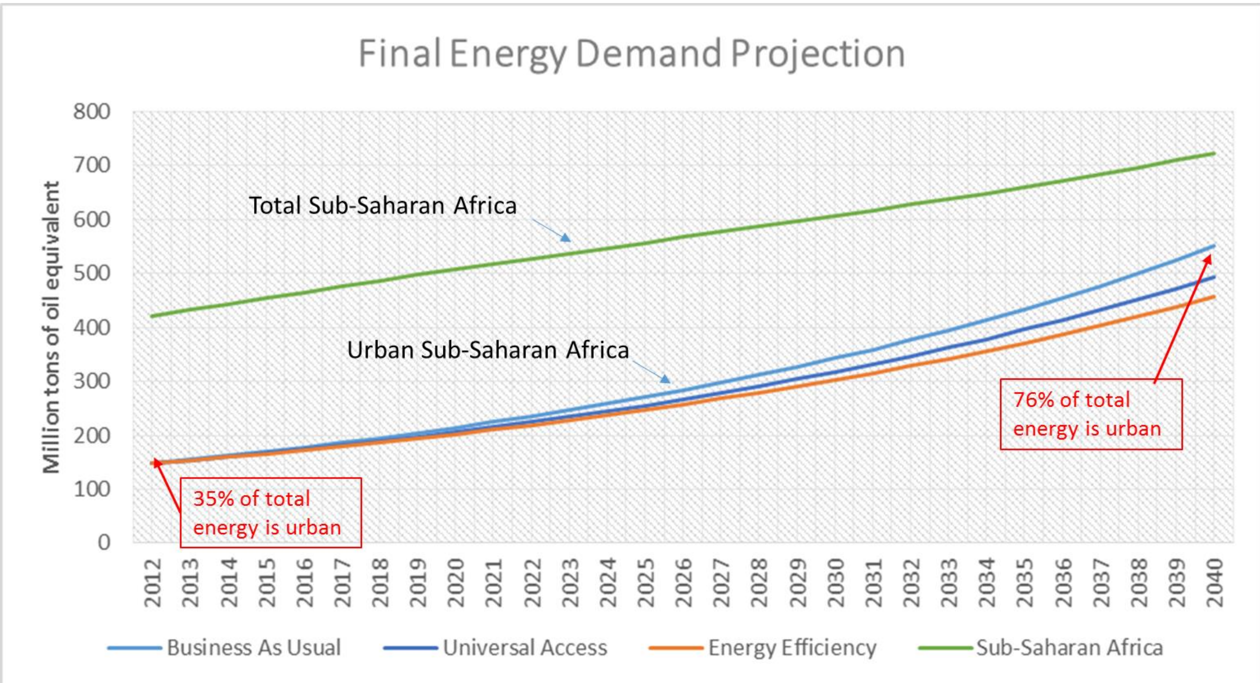

Figure 5: Urban sub-Saharan energy demand over time showing Business-as-Usual, Universal Access and Energy Efficiency scenarios. Total sub-Saharan Africa energy demand (urban and rural) is also shown.

With the rapid growth of energy demand in urban sub-Saharan Africa into the future comes a concomitant growth in carbon emissions, with emissions doubling in 2027 and increasing almost fourfold by 2040 in the Business-as-Usual scenario[2]. The Universal Access

[2] Note that this is higher than projections by the IEA (2014), where carbon intensities are expected to reduce because of shifts from industrial activity to the services sector (under their New Policy scenario).

scenarios results in only a very small reduction in emissions from Business-as-Usual. Although the scenario moves households from biomass fuels to carbon intensive modern energy sources such as electricity, there is still a small reduction in carbon emissions into the future due to modern fuels being more efficient.

Implementing energy efficiency is one of the easiest and cheapest ways to reduce carbon emissions. Implementing cost-effective and well-established interventions in each sector has a large cumulative effect. The Energy Efficiency scenario modelled here reduced carbon emissions by 14% over the Business-as-Usual case.

The impact of the Renewable Energy scenario on the carbon emissions of urban sub-Saharan Africa is significant. Due to the amount of hydro-electric power in the region, the electricity mix is already relatively clean and doubling the share of renewable energy in the energy mix, as called for by the Sustainable Energy for All targets, has a significant impact. This scenario reduces emissions by 11%.

The cumulative effect of the Universal Access, Energy Efficiency and Renewable Energy scenarios is seen in the Sustainable Energy for All (SE4ALL) scenario – it results in a 20% reduction in emissions over the Business-as-Usual scenario by 2040.

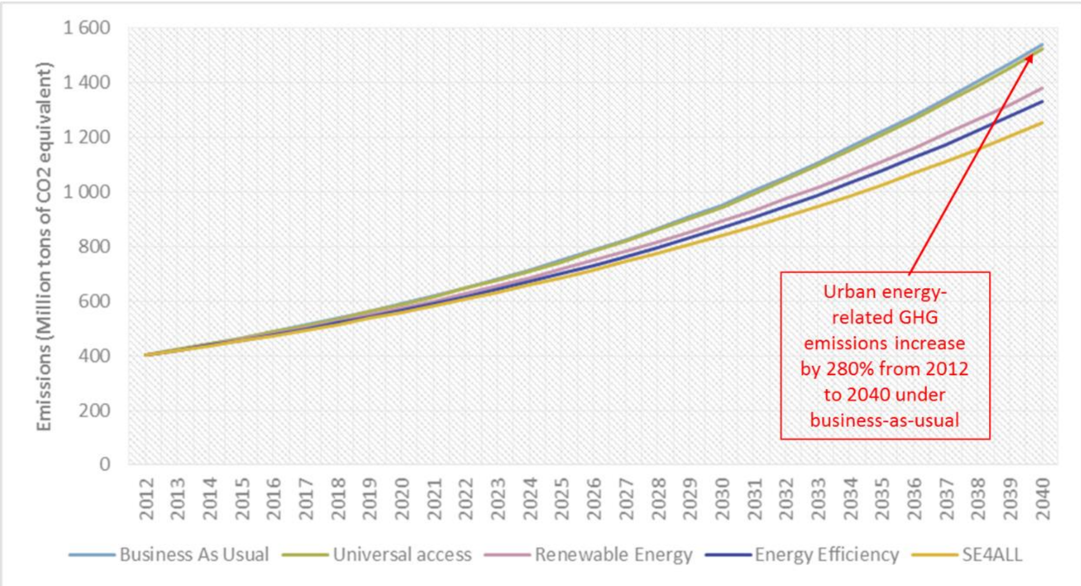

Figure 6: Projected emissions from urban sub-Saharan Africa over time for the Business-as-Usual, Universal Access, Renewable Energy, Energy Efficiency and Sustainable Energy for All (SE4ALL) scenarios

The emissions from the model were compared to those of Representative Concentration Pathway (RCP) 6.0, from the fifth assessment report of the Intergovernmental Panel on Climate Change (Hijioka, et al. 2008). RCP6.0 represents one of the intermediate projection scenarios, although current global emissions are already exceeding those projected by RCP6.0. In the LEAP model base year, 2012, urban sub-Saharan Africa represents approximately 1.2% of global emissions while total sub-Saharan Africa emissions represent approximately 1.8%. By 2040, this has grown to 4%, showing that sub-Saharan Africa – and especially urban areas – are likely to become a more significant player in the global emissions arena.

CONCLUSION

This paper suggests that urban areas have a key role to play in the energy future of sub-Saharan Africa, and may be an increasingly important global energy player. Urban areas will increasingly become the energy intensive hubs of the sub-continent. They are also where many sustainable energy interventions can be most effective given their geographic concentration, and because in cities large numbers of people fall under the jurisdiction of a single municipal authority. Understanding the state of energy in cities – where energy is being used, how this is likely to change over time, and locally appropriate measures to move to a more sustainable trajectory – is likely to be an important part in shaping a prosperous future for sub-Saharan Africa and implementing global intentions around the SE4All and energy-related Sustainable Development Goals.

APPENDIX: BRIEF NOTES ON EACH DEMAND SECTOR

Detailed notes on data and assumptions can be found in the *Modelling the Urban Energy Future of Sub-Saharan Africa: Technical Report* (SEA. 2015b). The below sections provide brief notes only.

Residential

The residential sector was divided into three demand sub-sectors; cooking, lighting and other. Data on proportion of households using different energy sources for cooking were taken from various sources including USAID StatCompiler and IEA (2014). Total cooking fuel consumption in the residential sector for Charcoal, LPG and Kerosene was taken from UN Statistics Division, 2011.

Total electricity, wood and coal consumption calculated using average consumption figures per household (IEA 2014, SOE 2015). Energy consumption data for lighting, refrigeration and electric appliances were taken from IEA 2014.

Commercial

The commercial sector was divided into two broad sub-sectors, formal and informal commerce. For formal commerce, a total figure (IEA, 2014) was used and this was further sub-divided into demand by end-use (SEA 2015).

For other fuels (charcoal, LPG, wood, kerosene), average values from models for other Sub-Saharan municipalities were drawn upon (ERC 2015). These were converted into a per capita value and multiplied by population of urban sub-Saharan Africa to get a total energy demand for each fuel type.

Data for informal commerce were derived from modelling reports from various Sub-Saharan African municipalities (ERC 2015).

Industrial

Data were obtained for manufacturing, construction and other industries (excluding metal mining and oil & gas, as these are generally not urban) from UN statistics Division, 2011 & 2012. It was assumed that all manufacturing and construction industries are urban. Total values for each fuel type were used and no disaggregation between types of industry was attempted.

Transport

Transport data were collected from the Africa Infrastructure Country Diagnostic (AICD) database (Gwilliam, et al. 2008). This database provided figures for passenger transport (total passenger kilometers) and freight transport (total tonne kilometers) for each country in Africa. These national figures were then reduced to estimated urban figures by dividing transport figures by the proportion of the GDP estimated to be generated in urban areas.

Proportions of various end-use vehicles in each transport sector were based on estimates from studies undertaken in Kenya and Nigeria (Trikam and Stone 2015). Energy intensity data were taken from the 2012 South African Integrated Energy Planning Report (DoE 2013).

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