



Low carbon energy scenarios for sub-Saharan Africa: An input-output analysis on the effects of universal energy access and economic growth



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ABSTRACT

Meeting Sub-Saharan African (SSA) human development goals will require economic development to be the priority over the coming decades, but economic development ‘at all cost’ may not be acceptable across these goals. This paper aims to explore five development scenarios for the five largest economies in SSA to understand the implications to CO₂-equivalent emissions (CO₂-e) and off-grid energy modernisation in 2030. Within this scope GDP growth; economic structure; availability of energy resources; international trade; and, the development of distributed generation for remote locations are considered. Regional CO₂ emissions were studied using a Multi-Regional Input-Output Model for Africa. Under the scenarios analysed all five nations will be unable to reduce 2030 CO₂-e emissions below 2012 levels, whilst simultaneously achieving forecast GDP growth and universal access to modernised energy services. 100% off-grid modernisation is estimated to require a three-fold increase in Primary Energy Supply and a 26% (1317 Mt) increase in 2030 CO₂-e emissions. Total regional CO₂-e emissions could be reduced from 45% to 35% by meeting a 50% renewable energy supply target by 2030. Climate Change policy would need to focus on multi-sector reform to reduce regional emissions as the agricultural sector is the largest emitter in Nigeria, Ethiopia and Kenya.

1. Introduction

The Sub-Saharan Africa (SSA) region has the lowest human development index in the world and must therefore make economic development a priority over the coming decades (Head, 2009). Economic development is critical to uplift the region out of abject poverty and create opportunities for prosperity. However, economic development at all costs may not provide optimum outcomes under the principles of sustainable development. Ainger and Fenner (2014) conclude that economic development is sustainable provided the impacts are reached within environmental limits, deliver an acceptable quality of life for all, whilst ensuring equal individual social and economic rights. The current lack of SSA development has meant the region has minimised its overall environmental impact. Moving forward the pressures of economic development on society and the environment are only going to become more acute. Within the SSA region there is therefore a unique opportunity for the prioritisation of economic growth aimed at improving human development while also striving to reduce total CO₂-e emissions (Head, 2009).

To date, the vast majority of SSA development research has focused

primarily on the energy sector. The work by Wolde-Rufael (2009) found that energy supply had a causal effect on economic growth, which was echoed by Kebede et al. (2010) and Bazilian et al. (2012). Akinlo (2008) implemented a Granger regression model to analyse the SSA region and found that policy aimed at creating additional energy supply capacity would make the largest contribution to stimulating forecast GDP growth. The consensus amongst existing SSA research on the economic development of the region suggests regional energy supplies are a fundamental constraint inhibiting regional economic development (Kebede et al., 2010). This conclusion is supported in the work of Turkson and Wohlgenuth (2001), and Karekezi (2002).

The United Nations (UN) pledged to achieve universal modernised energy access for Africa by 2030 (AGECC, 2010). The UN views modernised energy access as a critical pillar of improved human development, as 65% of the SSA population are off-grid using biomass energy for heating and cooking (AGECC, 2010). Yet, from a sustainable development perspective, limited research has been conducted to understand the future total CO₂ emissions in relation to different types of economic development in African countries using a systematic analytic method (Asane-Otoo, 2015). Therefore, there is significant

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scope and value in SSA regional development research on the implications of future CO₂ emissions under different GDP growth assumptions, distributed generation technologies, and availability of resources over the next 15 years. Furthermore, this research will help inform future policy to support low carbon growth and 100% off-grid modernisation of the SSA energy system.

Five SSA nations make up 70% and 40% of the total SSA GDP and population respectively, highlighting the large wealth disparity within the region (IMF, 2014). This disparity allows the scope of research nations to be reduced to Nigeria, South Africa, Angola, Kenya and Ethiopia, and still allow broad conclusions to be made regarding CO₂ emissions within the region.

1.1. Overall research aim and objectives

This research aims to give insight into implications of region specific GDP growth, energy supply development, and off-grid energy modernisation on regional development and total 2030 CO₂-e emissions. There are three specific GDP growth types to be examined, namely, Business-As-Usual, Industry-driven and Service-driven economic growth. These three structural economic pathways are then divided into two energy development scenarios, namely, fossil fuel dominated growth and renewable energy dominated growth. Taken together these scenarios provide five different development pathways including one baseline scenario.

The objectives of this research are:

- Estimate regional CO₂ emissions over the next 15 years considering forecast region specific GDP growth rates across five GDP and energy supply development scenarios.
- Estimate the CO₂ emissions & energy requirements for the five largest SSA economies in each scenario.
- Inform better policy decisions that foster regional development and a reduction in CO₂ emissions.

1.2. Sustainable development and energy generation potential of the five largest SSA economies

Sustainable development is centred around the morality of limits (Corker, 2011). The United Nations Development Programme (2007) concluded that the SSA region needs to strive for development as a first priority and commit to development with the lowest possible CO₂ emissions and ecological footprint. Head (2009) shows the SSA region can meet sustainable development targets by meeting three major limits, namely:

- A CO₂ emissions reduction of 80% on 1990 levels by 2050;
- A development ecological footprint of 1.44gha per capita;
- A continuous increase in the Human Development Index;

According to Parry et al. (2009) the scale of climate change adaptation for the developing world could be as high as \$130 billion per year until 2060; the UNDP (2007) estimate is over 100 billion per year until 2030. Only two nations within the SSA region have an annual total GDP larger than these estimates (IMF, 2014). A focus solely on adaptation strategies may not be an optimal strategy for this region from a sustainable development perspective. A focus on sustainable development would enable SSA nations to target low-carbon, high-growth industries in a job creation development model, that would both mitigate climate change and increase human development (Richardson et al., 2009). As has been shown by Winkler et al. (2002) climate change mitigation has a greater likelihood of successful long term regional human development compared to solely adaption strategies.

The SSA region has sufficient energy resources to support all current and foreseeable future energy needs (IEA, 2014a). At current

production levels, the region has 100 years' worth of recoverable oil, more than 400 years of coal and more than 600 years of natural gas. Nigeria holds over 95% of discovered SSA oil reserves or around 63 billion barrels. Ethiopia, Kenya and Uganda together hold around 3%. Nigeria also has the largest proven gas reserves holding 5 trillion cubic metres (tcm) followed by 0.3 tcm in Angola and <0.1 tcm in the Kenyan Lokichar Basin (IEA, 2014a). The majority of the SSA coal reserves are situated in Southern Africa where South Africa owns up to 90% of the 36 billion tonnes of proven reserves and the largest share of production capacity (IEA, 2014a). The SSA region contains three of the ten largest global uranium resource reserves; namely Namibia, Niger, and South Africa (IEA, 2014a).

The SSA region has an estimated annual hydropower generation potential of 1200 TWh, equating to 20 GW of potential hydro capacity. This is 8% of the world's total hydropower potential and more than triple the current SSA regional electricity consumption (IEA, 2014a). The region has only converted 10% of this potential into installed capacity. The region receives around 320 days of sunlight per year with estimated irradiance levels of 2000 kWh/m², with Southern Africa having levels of up to 2500 kWh/m² (IEA, 2014a). South Africa is one of the highest producers of solar power in the region but still only has 150 MW of capacity under construction (IEA, 2014a). The region has an estimated 1300 GW of wind potential, with the highest quality resources in Kenya and Southern Africa. The SSA East African Rift Valley has geothermal potential of 10–15 GW, which is one of the largest geothermal sites in the world. This site is situated in between Ethiopia and Kenya (IEA, 2014a).

Bioenergy plays a major part in the regional energy supply as more than 620 million people (65% of SSA population) do not have access to modern electricity services. This is clearly seen in Fig. 1 where biofuel and waste contribute over 50% of Total Primary Energy Supply (TPES) in the five SSA economies (IEA, 2014a). A key to meeting this transition is converting the huge proportion of current off-grid bioenergy consumption into modern energy services over the next 15 years whilst meeting GDP growth targets and minimising CO₂ emissions.

2. Methods

2.1. Input-Output modelling

Input-Output (I-O) models adopt a static framework due to the assumption of fixed technological change and zero substitutability between inputs leading to a matrix of fixed technical coefficients (West, 1995). The traditional I-O model, based on Leontief's (1941) seminal work on the structure of American economy, uses demand-driven linear functions to evaluate efficient input-output combinations, from a production perspective (Carvalho et al., 2015). The activity and commodity accounts are the only endogenous variables in the traditional I-O model, with final demand accounts being exogenous (Robinson, 2006). Therefore, I-O models are extremely effective at estimating the impact across different sectors of the economy under different growth assumptions (West, 1995).

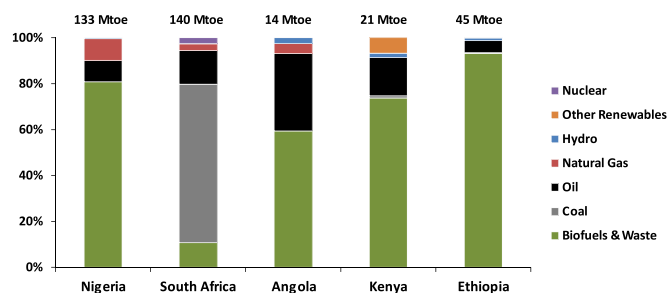


Fig. 1. TPES of the five largest SSA regional economies (IEA, 2014a,b).

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