***IMproving energy systems and energy access in Ethiopia: An inclusive approach***

Gabrial Anandarajah, University College London, g.anandarajah@ucl.ac.uk

Elusiyan Eludoyin, University College London, elusiyan.eludoyin@ucl.ac.uk

 Oliver Broad, University College London, o.broad@ucl.ac.uk

 Julia Tomei, University College London, j.tomei@ucl.ac.uk

 Ioannis Pappis, KTH Royal Institute of Technology, pappis@kth.se

 Andreas Sahlberg, KTH Royal Institute of Technology, asahl@kth.se

 Will Usher, KTH Royal Institute of Technology, wusher@kth.se

Sied Hassen, Policy Studies Institute, seidy2004@gmail.com

Robel Seifemichael, Policy Studies Institute, rseifemichael@gmail.com

Tewodros Walle, Addis Ababa Institute of Technology, teddymec2@gmail.com

 Fitsum S. Kebede, Addis Ababa Institute of Technology, perfects2000@gmail.com

 Solomon Teferi, Addis Ababa Institute of Technology, solomontem@yahoo.com

Getachew Bekele, Addis Ababa Institute of Technology, getachewb@gmail.com

## Overview

Ethiopia is one of the least developed and least electrified countries in the world with an access rate of 44 percent. The country faces the second highest electricity access deficit in Africa, with over 60 million people without access electricity from the grid, posing a binding constraint to economic growth and social development. The access deficit isn’t spread equally - about 96 percent of urban households are connected to the grid, while only 27 percent of rural households have access to electricity services. The Ethiopian Government has a very ambitious and challenging plan to make the country a middle-income country by 2025, with no increase in GHG emissions under its second Growth and Transformation Plan ([GTP II](https://www.greengrowthknowledge.org/national-documents/ethiopia-growth-and-transformation-plan-ii-gtp-ii)). In order to achieve this economic target, the National Electrification Program 2019 ([NEP2.0](https://www.africa-energy-forum.com/article/ethiopia-national-electrification-program-20-report)) sets another ambitious target of achieving universal electricity access by 2025 of which 65% is met with grid solutions and the remaining 35% is with off-grid technologies, mainly renewables. However, based on the progress made so far on capacity addition to the Ethiopian electricity system and the unprecedented impacts of the COVID-19 pandemic experienced across the world, there is a need for further research on understanding how electricity demand evolves and how the electricity system should be expanded in the future under various pathways.

The aim of this research is to develop possible transition pathways to modern energy, specifically clean electricity, by incorporating behavioural issues in energy system modelling using an inclusive approach where decision makers and users are engaged throughout the project.

## Methods

This research aims to unlock barriers in the energy system planning process and policy analysis by developing energy system modelling practices that adopt an inclusive approach through stakeholder engagement and enhancing modelling and analytical capacity of policy makers and planners so that the developed tools can be used for internal policy analysis. This paper uses social science research outputs (qualitative scenarios for both supply and demand side defined via interviews, questionnaires, stakeholder workshops, and the development of institutional regulatory frameworks) to quantify the energy, economics and environmental impacts of energy system development pathways for Ethiopia. It uses an electrification tool, OnSSET-Ethiopia (<http://www.onsset.org/>) which optimises the share of on-grid vs off-grid technologies to meet Ethiopia’s residential electricity demand (currently unelectrified), and an energy system model for medium-to-long term energy planning, OSeMOSYS-Ethiopia (<http://www.osemosys.org/>), which optimises Ethiopia’s long-term energy system development pathways to 2065.

**Energy service demand drivers and projection**: We carried out expert interviews using expert elicitation methods to identify (1) appropriate drivers for scenarios of electricity demand projections and how they will progress over time and (2) to understand the types of technologies that will be in stock in the future compared with base case, which will influence the calculated tier consumptions (Multi-Tier Framework – MTF - for measuring energy access was first introduced in the 2013 Global Tracking Framework (GTF) report, written by the World Bank’s Energy Sector Management Assistance Program (ESMAP)). The LEAP Energy modelling tool has been used to project energy demand using the drivers and their growth rates which were the output of the expert interview analysis.

**Qualitative pathways**: A stakeholder interaction workshop has been organised to derive supply-side development pathways for Ethiopia. It was attended by representatives from these intitutions: Ministry of Trade and Water; Ministry of Water, Irrigation and Electricity; Environment, Forest and Climate Change Commission; Ethiopian Energy Authority; Ethiopian Electric Utility; SNV, Ministry of Mining, Petroleum and Natural Gas; and, Blue Flame Gas. The workshop identified and discussed key issues and drivers that affect future resource and technology pathways and finally defined five qualitative scenarios (Business As Usual, High Ambition, Ambition, Big Business, and Slowdown).

**Consumer behaviour**: A household questionnaire survey (1400 urban households from 9 regions in Ethiopia) has been carried out in and around Addis Ababa to understand the potential for energy efficiency improvements within the residential sector, and to understand how consumers may respond to price changes. The questionnaire also included qestions to understand the imapcts of the COVID-19 pandemic on household energy demand. The research considers multiple technologies and uses multivariate probit model to taking into account the sequential or simultaneous adoption of energy efficient technologies and identifies the behaviour and socio-economic determinants of housholds’ investment in energy efficient technologies.

**Energy system development pathways**: We applied an open-source cost optimization tool for long-term energy planning, the Open Source energy Modelling System (OSeMOSYS) and an open-source tool for geospatial electrification planning, the Open Source Spatial Electrification Toolkit (OnSSET) to estimate the cost optimal electricity supply mix of on-grid and off-grid technologies to satisfy Ethiopia´s future electricity demand. The electricity demand, an exogenous input into the model, has been used in OnSSET and OSeMOSYs and the qualitative scenarios defined in the Stakeholder interaction workshop were modelled in OSeMOSYS. The two tools were soft-linked and applied to the electricity supply system of Ethiopia to develop cost optimal Ethiopia’s energy system development pathways to 2065. The output from the household survey analysis was used to develop behaviour scenarios in addition to core five sncearios modelled in OSeMOSYS.

## Results

## The analsyis will mainly focuses on the merit of the inclusive approach to develop Ethiopia’s energy system development pathways to 2065. Few key points are listed below:

* Based on local expert views of the country’s plausible development pathways, Ethiopia has the potential for slow growth over the next 40 years, remaining a low income country by 2060. Experts also consider high growth plausible, although not as fast as ambitioned in the government’s GTP II; with the country reaching lower-middle income country status by the early 2040s, and upper-middle income status by 2065, resulting in approximately a 58-fold increase electricity demand by 2065, and per capita level similar to that of Brazil’s today.
* There are several interesting findings in the household survey analysis that provide a basis to identify parametrs and to model behavious scenarios in OSeMOSYS model (behaviour scenarios has not been modelled yet). At present, very limited uptake of energy efficient appliances in Ethiopia households. This is partly due to lower low share of housholds’ expenditure on energy, on average 4% of the urban hosuholds’ income is spent on energy. It is encouraging to see that the young families who lives in urban areas are among the households who own high share of efficient appliances. And therefore, there is a potential in the future for greater diffusion of efficient appliances in the residential sector in Ethiopia.
* Early analysis of modelling results show that similar to the past, hydropower remains backbone of the electricity system, but under high demand projections is fully exploited. There would be a role for natural gas and even for nuclear power under high demand scenarios. Meeting the NEPII electrification targets, reliant on grid expansion, is more expensive than relying on an off-grid strategy. Solar is the leading power generation technology after hydropower.

## Conclusions

Developing energy system models using an inclusive approach through stakeholder engagement provide an opportunity to make the developed tools policy relevant and the scenarios developed serve the local needs which is important for developing countries. The stakeholder interactions made in this research via expert intervies, workshop and households survey brought new insights that are useful to develop new energy scenarios and pathways for Ethiopia. This is an going work and we expect to complete the behaviour scenarios modelling before the conference in July 2021.