An indicative climate, land, energy and water system (CLEW) analysis for Ethiopia

Introduction

In the present analysis, a stylized model was used to develop an integrated framework for the climate, land, energy and water system (CLEW) model. The climatic aspects were reported as a greenhouse gas outlook for Ethiopia, and the system was shocked by a dry climate future.[1] Land use aspects included an outlook for requirements to meet growing crop demands. The energy system focused on the electricity sector requirements and their evolution. The water system focused on the use of water in the agriculture, residential, industrial and commercial sectors.

The model itself is fully integrated and goes beyond a simple sector model by encompassing elements of the above. This is valuable, given that stresses, such as negative climate change, can have multiple compounding impacts that will be ignored in a single model system, and that multisector policies such as biofuels can be consistently evaluated using this system. Three scenarios were explored in this exercise: (a) a business-as-usual scenario; (b) a biofuel policy scenario (increase blending from 5 to 25 per cent); and (c) a dry climate scenario.

To be noted is that the model itself is programmed to minimize costs. The requirements for water, energy and land use are therefore arranged in such a way that the projected future has the lowest burden on society. The model outputs, however, may not be agreeable for cultural, institutional or other reasons. In future, those considerations can be implemented and the model can be recalibrated with feedback from local stakeholders.

The model is customizable and can be extended to reflect both local realities and increased detail. A key requirement for future work is stakeholder engagement, model recalibration (because data change with time) and its extension to assess other key policy issues, as well as a broader range of climate impacts.

Modelling insights

The climate, land, energy and water system model is run, and policy insights relating to those systems are reported for each one.

Selected implications for climate

The climate impact of full electrification amounts to 1.7 metric tons of emissions of carbon dioxide annually to supply lighting needs.

With regard to the emissions tracked in the energy sector, by far the largest increase comes from transport. The biofuel intervention considered in this analysis would reduce transport emissions by 2 per cent. Given that gasoline-run vehicles have a very low share in the transportation sector, there is a very low emission reduction owing to the introduction of bio-ethanol. Bio-ethanol production results in, on average, 13 per cent higher carbon dioxide emissions in the agriculture sector.

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[1] The General Circulation Model, (GCM)-GISS-E2-H, developed by National Aeronautics and Space Administration, was used to derive the climate change projections used to simulate a dry climate. The dry climate corresponds to projections from the RCP 4.5 scenario.

The system is particularly vulnerable to climate change. In the dry scenario, if there is no adaptation, then it is assumed that no alternative power generator will be built. As a result, approximately 3 terawatt hours of electricity, which was expected to be exported to neighbouring countries, is not done so. This will result in significant export losses. Furthermore, expensive and readily deployable diesel generators have to be used to satisfy internal electricity demand.

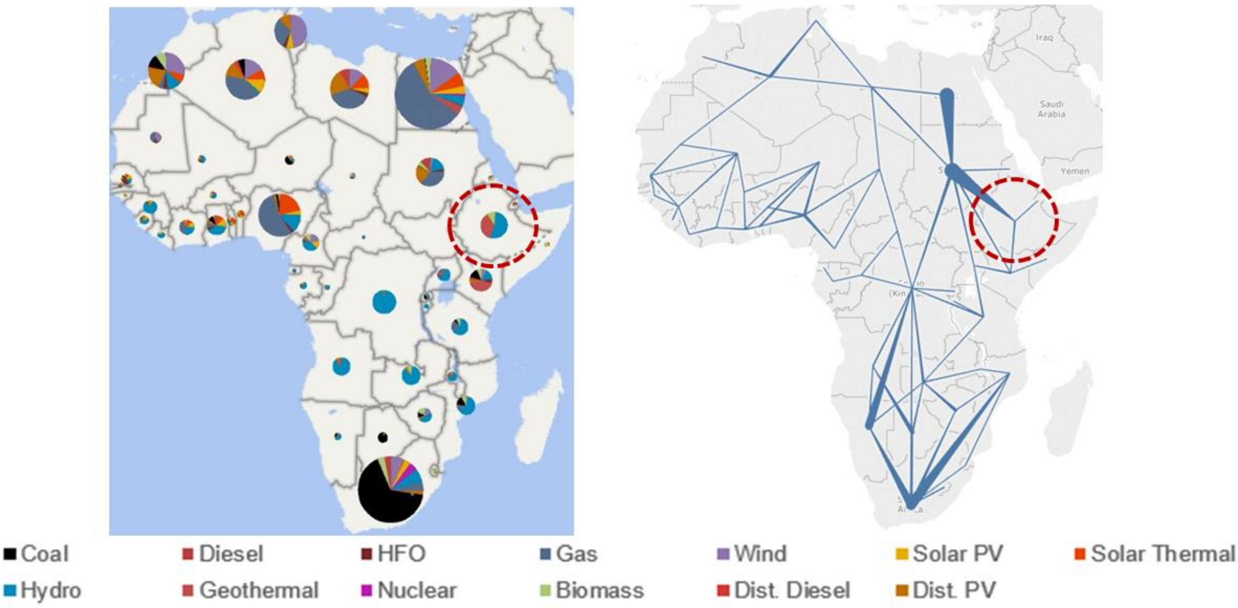
Selected implications for land

In the land sector, as food demand increases in the future, the conversion of pastures and meadows to crop land is required to provide the crop yield necessary. Specifically, crop land almost doubles from 2014 to 2030.[2] Under a biofuel policy scenario, in 2040, the land use under crop cultivation is expected to increase by 30 per cent owing to an increase in biofuel production.

Implications for energy

In the electricity sector, investment is made to reach full electrification. For the period 2015-2030, it is projected that capital investment of $22.3 billion will be required to achieve universal access to electricity and meet the rising electricity demand of the already electrified sectors of the economy. Electrification is undertaken using a mix of off-grid technologies and extending and connecting to the power grid. The grid-based electricity system in Ethiopia is based on hydropower and is expanding rapidly. Of the generated 23 terawatt hours from hydropower by 2030, 3 terawatt hours are expected to be exported. A snapshot for 2030 (see figure II) indicates high levels of trade (with imports proportional to the thickness of the line shown in the figure). The electricity generated flows through the Sudan to Egypt.

Figure I
Electricity capacities and trade in Africa and Ethiopia



[2] It should be clarified that, given that Ethiopia's intended nationally determined contribution stipulates that forests will be protected, the analysis assumes that forest area will remain constant.

On the one hand, there can be considerable financial benefits resulting from the profits from electricity sales. On the other, the significant infrastructure investment in hydro generation will rely on these earnings to pay off the investment. Bilateral power purchase agreements will have to be consolidated, which may act as an incentive for the operation of a competitive power market pool in East Africa. Notwithstanding the substantial electricity exports, energy imports as a whole are expected to rise, especially for oil products in the transport sector.

Figure II

Investment for full access to electricity (capacity expansion required for full electrification by 2030)

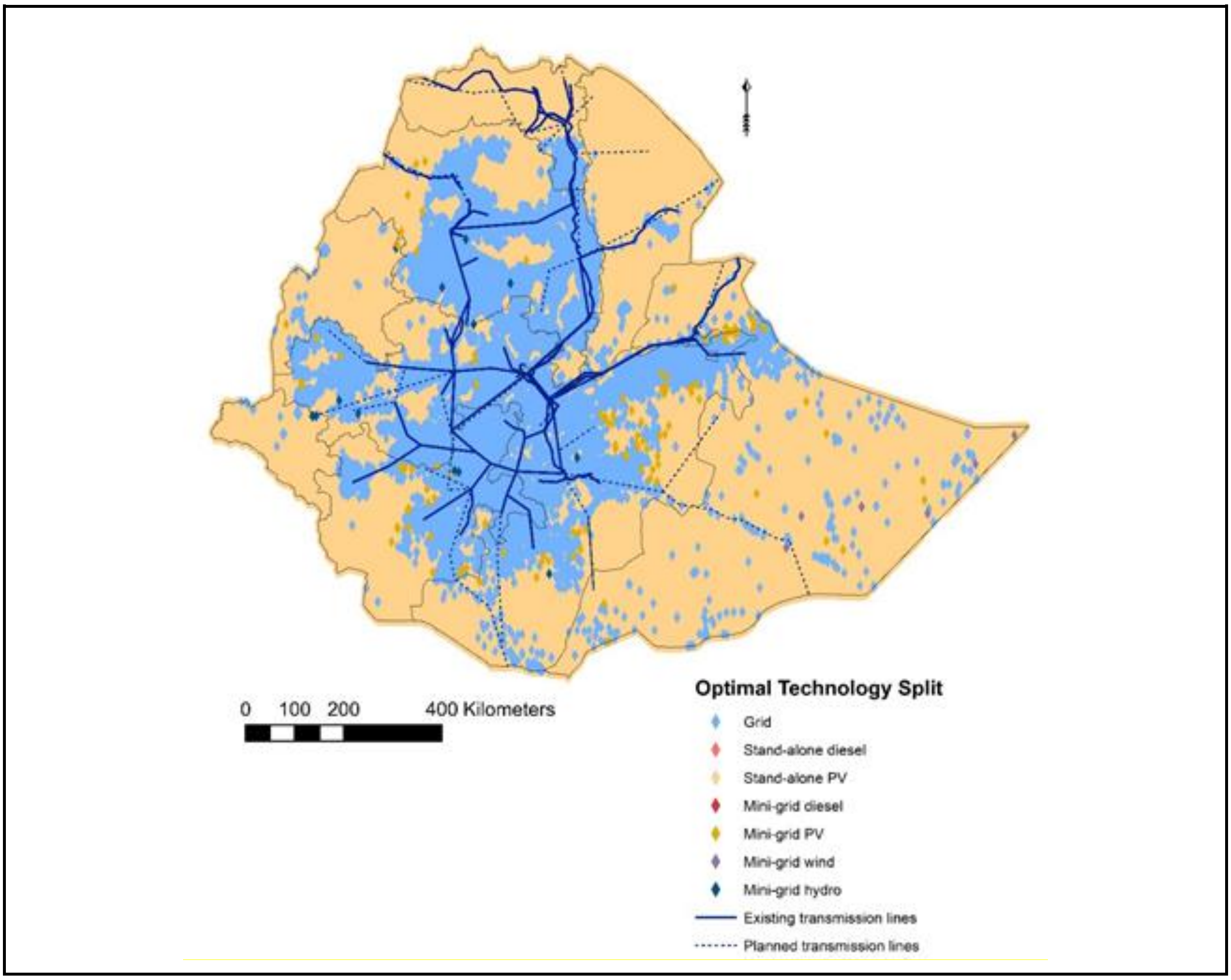
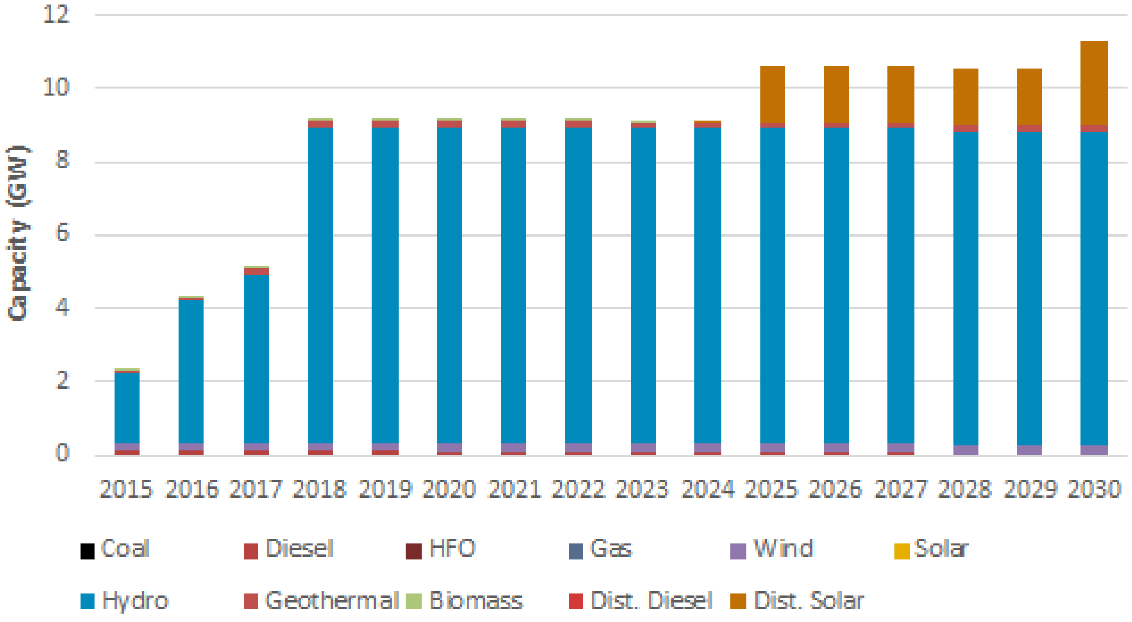


Figure III
Capacity investment in the electricity sector over space (for electrification) and time (for bulk grid generation)



Implications for water

Even though some of this new crop land is rain-fed, the vast majority has to be irrigated, driving agricultural water demand to an equivalent increase. While this puts pressure on local water resources, the abundant precipitation alleviates potential adverse impacts. The effect of a changing climate on this aspect, however, needs to be investigated further. Output from the analysis estimates the increase of irrigated land from 9 million ha in 2014 to 22 million ha in 2030.

In the dry climate scenario, there are multiple impacts in the economy. These include sharp increases in crop imports and, if alternative infrastructure in the power sector is not invested in, significant losses in electricity export potential.

Figure IV
Generation by power plant type under an anticipated climate

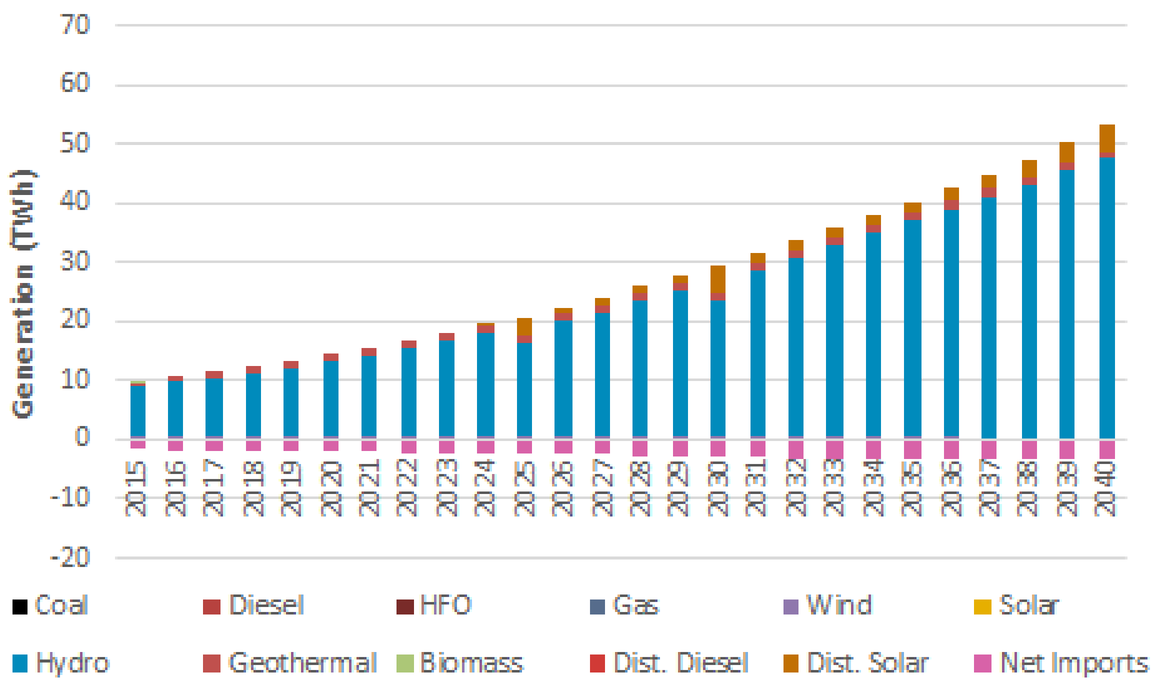
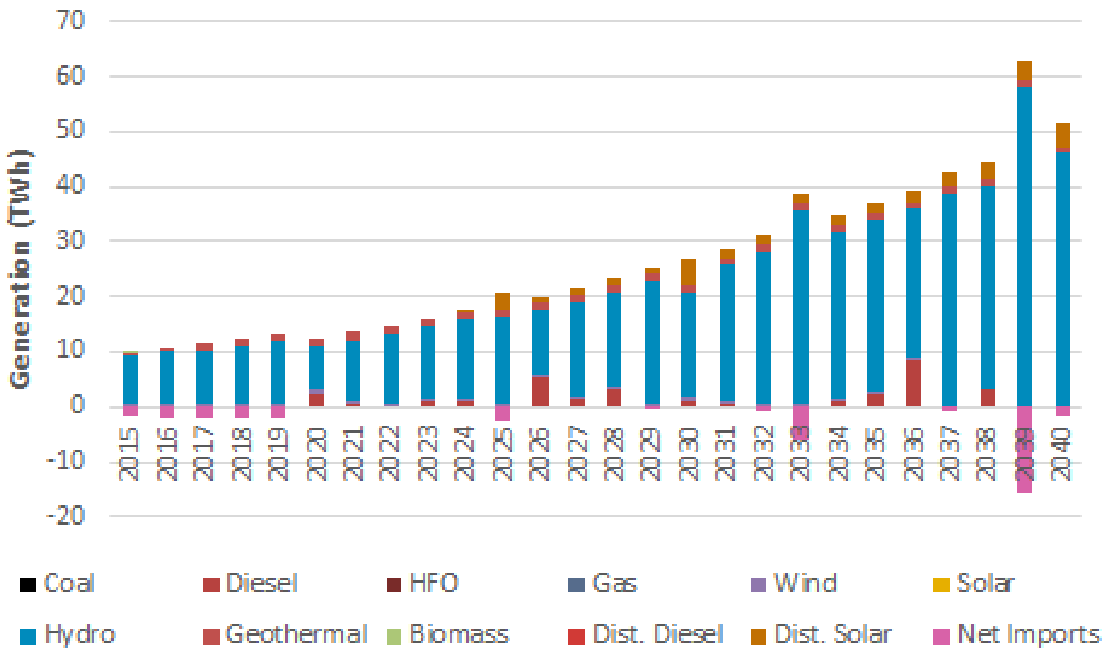


Figure V
Generation by power plant type under dry climate shock



Conclusion

Investment is required to achieve national development goals. Meeting that objective, however, is at risk owing to links between systems that cause constraints and potential climate change. Greenhouse gas emission outlooks are positive owing to the potential of hydro and solar energy, thereby mitigating the need for fossil fuels in the electricity sector. Nevertheless, emission increases are greatest in the transport sector and can be reduced with a biofuel policy. Given that land is limited, deforestation and land use change to meet national development. This has implications for increasing the domestic growth of biofuel feedstocks. If done, food crops are displaced. A drying climate can have an impact on the economy significantly, thus affecting both power exports and food crop patterns.

The model developed is indicative and has the potential for significant extension and application. This includes the evaluation of other pathways and technology deployment (e.g., the electrification of transport) and ground-truthing with local feedback and input. Of specific interest will be the investigation of pathways that are both robust to climate change and that take advantage of the links among the sectors modelled.

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