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

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 Sierra Leone, 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 dry climate scenario, under which there is limited adaptation in the power sector and water scarcity in other ones; and (c) the introduction of a liquid biofuel policy.

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

For land, considering current development trends, forest cover decreases by 15 per cent for the period 2014-2030. This land use change leads to increased emissions, decreasing the capacity of local carbon sinks.

The climate impact of full electrification reaches 0.2 metric tons of carbon dioxide annually by 2030. For the other emissions tracked in the energy sector, by far the largest increase comes from transport. With regard to the biofuel intervention considered in this analysis, a 3 per cent blending of gasoline with ethanol would result in the limited reduction

[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.

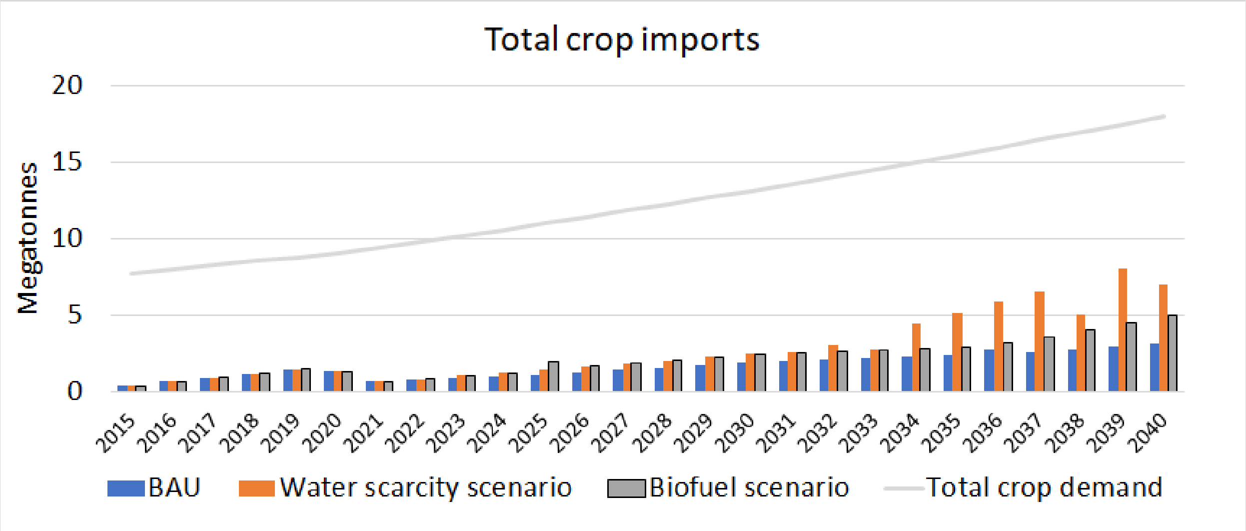
(approximately 1 per cent) in greenhouse gas emissions in the transportation sector**.** This value is expected to increase with the corresponding increase in the blending share. While emissions are relatively small for the energy sector, the impact on crops is high.

The system is particularly vulnerable to climate change. This is clear in the food and energy sectors. In the water scarcity scenario, some 5.6 megatons need to be imported in the model period, which is approximately 16 per cent higher than in the base scenario. In the dry scenario, if there is no adaptation, it is assumed that no alternative bulk power generator will be built. As a result, shortfalls in hydropower generation of beyond 2 terawatt hours in specific years will have to be supplied by readily deployable, yet highly inefficient and expensive diesel generators. If diesel generators cannot be deployed and power cuts ensue in the formal economy, then there will be approximately $6.7 billion in socioeconomic damage annually.

Selected implications for land

In the agricultural sector, food demand is projected to increase owing to the growing population. The conversion of forest land, pastures and meadows to crop land is required to satisfy the expected demand. Furthermore, the need for increased crop production necessitates investment for the conversion of pastures and meadows to agricultural land and the establishment of irrigation systems. If shocked by a drier climate, the total crop imports are expected to increase by 66 per cent during the modelling period, compared with the business-as-usual scenario. A biofuel policy scenario will require crop imports of up to 28.5 per cent higher than otherwise projected. Total crop demands and imports are presented in figure I.

Figure I
Selected crop import levels by scenario



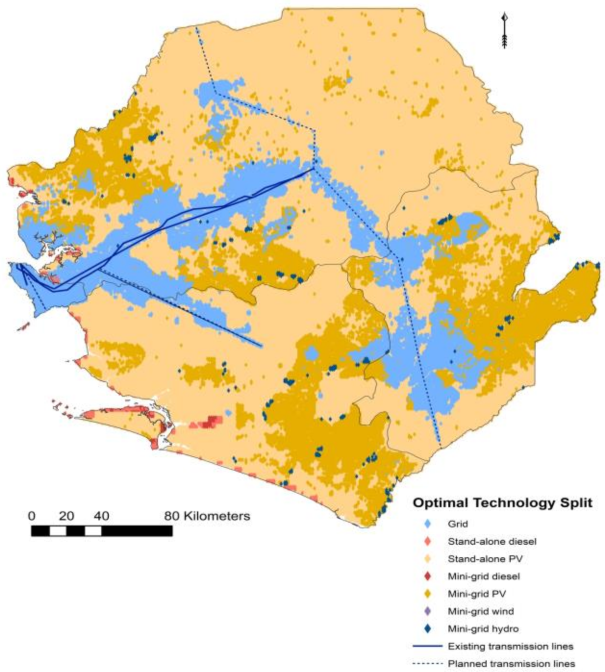
Selected implications for energy

In the electricity sector, investment is made to reach full electrification in Sierra Leone. This is undertaken using a mix of off-grid technologies and extending and connecting to the power grid (see figure II). The total cost to bring lighting to all will amount to $270 million. Under a dry climate change outlook with water scarcity, the majority of new investment in bulk energy generation, which is needed to drive the economy, will be in low-carbon hydro generation. In total, capital expenditure in bulk electricity generation is expected to be $1.1

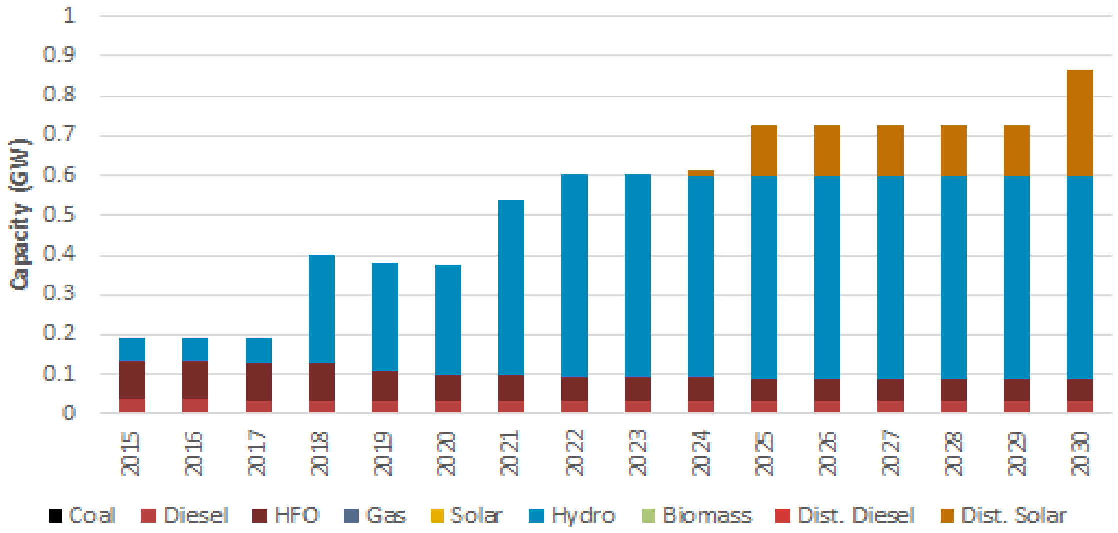
billion between 2015 and 2030. Relatively, capital-intensive investment such as this will require public and/or private investment of a significant scale.

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

(a) Investment for full access to electricity by 2030



(b) Capacity expansion required for full electrification by 2030



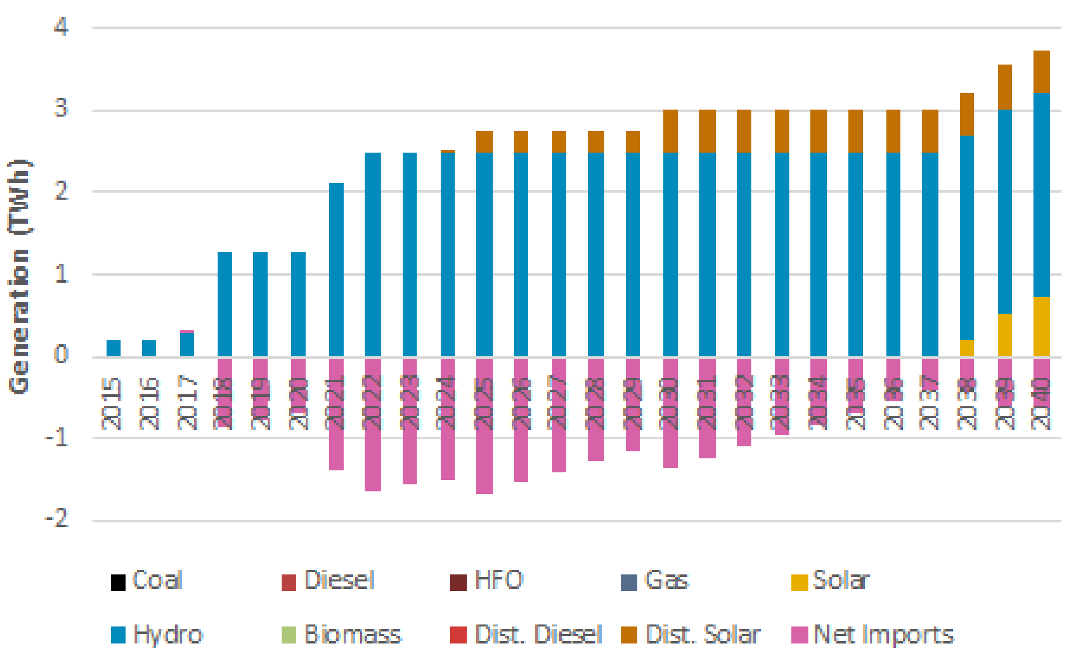
Selected implications for water

Similarly, even though some of the new crop land is rain-fed, the vast majority has to be irrigated, doubling agricultural water demand. This puts pressure on local water resources. Output from the analysis estimates irrigated land increases from 150,000 ha in 2014 to 1 million ha in 2030.

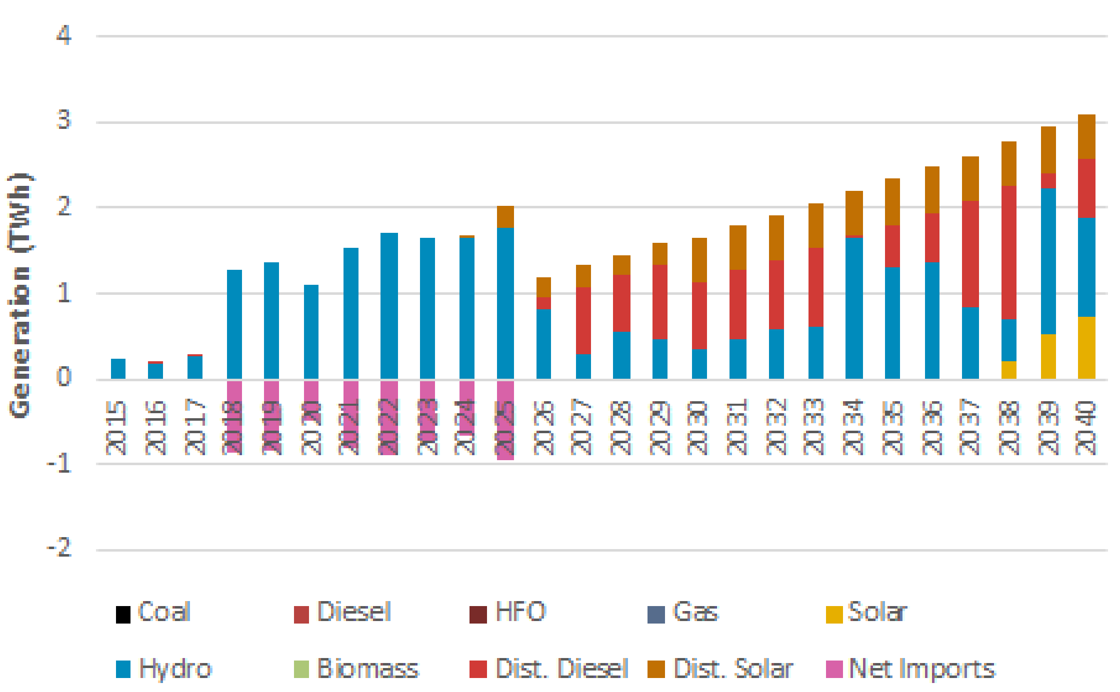
In the dry climate scenario, there are multiple impacts on the economy. These include a significant increase in crop imports and, if alternative infrastructure in the power sector is not invested in, significant shortages in power generation, which will have to be made through the deployment of expensive and readily deployable diesel generators.

Figure III
Electricity generation, exports (negative imports) and shortfalls in supply

(a) Generation by power plant type under an anticipated climate



(b) 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, crop imports increase. A dry climate can have a significant impact on the economy, thus affecting power generation, which will cripple the formal economy, and further ramping up the need for crop imports.

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 to reduce its emissions, rather than biofuel production). Furthermore, ground-truthing with local feedback and input is to be prioritized. 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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