APPROPRIATE ELECTRICITY MODELING APPROACHES FOR EMERGING ECONOMIES: THE CASE OF LAOS AND KENYA

Nkiruka Avila, University of California Berkeley, +14056519752, niavila@berkeley.edu

Overview

Two of the major challenges facing emerging economies today are expanding energy access and alleviating poverty in a carbon-constrained world (Casillas and Kammen, 2010). There are over 1.1 billion people without access to electricity, located mainly in parts of Asia and sub-Saharan Africa (IEA and World Bank, 2015). These countries must balance their economic development goals with local and global environmental concerns. The design of sustainable electricity systems needed to fuel development requires context-specific power system modeling. However, only few studies have focused on national and sub-national power system modeling (de Leon Barido et al., 2015). This is partly due to limited data availability and the lack of open-access modeling tools. Therefore, an open-access cost optimization capacity expansion model, known as PROGRESS (Programmable Resource Optimization for Growth in Renewable Energy and Sustainable Systems), has been built to explore sustainable pathways for power systems expansion in emerging economies. This paper focuses its case study applications on coal development plans in Lao PDR and Kenya. The model shows that coal is not the least-cost option for generation expansion in both Lao PDR and Kenya, and that renewable sources such as wind, solar and geothermal can be substituted.

Methods

The PROGRESS model requires a set of common input variables: a portfolio of existing and potential resources; projections for variable (fuel) and capital costs; annual load forecasts; and characterization of the operational features of the different energy technologies such as resource potential, average capacity factor, and peak contribution. The resource portfolios considered in Kenya and Laos are: small and large hydropower, geothermal, natural gas, diesel, coal, wind, biomass, solar photovoltaic (PV), and nuclear power. The model considers all existing plants in the Lao and Kenya power systems as of 2016. It outputs the annual investment required for the least-cost generation portfolio constrained to meet annual load and peak demand.

PROGRESS includes a 15% capacity reserve margin to account for operational reliability. It allows yearly and hourly temporal resolution for load and renewable energy profiles. Hourly temporal resolution allows PROGRESS to account for the variability of wind and solar energy production, and captures possible correlations between electricity demand and renewable energy production. Where the hourly temporal resolution data is not accessible, average capacity factors are used to for each resource. Because of this, PROGESS also accounts for non-dispatchable renewables using the peak contribution factor, which weights the contribution of each generation resource used to meet peak demand. For example, solar PV has a 0% contribution when the peak demand occurs at night. It has relatively low geo-spatial resolution, a trade-off that permits modeling with smaller accessible data sets. It is able to perform quick sensitivity and probabilistic analyses to manage the uncertainty in model parameters. PROGRESS is also easily adaptable to have increased geo-spatial resolution by categorizing the country into smaller electricity load areas using grid location data where available. PROGRESS is easily reproducible thereby enabling power systems analysis in data-constrained contexts and encouraging broader participation from regulators and policymakers.

Case Studies:
The PROGRESS model was used to explore sustainable capacity expansion pathways in both Laos and Kenya over a fifteen year time horizon (till 2035) based on each country's current policy context and future demand forecasts.

Lao PDR's electricity mix is mainly fuelled by hydropower and coal. It has a high electricity export strategy based mainly on hydropower and has also announced coal development plans. Sustainable alternatives to its coal development plans of about 1 gigawatts (GW) were explored.

Kenya is one of the fastest growing economies in sub-Saharan Africa and has electricity expansion plans to rapidly fuel its growth. This plan includes the development of 4.5 GW of coal by 2030. Alternatives to this coal development plan were explored as well.

Results

In both cases, the analysis showed that solar and wind integration does not require one-to-one storage or backup capacity on the grid. Rather, their variability and intermittency can be managed by the overall grid flexibility inherent in the operational characteristics of other resources such as hydropower, biomass and natural gas.

The analysis showed that Laos will need about 41 GW of additional generation capacity by 2035. There is potential for diversification of the nation's electricity mix using solar and wind resources. A diverse electricity mix will lessen the grid's environmental impact, and enable broader power system investments and greater economic diversity, while shielding Laos from the environmental and financial risks of coal generation.

The analysis showed that Kenya will need 26 GW of additional generation capacity by 2035. It also showed that load growth can be met sustainably and cost effectively using geothermal and wind resources predominantly, and with some natural gas.

More importantly, the model showed that coal development is not an economically optimal choice in either country. Building coal now as a stop gap to future transitions to low-carbon systems may lock Kenya and Lao PDR into a sub-optimal expansion pathway that is economically and environmentally expensive.

Conclusions

There is significant potential for clean energy to improve electricity access and alleviate poverty in Asia and sub-Saharan Africa. This potential has been demonstrated by national level power systems modeling in Lao PDR and Kenya. The choice to investment in fossil fuels, particularly coal, should be approached judiciously to prevent locking in environmentally damaging expansion pathways. Successful integration of high penetrations of variable renewables may require high grid flexibility which can be sourced from existing resources such as large hydropower and from new resources such as grid energy storage costs. Many countries battling with energy and poverty challenges today will eventually be at the forefront of rapid economic development in the coming years. Their energy choices will be critical to ensuring a global sustainable future. Simple open-access tools such as PROGRESS enables the vetting of possible power expansion pathways, thereby providing critical insight to policymakers and other stakeholders.

References

Casillas, C. E., & Kammen, D. M. (2010). The energy-poverty-climate nexus. Science, 330(6008), 1181-1182.

de Leon Barido, D. P., Johnston, J., Moncada, M. V., Callaway, D., & Kammen, D. M. (2015). Evidence and future scenarios of a low-carbon energy transition in Central America: a case study in Nicaragua. Environmental Research Letters, 10(10), 104002.

IEA, World Bank. (2015). Sustainable Energy for All 2015—Progress Toward Sustainable Energy. International Energy Agency and The World Bank, Washington DC, USA.