Thesis title

Coupling energy systems planning and operation for renewable power capacity expansion in Africa

Short description

Increasing population [1] and energy access [2] are triggering investments in power capacity in Africa. As these regions are already affected by climate change impacts, there is a need to evaluate potential pathways to decarbonize the current energy system and develop new capacity to satisfy the existing and future demand [3]. To evaluate the many infrastructural options available, energy system models are used to simulate and optimize energy system under future socio-technical scenarios [4].

Energy system models for long-term capacity expansion adopt simplified system operations, typically computing the energy balance with respect to a predefined demand at the monthly, seasonal, or annual time step. On the other hand, power system simulators typically run at an hourly resolution or higher. By discarding information at a higher time resolution, relevant detail regarding renewables integration is lost, especially when considering non-dispatchable wind and solar in combination with dispatchable reservoir hydropower. Overlooking the potential of these operational schemes precludes the development of sustainable energy pathways in regions with high hydropower capacity. Furthermore, these operational alternatives might have lower social and environmental impact than building new reservoirs in regions where hydropower potential remains.

The aim of the thesis is to couple the long-term energy system planning model OSeMOSYS-TEMBA [5] with the power system simulator PowNet [6] to reconcile coarse-scale energy planning decisions with fine-scale renewables and hydropower operations. In particular, the student is expected to carry out the following activities:

1. Literature review: reviewing the state of the art of energy system models for planning and operations with a focus on capacity expansion considering renewables integration in the African continent.
2. Run optimizations using the energy system model OSeMOSYS-TEMBA under different scenarios and analyze corresponding outputs.
3. Implement a structured conversion of the output from OSeMOSYS-TEMBA into datasets to be used as input in PowNet.
4. Reconcile differences between the outputs of the OSeMOSYS-TEMBA and PowNet models with respect to hydropower and variable renewables generation and discuss potential alternatives for capacity expansion.

Relevant courses and knowledge: Natural Resources Management / Advanced Environmental Systems Analysis

Number of Students: 1 or 2

Requisites*:* The student should be comfortable with data handling and programming skills (preferably Python, Matlab).

References

(1) Samir, K.C. and Lutz, W., 2017. The human core of the shared socioeconomic pathways: Population scenarios by age, sex and level of education for all countries to 2100. Global Environmental Change, 42, pp.181-192.
(2) Dalla Longa, F. and van der Zwaan, B., 2021. Heart of light: an assessment of enhanced electricity access in Africa. Renewable and Sustainable Energy Reviews, 136, p.110399.
(3) Lucas, P.L., Nielsen, J., Calvin, K., McCollum, D.L., Marangoni, G., Strefler, J., van der Zwaan, B.C. and van Vuuren, D.P., 2015. Future energy system challenges for Africa: insights from Integrated Assessment Models. Energy Policy, 86, pp.705-717.
(4) Pfenninger, S., Hawkes, A. and Keirstead, J., 2014. Energy systems modeling for twenty-first century energy challenges. Renewable and Sustainable Energy Reviews, 33, pp.74-86.
(5) Pappis, I., Howells, M., Sridharan, V., Usher, W., Shivakumar, A., Gardumi, F., Ramos, E., Hidalgo González, I., Medarac, H. and González Sánchez, R., 2019. Energy projections for African countries. EUR, 29904.
(6) Chowdhury, A.K., Kern, J., Dang, T.D. and Galelli, S., 2020. PowNet: a network-constrained unit commitment/economic dispatch model for large-scale power systems analysis. Journal of Open Research Software, 8(1).