AN ENERGY SYSTEM OPTIMIZATION MODEL WITH LIFE-CYCLE ASSESSMENT PERSPECTIVE

Thushara Addanki, Technical University of Munich, +49(89)289-52732, thushara.addanki@tum.de
Andrea Cadavid Isaza, Technical University of Munich, +49(89)289-52727, andrea.cadavid@tum.de
Cristina de la Rua, Technical University of Munich, +49(89)289-52737, cristina.de-la-rua@tum.de
Leonhard Odersky, Technical University of Munich, +49(89)289-52752, leonhard.odersky@tum.de
Thomas Hamacher, Technical University of Munich, +49(89)289-52741, thomas.hamacher@tum.de

Overview

An in-depth understanding of the state of the energy sector, while drafting climate policies, requires comprehensive tools. Most of the current energy models offer limited assistance by considering only a few stages in the life cycle of energy systems. With the expansion of renewable energy technologies such as solar and wind energy in the energy mix, the decentralized energy systems bring many contrasting factors to the table, such as clean energy generation but emissions during the manufacturing of these technologies and production of the materials within. Such impacts from other stages of life are highlighted by life cycle assessment (LCA) [1], which is usually done as a post-analysis. This work discusses a first approach towards developing a robust new model framework to integrate important insights from LCA approaches and add an essential phase of a plant's life cycle: material production within optimization.

Methods

An opensource optimization model called *urbs* [2] is upgraded to include the material production phase. *urbs* can be used to optimize either total costs or total emissions of an energy system. It has an intertemporal mode through which energy system can be simulated and optimized for multiple years together. The model constraints are modified so that an extra energy demand is identified and added to the previous years for assembling new power plants and manufacturing key materials. The energy needs and corresponding emissions for these upstream processes are derived from database ecoinvent 3.7 [3]. The new model framework makes sure that the new power plants come into operation only after they have been built in previous years.

Results

A generic example case is studied to compare the model results before and after implementing the new framework. It is a single region electricity model from year 2022 to 2062 with few conventional power plants like coal, combined cycle, and hydro; and intermittent renewable power plants like photovoltaics (PV) and wind. The model is optimized for both total costs and total emissions separately. The results of this study show that the optimum mix of the power plants changes with introduction of material production phase. In all scenarios, the new model favored wind capacity expansion more than PV, which is opposite to the standard *urbs* model. This is due to the high emissions and energy needs to manufacture PV plants, especially Silicon production that go into modules.

Conclusions

The key takeaway from this study is that a successful integration of the energy model with the upstream process definition is possible and would be useful in simulating more comprehensive and meaningful scenarios, especially for the research on low or zero-carbon energy systems. However, it needs to be highlighted that the new model offers only a first step in the direction of LCA hard-coupled energy models. There is much room for improvement like defining the material production process for storages and transmission systems, considering end-of-life stages, and integrating impact assessment indices within the energy model. Furthermore, the new model framework gives more useful results when simulated for more than one node where the material production takes place thousands of kilometers away from most of the demand centers.

References

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