RENEWABLE ENERGY CONSTRAINTS AND THE STORAGE CYCLING TRAP: UNINTENDED EFFECTS AND IMPLICATIONS FOR POWER SECTOR MODELING

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Overview

To decarbonize the economy, many governments have set targets for the use of renewable energy sources. These are often formulated as relative shares of electricity demand or supply. Implementing respective constraints in energy models is a surprisingly delicate issue. They may cause a modeling artifact of excessive electricity storage use. We introduce this phenomenon as 'unintended storage cycling,' which can be detected in case of simultaneous storage charging and discharging. In this paper, we first provide an analytical representation of different approaches for implementing minimum renewable share constraints in models, and how these may lead to unintended storage cycling. Using a parsimonious optimization model, we then quantify related distortions of optimal dispatch and investment decisions as well as market prices, and identify important drivers of the phenomenon. Based on this, we provide recommendations on how to avoid the distorting effects of unintended storage cycling in energy modeling.

Methods

We use a parsimonious power sector optimization model to analytically show how different minimum renewable constraint formulations relate to costs and market values of storage. Additionally, we use a numerical implementation of our power sector model to derive optimal dispatch and capacity expansion decisions. It is a stylized version of the larger DIETER capacity expansion model (Zerrahn et al., 2017; Zerrahn & Schill, 2018)

Results

We show that unintended storage cycling is a model artifact that may arise in cost-optimizing energy models with a binding renewable energy constraint. Instead of curtailing renewable surplus, the excess electricity is removed from the system by converting it into unintended storage losses from simultaneous storage charging and discharging. The increase in renewable generation can be realized without additional renewable capacity installations, thus helping to achieve the renewable energy target at lower costs. Optimal dispatch and investment patterns of all other technologies may be flawed and, at least party, aim at generating unintended storage losses.

Conclusion

Policy recommendations based on flawed numerical conclusions expose policy-makers to an incomplete or even perverted decision basis. We thus recommend to include all storage losses to the renewable energy constraint used in energy models. Unintended storage cycling is a special case of unintended energy cycling that may arise in comprehensive energy models considering a large number of technologies or different economic sectors, such as transport or heat provision. Any feasible losses arising in the energy model through unintended energy cycling via re-conversion processes, standing losses, or transmission have to be considered in the loss term of the renewable share constraint. Depending of the scope of the model, this may entail a complex formulation of the renewable energy constraint.

References

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