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Debunking the speed-fidelity trade-off: Speeding-up large-scale energy models while keeping fidelity

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Abstract-

Energy system models are essential for planning and supporting the energy transition. However, increasing temporal, spatial, and sectoral resolutions have led to large-scale linear programming (LP) models that are often (over)simplified to remain computationally tractable—frequently at the expense of model fidelity. This paper challenges the common belief that LP formulations cannot be improved without sacrificing their accuracy. Inspired by graph theory, we propose to model energy systems using energy assets (vertices), as a single building-block, and flows to connect between them. This reduces the need for additional components such as nodes and connections. The resulting formulation is more compact, without sacrificing accuracy, and leverages the inherent graph structure of energy systems. To evaluate performance, we implemented and compared four common modelling approaches varying in their use of building blocks and flow representations. We conducted experiments using TulipaEnergyModel.jl and applied them to a multi-sector case study with varying problem sizes. Results show that our single-building-block (1BB-1F) approach reduces variables and constraints by 26% and 35%, respectively, and achieves a 1.27x average speedup in solving time without any loss in model fidelity. The speedup increases with problem size, making this approach particularly advantageous for large-scale models. Our findings demonstrate that not all LPs are equal in quality and that better reformulations can lead to substantial computational benefits. This paper also aims to raise awareness of model quality considerations in energy system optimisation and promote more efficient formulations without compromising fidelity.

Index Terms- Energy sector coupling; Optimisation modelling; Energy system models; Linear programming (LP); Computational efficiency

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