INVESTIGATING THE ECONOMIC GRANULARITY GAP IN THE MODELLING OF BATTERY ELECTRIC VEHICLES: AN ANALYSIS FROM A POWER-SYSTEM AND A USER-CENTRIC PERSPECTIVE

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Overview

Strategies for decarbonising large-scale energy systems have a decisive impact on future energy costs and must, therefore, be thoroughly evaluated. Energy systems optimisation models (ESOMs) are frequently employed in the analysis and planning of energy systems. However, their scope and detail in terms of space, time, technologies, and economic sector can vary widely. Due to computational limitations, they can either have a high-resolution scope or a broader less detailed scope in the spatial and temporal dimensions. This difference between modelling scopes has been labelled with the term granularity gap [1]. Solutions to address this modelling gap include boosting the resolutions of the established optimisation model and various types of model coupling [1]. Specifically, the economic granularity gap refers to the modelling of discrepancies between a system-cost minimising approach from ESOMs and a micro-level simulation approach, where the behaviour and interactions of individual agents follows their own individual strategies like in a real-world case. Operating decisions of private actors are indeed having an ever increasing influence on the energy system [2, 3]. However, ESOMs are falling short in including such actors and their decisions in the modelling approach. Against this background, this work analyses whether the economic granularity gap in the case of battery electric vehicles (BEVs) significantly affects the system design and operation that results from an ESOM. To illustrate these effects on the charging profiles of BEVs, results from a ESOM with optimised charging from an overall system's perspective are compared to that of a model that captures the economic rationality of time-varying tariffs and user-centric charging decisions for a case study in Germany.

Methods

Instead of extending existing models, the identified granularity gap in the case of BEVs is analysed by comparing results from the energy systems optimisation model REMix [4] with a user-centric optimisation based on the VencoPy model [5].

To analyse the influence of optimised charging under consideration of different time-varying tariffs for different household types, the VencoPy framework is used [5]. VencoPy calculates boundary conditions for the charging behaviour and of possible vehicle-to-grid potentials based on mobility data and techno-economic assumptions. This allows to investigate the increased demand for electricity due to the electrification of passenger road transport. Figure 1 shows a schematic representation of the model building blocks. Based on driving profiles of typical households as well as on technical data and assumptions about BEV, boundaries for minimum and maximum states of charge (SoC) of the vehicle batteries are calculated. From this, hourly resolved demands for uncontrolled charging, as well as load shift potentials for controlled charging can be derived for different BEV fleets. The VencoPy framework was used in different projects [5, 6, 7]. Among others, it was applied to the German transport survey "Mobility in Germany" to investigate the influence of BEV on the future load shifting potential and its impact on the German power system. The framework was applied in a case study involving two recent German national travel surveys [8, 9] to exemplify the implications of different mobility patterns of motorised individual vehicles on load shifting potential of BEV fleets [5]. Exemplary results of the framework include the distance travelled per hour, the connection availability, and the upper and lower limit for the battery SoC. Based on different decision methods, charging and discharging profiles can be calculated. More recently the framework has been expanded to also allow tariff-based optimisation by additionally taking time-varying prices into account in the charging control mechanism.

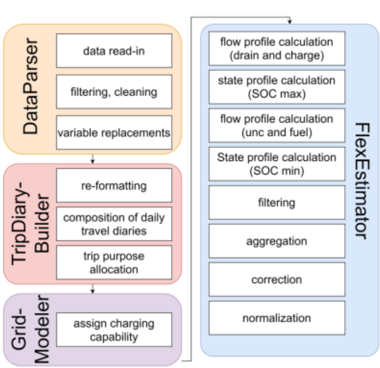

Figure 1: VencoPy model workflow components.

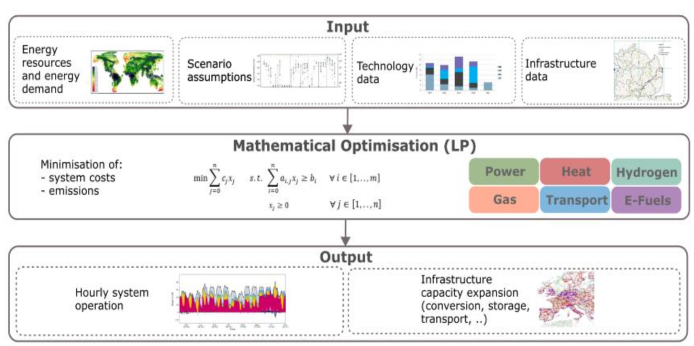

Figure 2: Structure of the REMix framework.

ESOMs represent a widely used technique to determine decarbonisation pathways to assist policymakers in the definition of future energy systems. The REMix energy system modeling framework provides a linear framework with high spatial and temporal resolution to analyse energy system transition scenarios [4]. After initially being restricted to the power sector [8], the framework has progressively improved to incorporate the flexible coupling to the heating, industry and transportation sectors, through a multi-modal configuration that enables the use of electricity from variable renewable energy sources in all sectors. Considering boundary conditions, such as the development of demand or the flexibility of generators and consumers, REMix can be used to evaluate the interaction between all technologies in hourly resolution and to determine the minimum-cost expansion and operation of the energy supply system under consideration (Figure 2). Numerous models of the German and European energy system with various foci have been modeled and examined in the past using the framework, as well as energy systems of other countries [10, 11, 12].

Results

Granularity gaps often emerge across several model dimensions in energy systems modeling. To investigate if the economic granularity gap in the case of BEVs significantly affects system designs that result from an energy system optimisation model, the results from the REMix framework and a user-centric optimisation in the VencoPy model are compared.

The results provide an assessment of how the representation of charging profiles and flexibility of BEVs might affect energy systems optimisation results. Both frameworks are applied to different scenarios for controlled charging of BEV fleets in Germany. ESOMs, which are typically used to study cost-minimal transformation pathways, assume a perfect behaviour of market participants from a central planner's perspective. They thus neglect the decision-making of individual market participants, which also influences the demand-side flexibility in the case of BEVs [13]. The results also show how the difference between power-system and user-centric optimal charging decisions can lead, for example, to lower electricity imports and transmission grid expansion, a different usage of flexibility from the system perspective, and different system costs.

Conclusions

Models are applied to gain insights into possible futures of the energy system, e.g., to serve for decision support in energy policy and industry. Drafting ideal system designs by energy systems optimization models provides templates to navigate possible system transformation. However, discrepancies between the optimal and the real-world occur and granularity gaps arise across several model dimensions [1]. Moreover, electricity tariffs are a main economic driver for private consumer investments in distributed energy resources (DERs), such as photovoltaic (PV), electric vehicles and storage systems [14]. Utilities' rate designs and policy makers' decisions around different tariff components (volumetric rates, demand charges, feed-in compensations, etc.) affect the economic viability of DER technologies, fostering or discouraging behind-the-meter investments [15]. Including decentralised user-centric decisions in energy systems optimisation models can provide a starting point to include different perspectives in energy systems transformation pathways as well as allowing a more proper identification of appropriate regulatory regimes, as for example incentives for system alignment of decentralised actors.

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