Quantifying the economic granularity gap by model coupling: The case of prosumer self-consumption in Germany

Topics: 1 and/or 4

Seyedfarzad SARFARAZI[1] (1), Karl-Kien CAO (1), Shima SASANPOUR (1), Valentin BERTSCH (2)

(1) German Aerospace Center, Institute of Networked Energy Systems, Department of Energy Systems Analysis, Curiestraße 4, 70563 Stuttgart, Germany
(2) Chair of Energy Systems and Energy Economics, Ruhr University Bochum (RUB), 44801 Bochum, Germany

Motivation and central research question

Energy system models are widely used to assist political decisions required to successfully mitigate climate change in the energy sector. While energy system optimization models (ESOMs) are applied to study the optimal transformation pathways, they assume a perfect behavior of market participants from a central planner's perspective. Neglecting the decision-making under uncertainties or ignoring distortions due to regulatory frameworks leads to an "economic granularity gap" compared to the real-world energy system [1]. Since agent-based models (ABMs) are good tools to capture the behavior of the market actors, attempts were made to identify this gap by model coupling of an ESOM and an ABM [2]. We propose an automated workflow for such model coupling and quantify this gap for the case of prosumer self-consumption.

Methodology

To quantify the economic granularity gap that arises in energy system modelling, we couple the ESOM REMix [3] and the electricity market ABM AMIRIS [4]. As a case study, we investigate prosumer self-consumption. To model this case, a prosumer and an aggregator are implemented in AMIRIS.

Our proposed model coupling workflow (Figure 1) starts by parameterizing and running REMix. The results of REMix, which represent an optimized energy system expansion and operation, are fed into AMIRIS. To process the required parameters in a reproducible and scalable way, and make the REMix results compatible with AMIRIS we use a tool that is based on the open-source workflow manager ioProc [5]. At this point, we harmonize the models to validate the model coupling. In the absence of uncertainty and the regulatory framework in AMIRIS, the resulting electricity prices from both models should be the same.

In the next step, AMIRIS is parameterized and run with a specific regulatory framework (such as feed-in incentives as well as regulatory induced charges on household electricity prices). The actors' behavior in AMIRIS may deviate from the optimized one of the central planner (REMix). To measure the emerged economic granularity gap, REMix is then run for the second time using the resulting PV-storage dispatch in AMIRIS as the lower bound of the storage dispatch. To integrate these tools and processes into an automated, executable workflow, the Remote Component Environment (RCE) software is used [6].

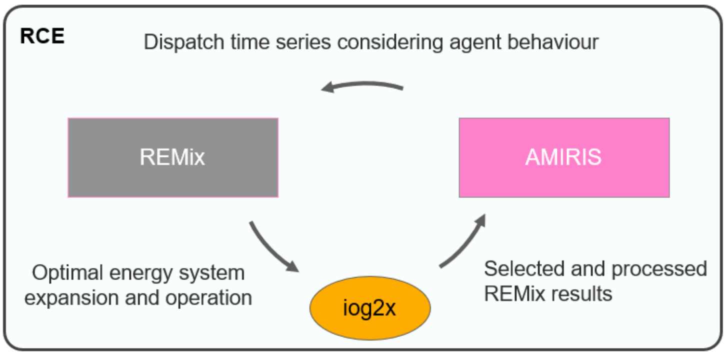

Figure 1: Schematic overview of model coupling workflow

[1] Seyedfarzad.sarfarazi@dlr.de, +49 711 6862-8290, www.DLR.de/ve

Results and conclusion

We propose an automated workflow to couple an ESOM and an ABM to quantify the economic granularity gap that arises in energy system modelling. After the complete harmonization of the models, the emerged economic granularity gap for the case of prosumer self-consumption under two electricity tariff schemes is studied. Figure 2 shows the dispatch of PV-storage systems under static and real-time pricing (RTP)[2] tariff schemes in AMIRIS. As can be seen, the introduction of a dynamic electricity tariff scheme influences the self-consumption pattern of prosumers. The most prominent change in the usage of the battery storage happens from 20:00 to 22:00. In the case of an RTP tariff, in these hours the prosumer takes advantage of low retail prices and covers her electricity demand from the grid. The battery discharges later, during the hours 00:00 to 04:00, to cover the electricity demand.

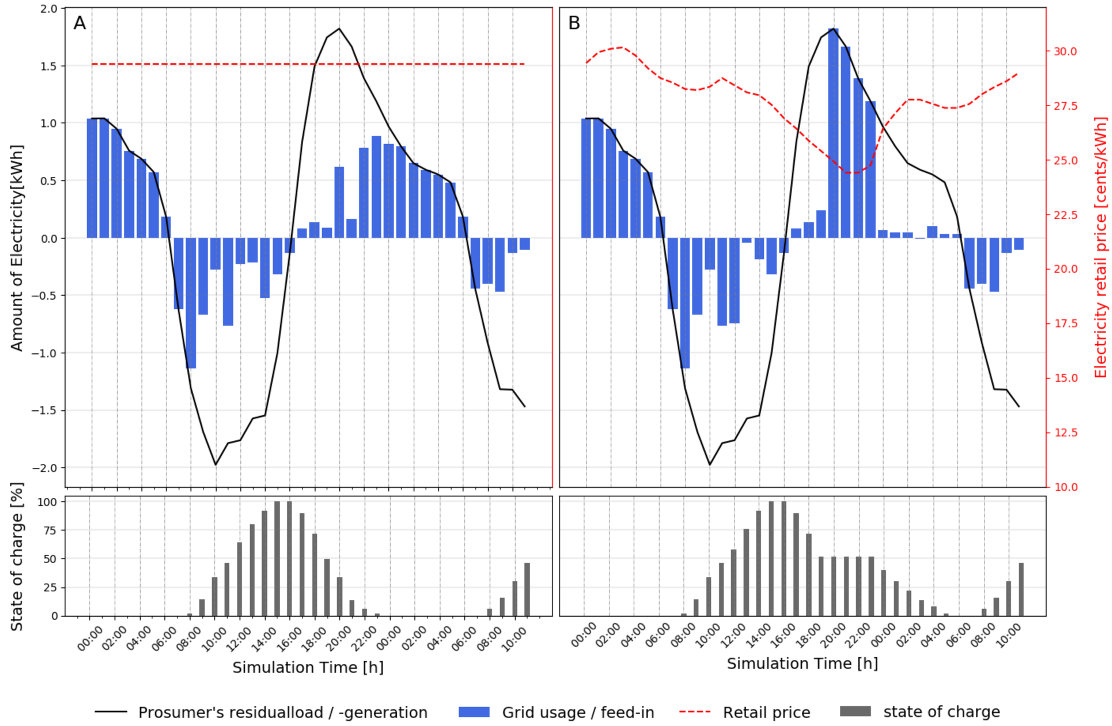

Figure 2: Prosumer dispatch for an exemplary 36 hours simulation time under A) static pricing and B) real-time pricing.

Despite the necessity of appropriate grid infrastructure, such a response of prosumers in the case of the RTP scheme is beneficial from an overall system's perspective, as it increases the alignment of power consumption of distributed generation with the wholesale market signals. Our preliminary results show that exposing the prosumers to RTP signals contributes to narrowing the economic granularity gap. The implementation of such tariffs requires communication infrastructures (e.g. smart-meter gateway) that are currently only partially available for small-scale households in Germany.

Literature

[1] Cao, Karl-Kiên, et al. "Bridging granularity gaps to decarbonize large-scale energy systems—The case of power system planning." Energy Science & Engineering (2021).
[2] Torralba-Díaz, Laura, et al. "Identification of the Efficiency Gap by Coupling a Fundamental Electricity Market Model and an Agent-Based Simulation Model." *Energies* 13.15 (2020): 3920.
[3] Gils, Hans Christian, et al. "Integrated modelling of variable renewable energy-based power supply in Europe." Energy 123 (2017): 173-188.
[4] Deissenroth, Marc, et al. "Assessing the plurality of actors and policy interactions: agent-based modelling of renewable energy market integration." Complexity 2017 (2017).
[5] https://pypi.org/project/ioproc/
[6] Seider, Doreen, et al. "Open source software framework for applications in aeronautics and space." 2012 IEEE Aerospace Conference. IEEE, 2012.

[2] Real-time electricity tariff represents a case where the electricity tariff scheme consists of time-varying retail prices, which are proportional or parallel to the electricity wholesale market price.