ON THE IMPORTANCE OF ACCURATE DEMAND REPRESENTATION IN LARGE SCALE ENERGY SYSTEM MODELS

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Contents

Source: Institut für Elektrizitätswirtschaft und Energieinnovation/TU Graz

Evolution of Energy System Models*

Paradigms	Challenges
Optimization models	Detailed time and space
Simulation models	Uncertainty and transparency
Power systems and markets models	Complexity and optimization
Mixed-methods scenarios	Capturing the human dimension

* S. Pfenninger, A. Hawkes, and J. Keirstead, "Energy systems modeling for twenty-first century energy challenges," *Renew. Sustain. Energy Rev.*, vol. 33, pp. 74–86, 2014.

Electricity Demand in Energy System Models

- **Energy System Models:** Large optimization models built using a bottom-up perspective and assuming a centralized decision maker. Our focus will be on **electricity**

$$\min \sum_{k,g} C^g p_{g,k} + \sum_{k,i} C^{nsp} nsp_{i,k} + \sum_{k,i,j} C^N f_{k,j,i}$$

Objective function

$$\text{s.t.} \quad \underline{P_w} \leq p_{w,k,i} \leq CF_k \overline{P_w} \quad \forall k, w, i$$

$$\underline{P_t} \leq p_{t,k,i} \leq \overline{P_t} \quad \forall k, t, i$$

Max. production

$$\sum_j f_{k,j,i} - \sum_j f_{k,i,j} + nsp_{i,k} + \sum_{g \in i} p_{g,k} = D_{k,i} \forall k, i$$

Balance constraint

$$p_{t,k} - p_{t,k-1} \leq RU \quad \forall k, t$$

$$p_{t,k-1} - p_{t,k} \leq RD \quad \forall k, t$$

Ramping constraints

$$f_{k,i,j} \leq \overline{F_l} \quad \forall k, i, j$$

$$f_{k,j,i} \leq \overline{F_l} \quad \forall k, i, j$$

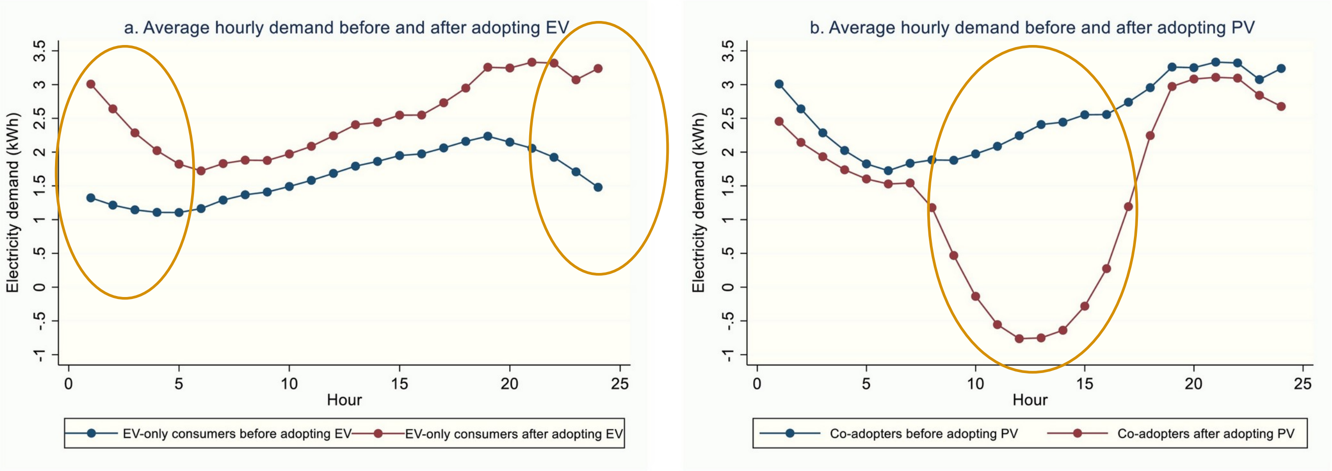
Flow conservation

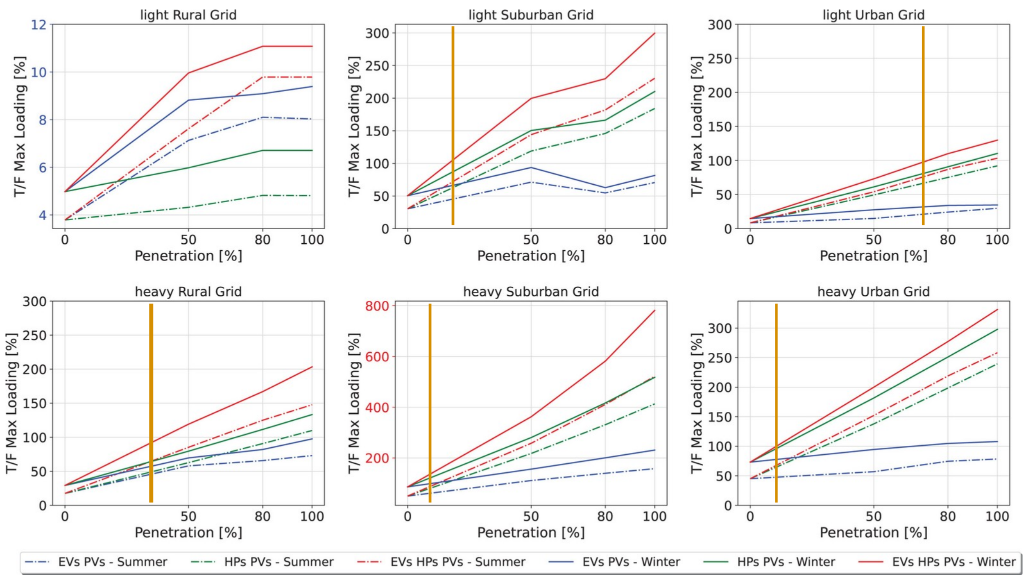
Formulation of a simplified **energy system model**

- Balance equation is an **equality** constraint
- Must be satisfied **exactly** at every time period
- Makes the modeling of **uncertainty** difficult

Electricity Demand in Energy System Models

- Behavior of **electricity demand** is changing, and will change even more in the coming years





- This changes in behavior have both, **economic** and **operational implications**

J. Liang, Y. (Lucy) Qiu, and B. Xing, “Impacts of the co-adoption of electric vehicles and solar panel systems: Empirical evidence of changes in electricity demand and consumer behaviors from household smart meter data,” *Energy Econ.*, vol. 112, no. May 2021, p. 106170, 2022.

N. Damianakis, G. R. C. Mouli, P. Bauer, and Y. Yu, “Assessing the grid impact of Electric Vehicles, Heat Pumps & PV generation in Dutch LV distribution grids,” *Appl. Energy*, vol. 352, no. June, p. 121878, 2023.

Electricity Demand in Energy System Models

Aggregated forecasts
Usually for each year

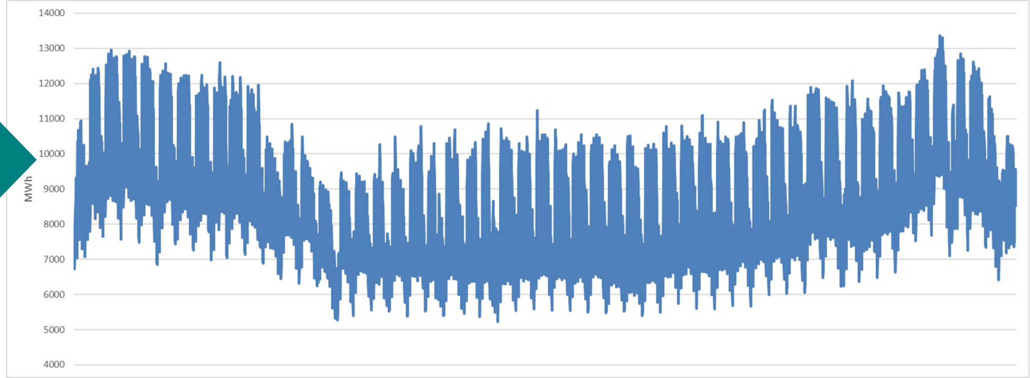
Centralized database

Flexible configuration:
- Profiles
- Demand per node
- Statistical sampling

Input data ready to be included in energy system model

THE WORLD BANK

STATISTIK AUSTRIA
Die Informationsmanager



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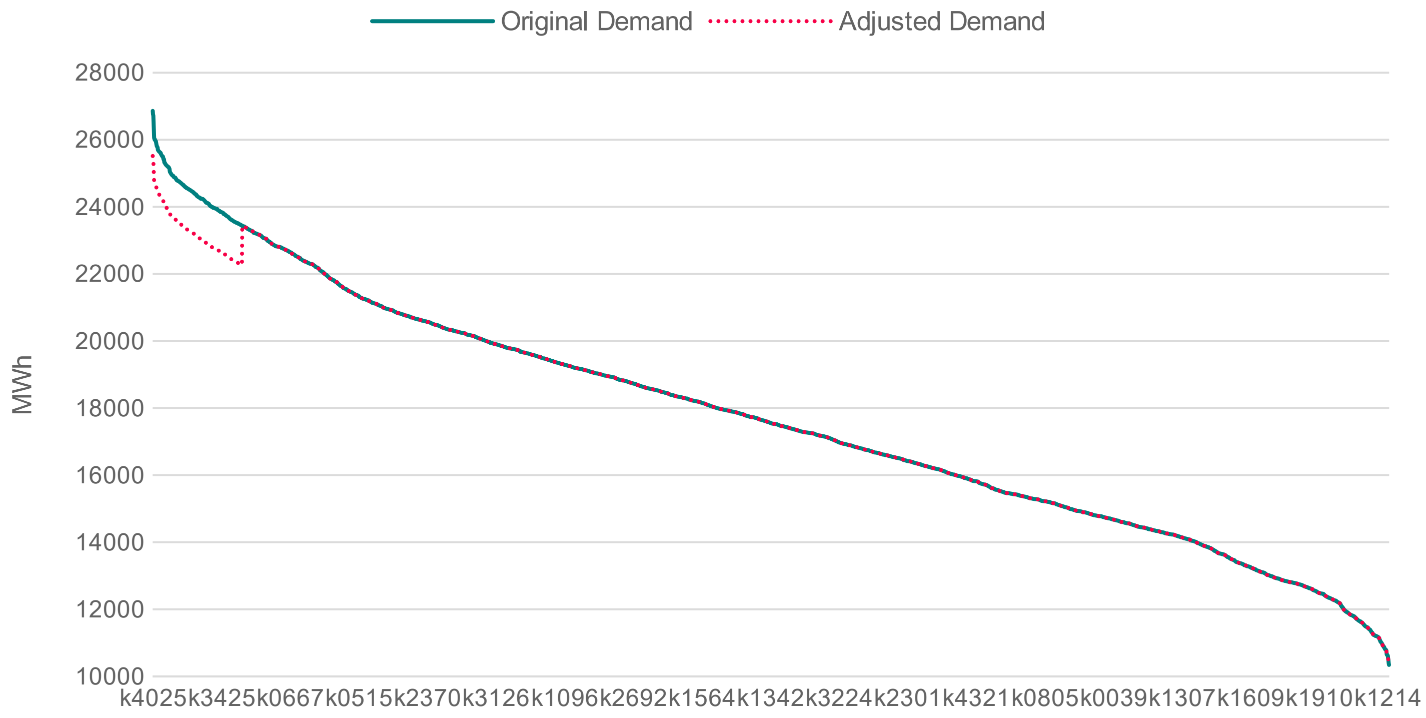
https://thenounproject.com/icon/yaml-file-document-icon-2604949/
https://en.wikipedia.org/wiki/File:Python-logo-notext.svg

Reducing Electricity Demand in Peak Hours

- **Scenario 1:** Reduce 5% of the electricity demand for the hours with 10% highest consumption for the Austrian Power System in 2030



Technology	Base Case	Energy Saving	Difference (%)
Batteries (MW)	38,79	8,68	-78%
Batteries (MWh)	92,88	17,36	-81%
Biomass (MW)	128,82	129,68	1%
Solar (MW)	15 903,00	15 649,20	-2%
Wind (MW)	5 116,88	5 116,45	0%
Obj. Function (MEUR)	2 170	2 139	-1,44%

- Short-term storage investment decisions change greatly under different peak demand scenarios

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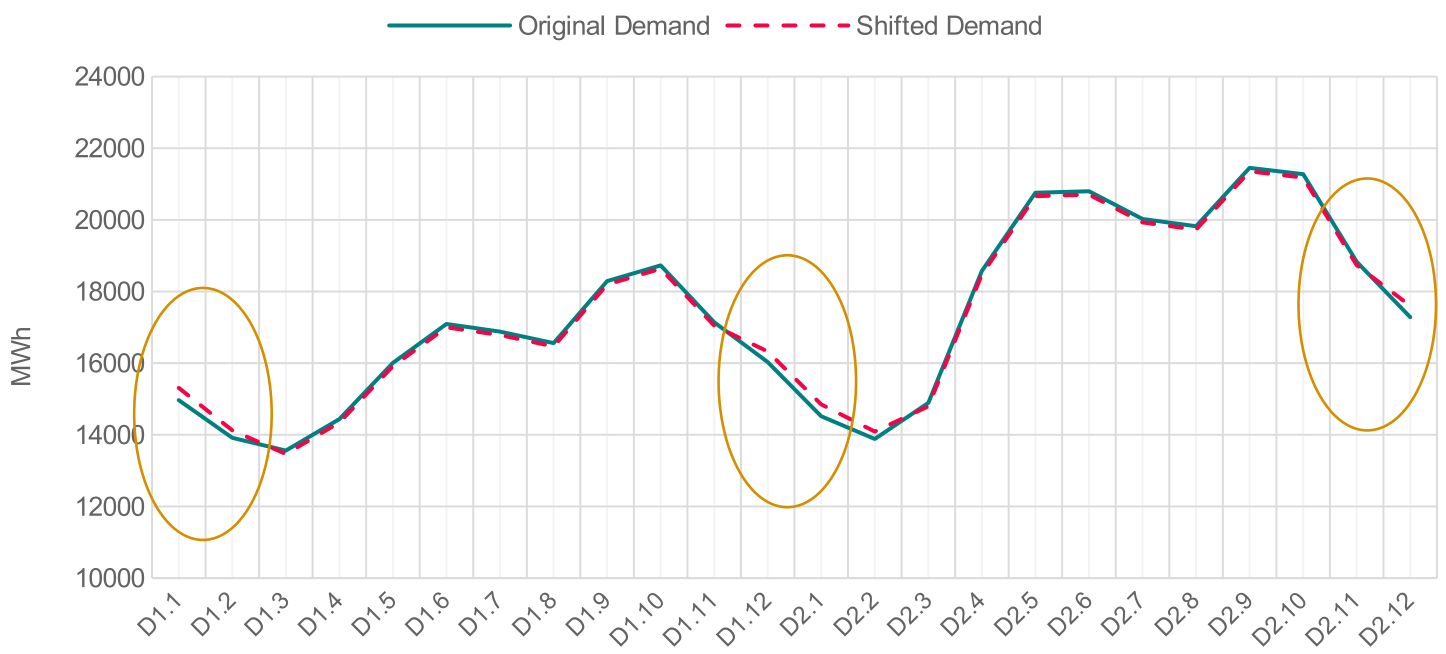
IEE Institut für Elektrizitätswirtschaft und Energieinnovation

Accounting for Electric Vehicles

- **Scenario 2:** Change the hourly profiles to account for electric vehicles adoption in the Austrian Power System in 2030



Technology	Base Case	Energy Saving	Difference (%)
Batteries (MW)	38,79	33,56	-13,5%
Batteries (MWh)	92,88	71,69	-22,8%
Biomass (MW)	128,82	128,85	0,0%
Solar (MW)	15 903,00	15 813,00	-0,6%
Wind (MW)	5 116,88	5 117,85	0,0%
Obj. Function (MEUR)	2170,36	2168,89	-0,1%

- Even small changes in the distribution of the demand lead to significant changes in particular investment decisions

Conclusions

- While demand-side management is a technology that might not be widespread in the medium term, there are behavioral changes in consumption that researchers should start to consider in their models

- The challenges posed to grid operators by electric vehicles and photovoltaic panels are already known; however, they also affect the long-term planning of energy systems

- We focused on the domain, but also at the geographical level this should be analyzed in more detail at the geographical level

- As future research, we would like to use results from macroeconomic models to fine-tune our demand data to consider economic activity, i.e., how much would the demand change in a given region because of increased mining activity?

Danke!

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