Effects of distortions in end-user tariffs on long-run equilibria with a high share of Prosumage households

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Motivation

- Recent trends show a **rise in investments in PV battery systems**, highlighting the growing significance of decentralized flexibility.
- Private households are encouraged to **maximize self-consumption** due to the current design of retail tariffs.

What are the effects of distortions in end-user tariffs on long-run equilibria with a high share of Prosumage households?

We examine this question by considering:

- Endogenous investments from both the wholesale and prosumer side
- Consideration of realistic market conditions
- Different retail and feed-in tariffs

Agenda

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Iteration of two LPs

- Two iteratively coupled linear programs to combine the optimization calculus of decentralized actors at the retail level with cost minimization at the wholesale level.

Wholesale LP

- Wholesale market + Retailer
- Objective: Min. total costs
- s. t. CO_2-budget
- End. investment in renewables, gas and storage
- Retailer must satisfy demand

→ Results: shadow prices

$q_t^{gridout}$

p_t^{ret}

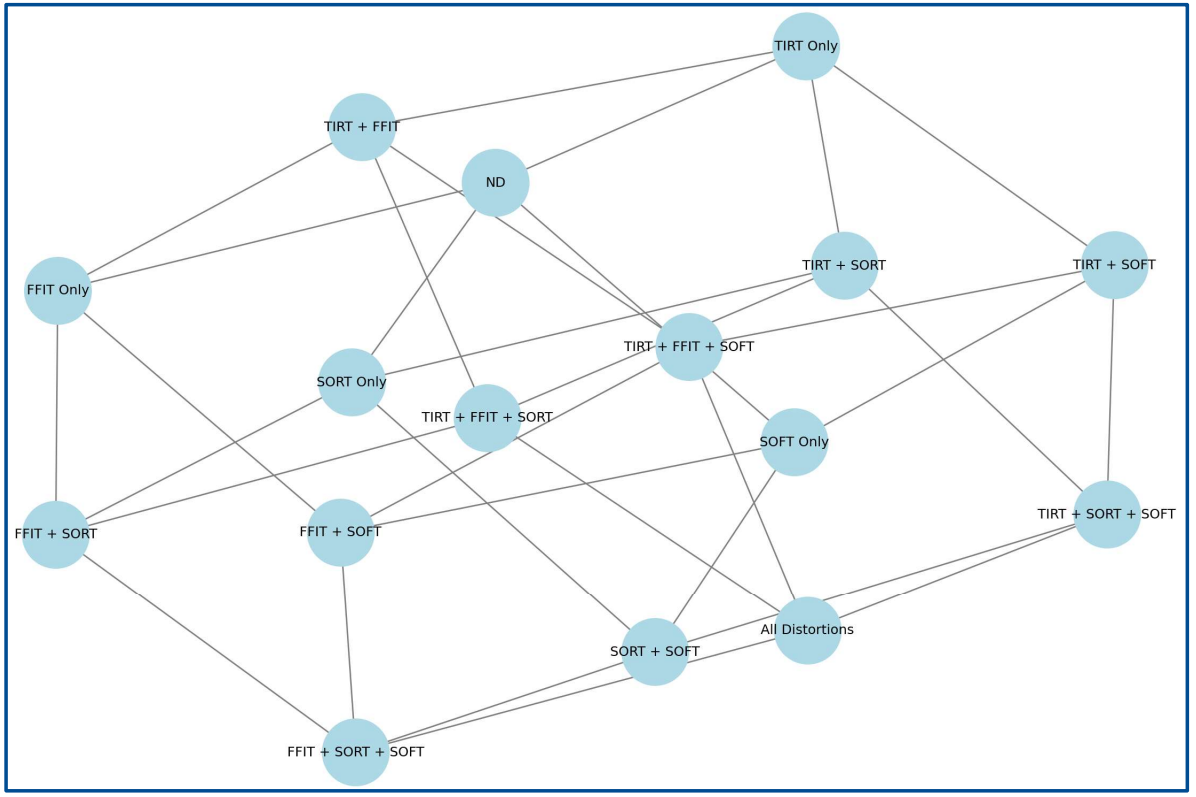
Prosumer LP

- Prosumer
- Objective: Min. total costs
  - Receives p_t^{FIT} for q_t^{gridin}
  - Pays p_t^{ret} for $q_t^{gridout}$
- End. investment in PV and storage

→ Results: optimal operation strategies + time granular purchases from retailer

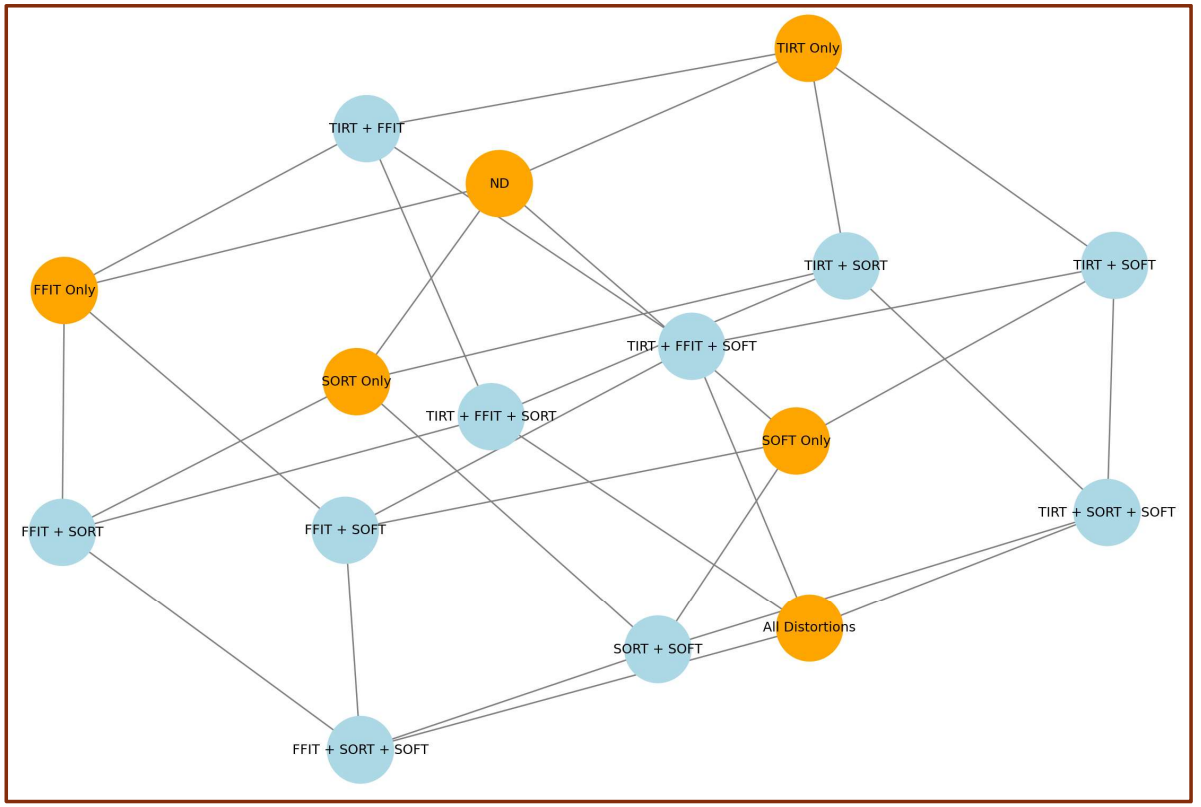
Distortions through tariffs I/II

- The starting point is the market equilibrium without distortions (pure market)
- Based on this, we consider four distortions:
  1. Time-independent retail tariffs (**TIRT**)
  2. Fixed feed-in tariffs (**FFIT**)
  3. Surcharges on retail tariff (**SORT**)
  4. Surcharges on feed-in tariff (**SOFT**)



Distortions through tariffs II/II

- 16 possible combinations
- We focus on 6 of the 16 cases
  1. No Distortions
  2. TIRT Only
  3. SORT Only
  4. FFIT Only
  5. SOFT Only
  6. All Distortions



Indicators

Prosumer level

- The **rate of self-consumption (RSC)** is determined by the relation between self-consumed electricity and PV-generation.

$$RSC = \frac{\sum_{t=1}^{T} Q_{t,y}^{SC} \cdot \Delta t}{\sum_{t=1}^{T} (PV_t \cdot (1-\alpha) - PV_{t,y}^{Curt}) \cdot \Delta t}$$

- The **rate of self-sufficiency (RSS)** is defined by the share of the load consumption that is supplied by direct-consumption and electricity discharged from the storage.

$$RSS = \frac{\sum_{t=1}^{T} (Q_{t,y}^{DC} + Q_{t,y}^{StoOut}) \cdot \Delta t}{\sum_{t=1}^{T} D_t \cdot \Delta t}$$

System level

- System costs
- Endogenous CO2-Price
- Capacity investments

cf. Dietrich, A., & Weber, C. (2018). What drives profitability of grid-connected residential PV storage systems? A closer look with focus on Germany. *Energy Economics*, *74*, 399-416.

Parameterization

Database (all open access)

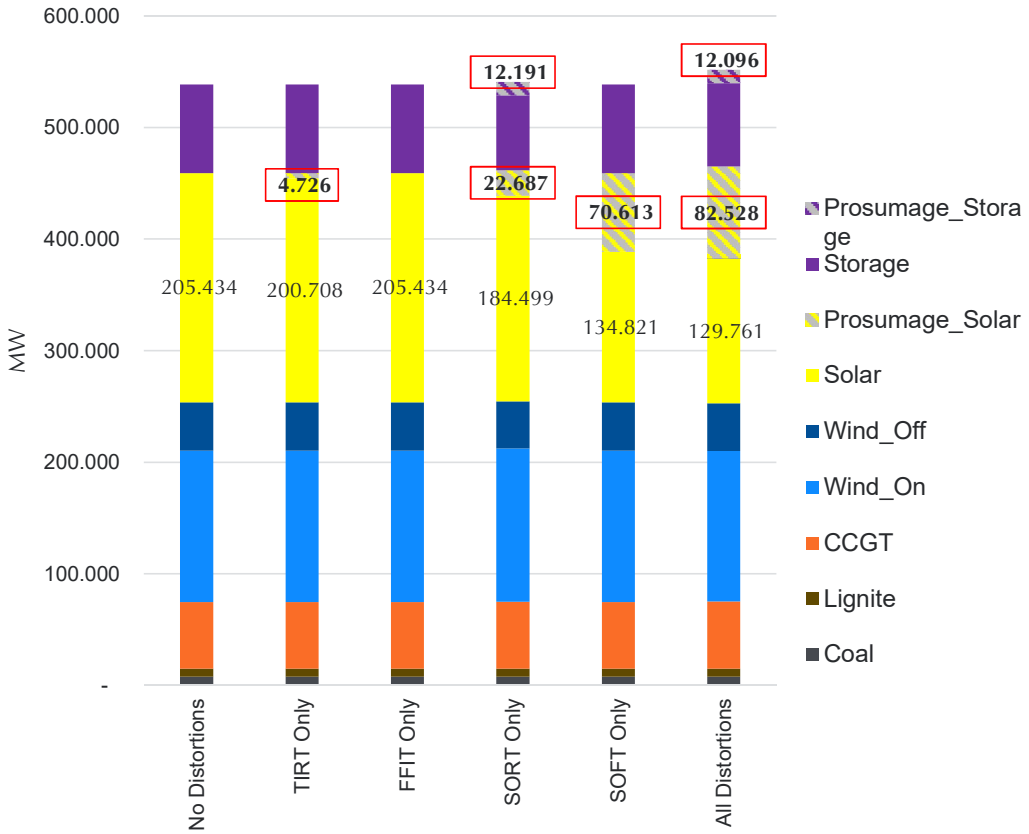
- AGORA-Study *"Towards a climate-neutral Germany by 2045"*
- Open-Power-System-Data
- BDEW-standard load profiles

Target year	**2030**
Gross electricity consumption	**643 TWh**
thereof priv. households	**129 TWh**
Number of priv. households	**41 million**
thereof Prosumage households	**10 million**
Emission cap energy industry	**88.2 Mt CO_2e**
PV potential Prosumage households	**100 GW**

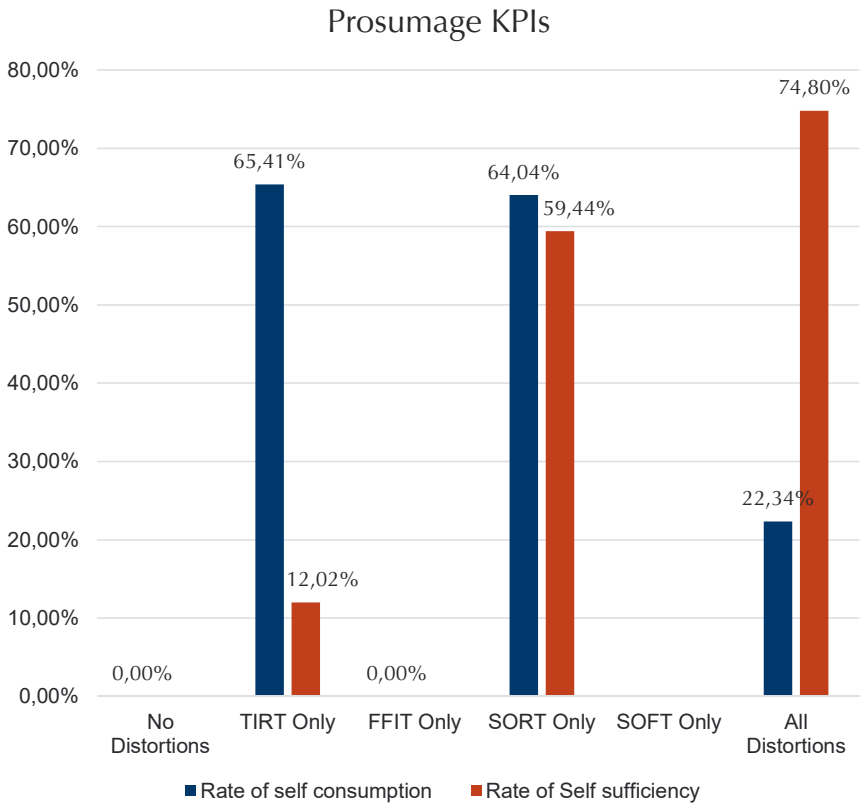
Tariff parameterization

- TIRT
  - (weighted) average wholesale market price
- FFIT
  - based on solar market value
- SORT
  - Historical value based on Monitoring report 2023, Federal Network Agency
- SOFT
  - Delta between "EEG"-feed-in tariff and market value

Capacities



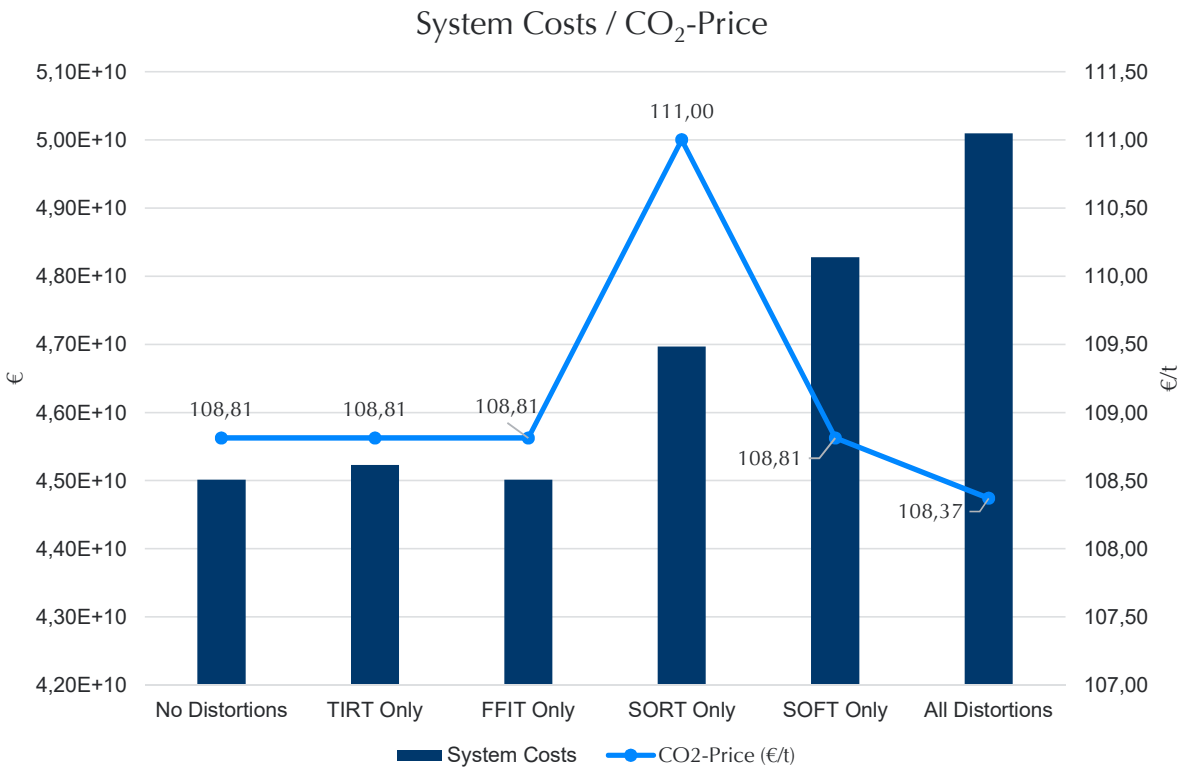
- **TIRT** creates an incentive for Prosumage households to invest in PV.
- The **FFIT** has no effect (at this level here).
- **SORT** creates a stronger incentive to invest in PV than the TIRT and we are even seeing investment in storage.
- In the **SOFT** case, the incentive to feed in is so great that households invest in 70 GW of solar and nothing in storage.
- The combination of **all distortions** leads to even greater investment in solar and some in battery storage.



- **TIRT** creates an incentive to consume a large proportion of the electricity generated themselves.
  - However, the proportion of total electricity consumption is low.
- **SORT** reduces demand from prosumers and also promotes self-consumption.
  - In addition, it encourages self-sufficiency by passing on time-dependent prices.
- In the **SOFT-Only** case, the incentive to feed in is so great that nothing is consumed or stored.
- The combination of **all distortions** leads to very large quantities of electricity generated by prosumers. This is reflected in the low rate of self-consumption, as a large surplus is fed into the grid.

System Level

- The **total system costs** are lowest in the case without any distortion and highest in the case with all distortions at the same time.
- The introduction of FFIT has no effect and therefore no effect on system costs.
- We see the **highest CO_2 price** in the SORT-Only case, as the prosumer behavior leads to a slightly higher demand for time-independent (here CCGT) generation capacity.



Conclusion

Distortions in end-user tariffs lead to significant shifts in Prosumage household behavior and system dynamics.

- Incentives from distortions like SORT significantly boost **Prosumer PV investment.**
- While some tariffs promote battery storage investment by enhancing the **value of self-consumption**, others, particularly SOFT, divert focus solely to solar generation due to lucrative feed-in incentives.
- The application of these tariffs **increases overall system costs**, peaking when all distortions are present simultaneously.

References

- Bernath, C., Deac, G., & Sensfuß, F. (2021). Impact of sector coupling on the market value of renewable energies–A model-based scenario analysis. *Applied Energy*, *281*, 115985.
- Bertsch, V., Geldermann, J., & Lühn, T. (2017). What drives the profitability of household PV investments, self-consumption and self-sufficiency?. *Applied Energy*, *204*, 1-15.
- Dietrich, A., & Weber, C. (2018). What drives profitability of grid-connected residential PV storage systems? A closer look with focus on Germany. *Energy Economics*, *74*, 399-416.
- Fridgen, G., Keller, R., Körner, M. F., & Schöpf, M. (2020). A holistic view on sector coupling. *Energy Policy*, *147*, 111913.
- Gabriel, S. A., Conejo, A. J., Fuller, J. D., Hobbs, B. F., & Ruiz, C. (2012). *Complementarity modeling in energy markets* (Vol. 180). Springer Science & Business Media.
- Günther, C., Schill, W. P., Zerrahn, A. (2021). Prosumage of solar electricity: Tariff design, capacity investments, and power sector effects. *Energy Policy,* 152 (2021), 112168.
- Kappner, K., Letmathe, P., & Weidinger, P. (2019). Optimisation of photovoltaic and battery systems from the prosumer-oriented total cost of ownership perspective. *Energy, Sustainability and Society*, *9*(1), 1-24.
- Schill, W. P., Zerrahn, A., & Kunz, F. (2017). Prosumage of solar electricity: pros, cons, and the system perspective. *Economics of Energy & Environmental Policy*, *6*(1), 7-32.

Thank you for your attention!

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