DIW BERLIN

IEA Workshop - Future Energy Market Designs: Research and Innovation Needs

Solar PV prosumage: pros, cons, system perspectives

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Berlin, October 23, 2018

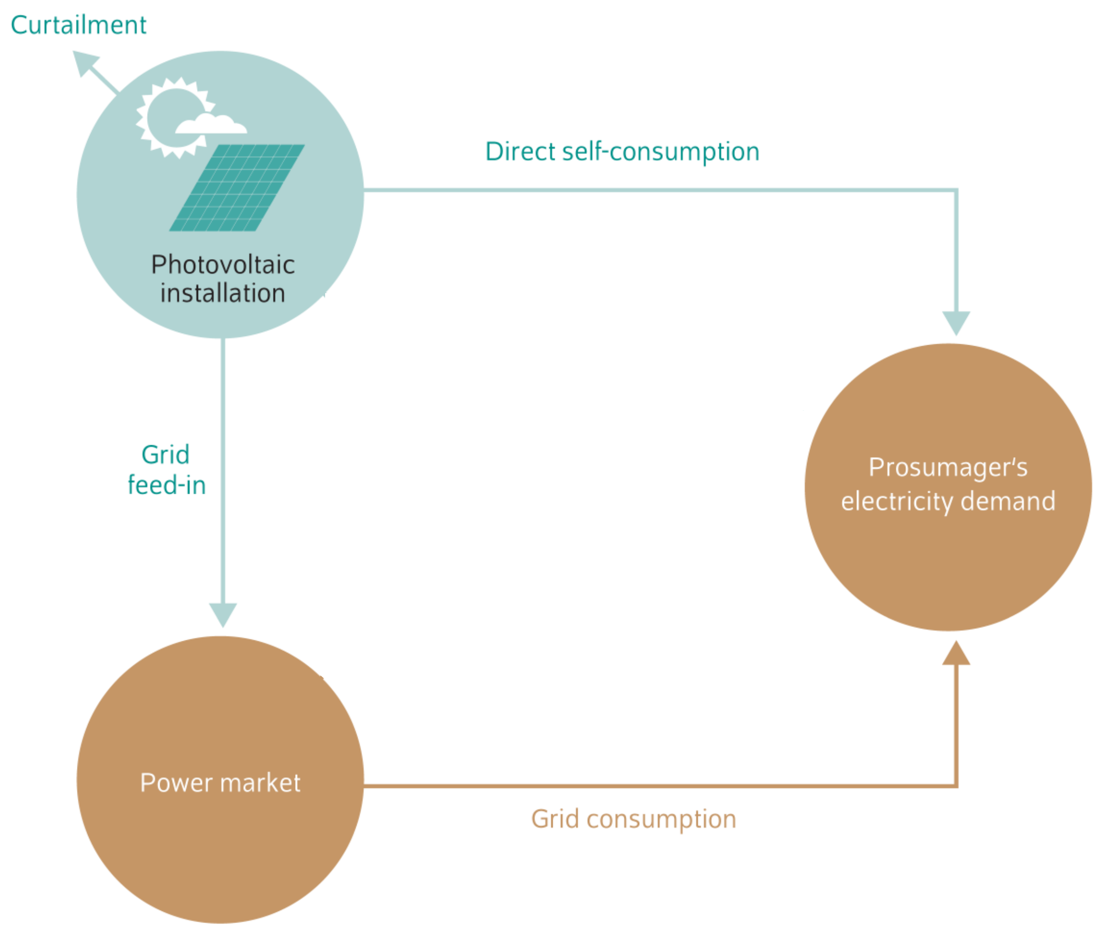
Qualitative discussion and quantitative analysis on the role of prosumage in future energy systems

Future research needs on market design and regulation

Talk based on completed and ongoing research at our institute

1 Prosumage

Prosumer



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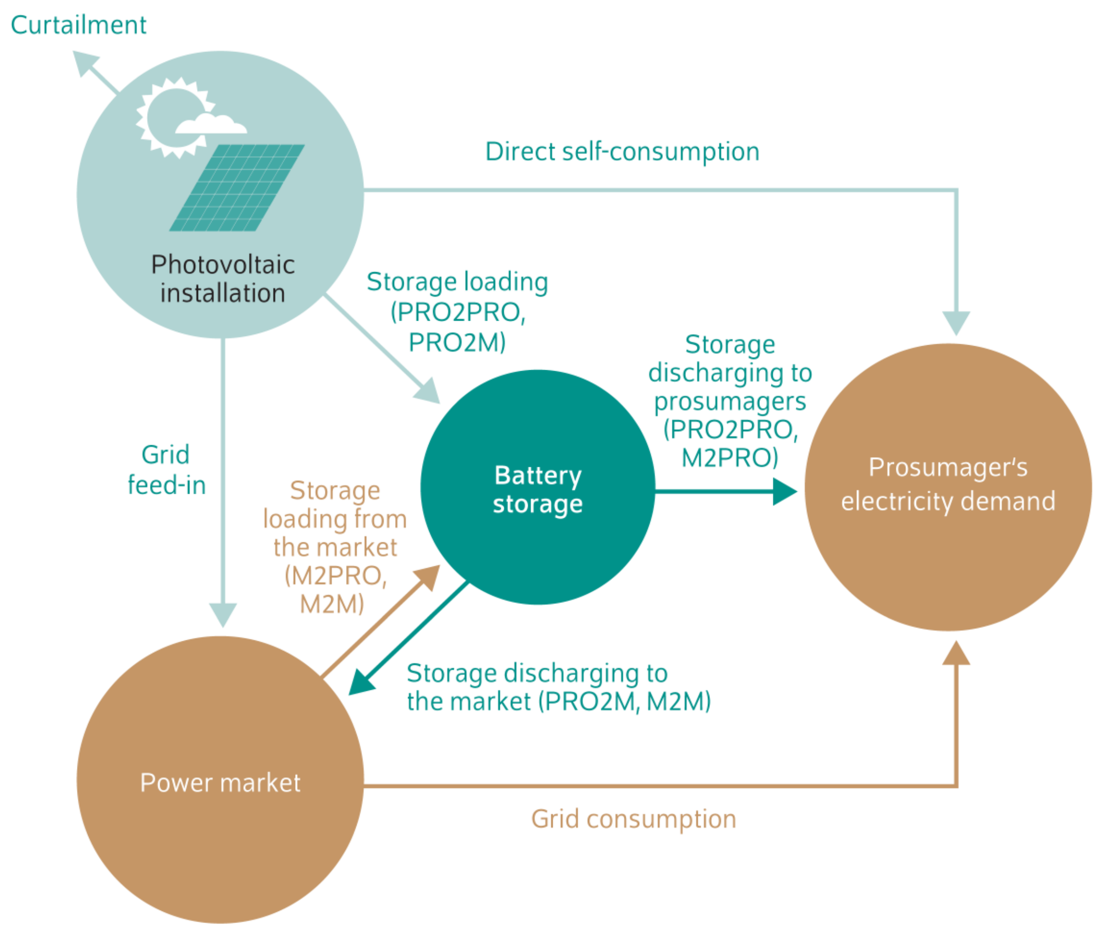
1 Prosumager



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Prosumagers

- **pro**duce their own PV electricity at times or feed it to the grid
- con**sume** electricity from the grid at other times
- make use of stor**age** (stationary batteries, vehicle batteries, heat storage)

Self-consumption vs self-generation

- Self-consumption: supply perspective
- Self generation: demand perspective

2 Prosumage in Germany

Prosumage is a growing segment (RWTH 2018)

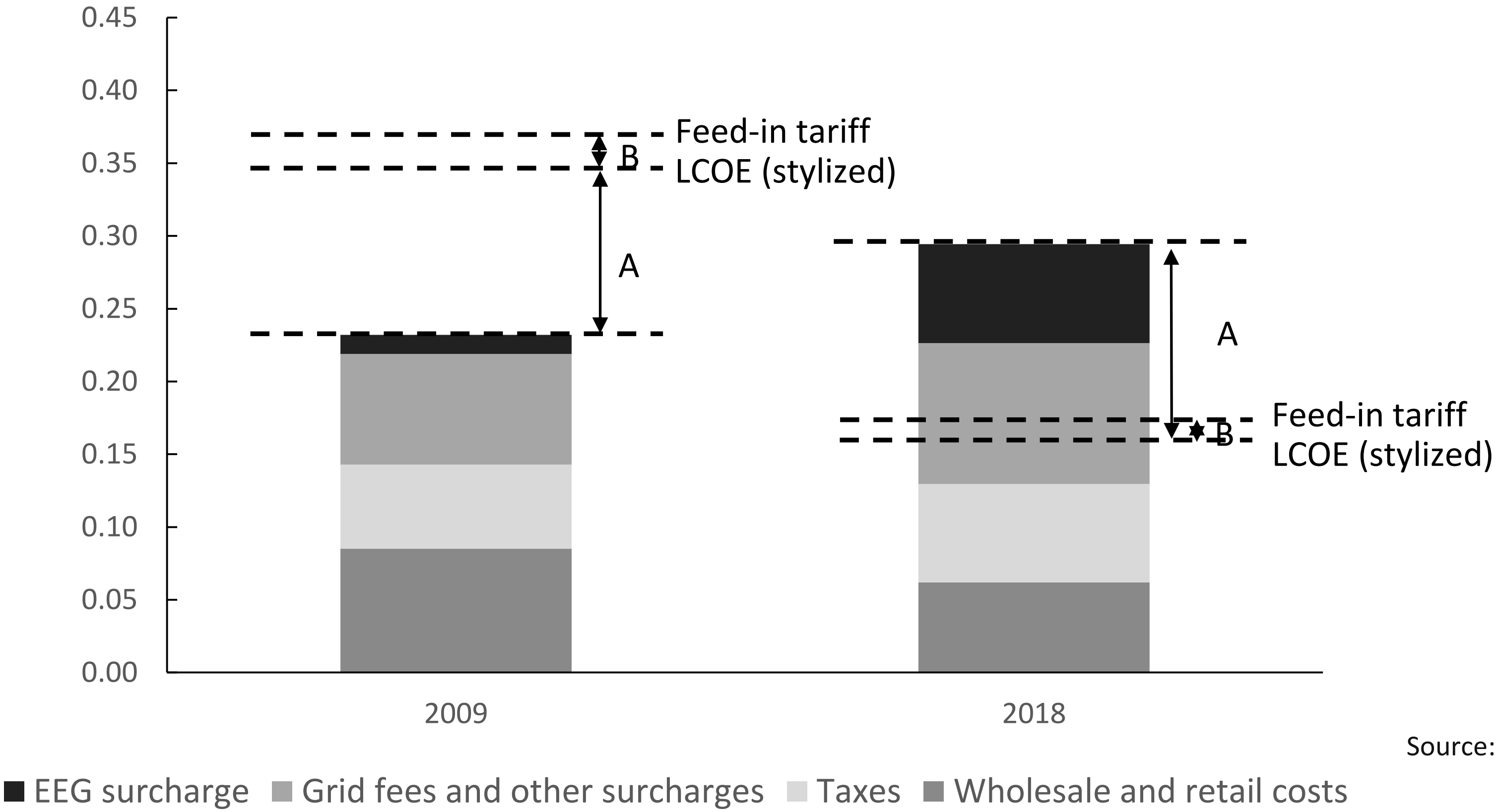
- 85,000 prosumage systems with 600 MWh battery capacity by the end of 2017
- Every other small (< 30 kWp) PV installation in 2017 with battery

Drivers of growth

- Direct support: subsidized loans and investment grants (KfW program 275)
- Falling battery system costs (RWTH 2018)
  - Price reduction by 50% since 2013
  - On average 1,300 Euro/kWh (gross)
- Indirect support: regulatory incentives

FITs, LCOE, and household tariffs

- Germany: volumetric grid charges and EEG surcharge
  - Self-generation exempt (40% surcharge for PV > 10 kW)



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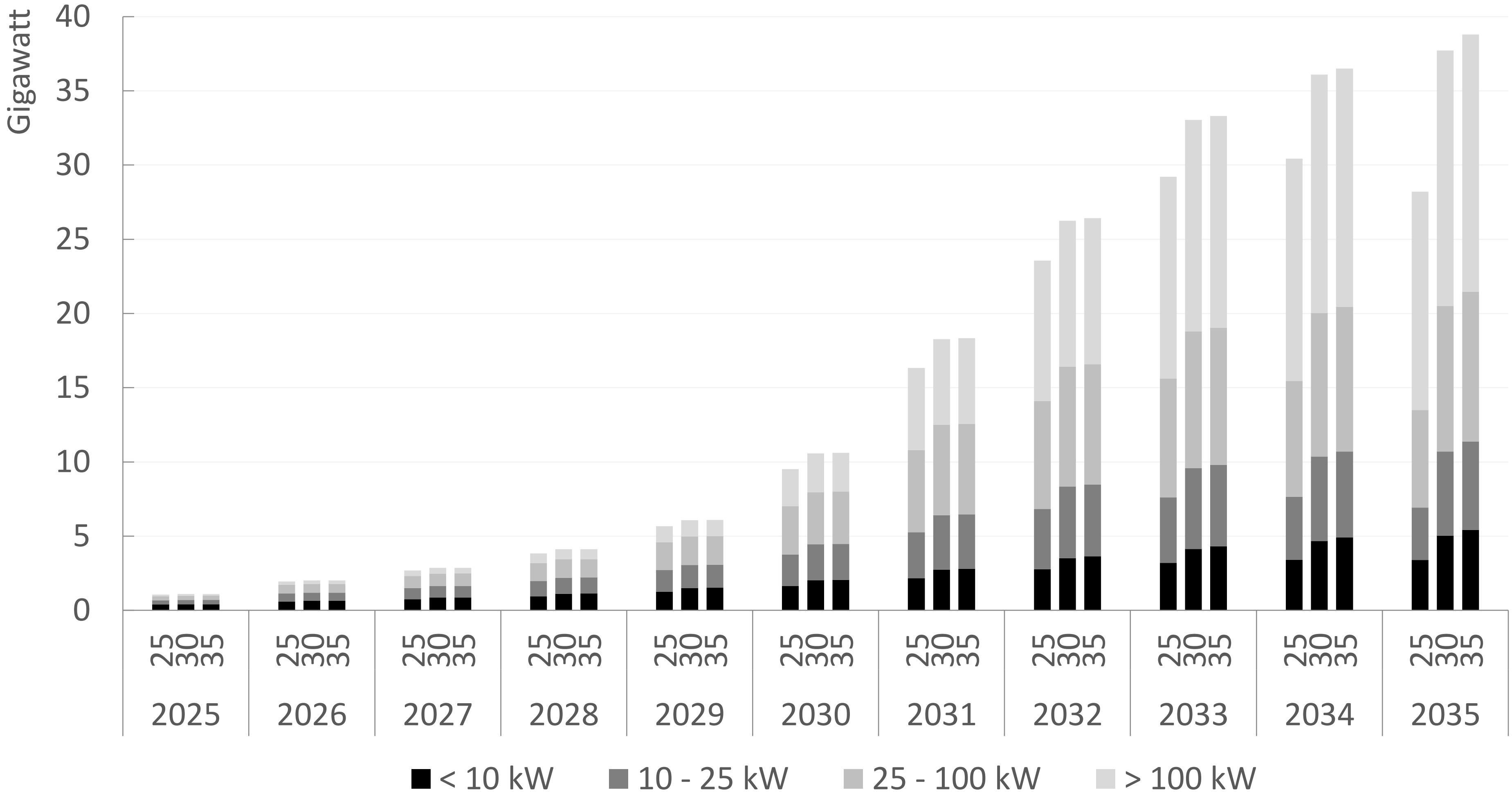
2 Back-of-the-envelope future projection

Future potentials, *ceteris paribus*

- Beginning from the mid-2020s, large PV capacities will drop out of the FIT



Source: own illustration

3 Qualitative discussion: pros, cons

Pros and cons depend on the perspective

- Prosumagers and consumers
- Incumbent industry, new industry, service providers
- Electricity system, system operators

Arguments in favor of prosumage

- Consumer preferences
- Lower/more stable electricity costs
- Participation/acceptance of energy transition
- Activation of private capital/rooftop space
- Distribution grid relief

Arguments against prosumage

- Increasing system costs
- Distributional impacts

Arguments with ambiguous conclusions

- Transmission grid relief
- Flexibility
- Driver for sector coupling
- Energy efficiency vs rebound effect
- Local economic and macroeconomic benefits, increased competition
- Political economy, path dependency, policy coordination
- Data protection and security

4 Quantitative analysis: system perspectives

DIETER

- Open-source electricity system model
- Cost minimization over dispatch and investment
- Hourly resolution, full year
- Loosely calibrated to German data

DIETER‘s website

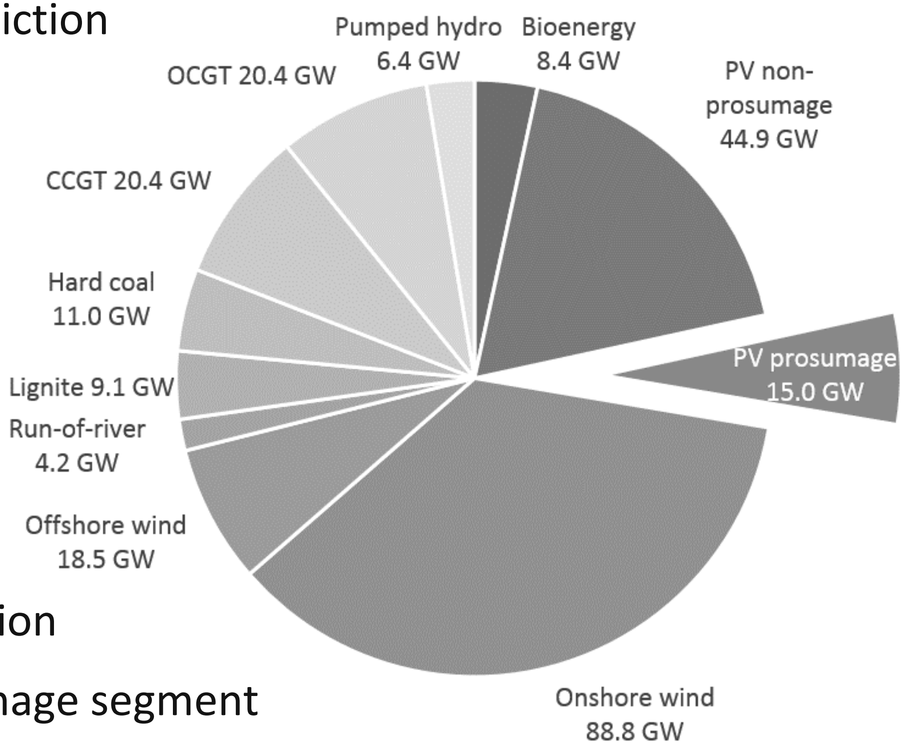
- www.diw.de/dieter
- Code under MIT license

4

Model-based illustration of system effects: scenario

Implicit assumption of optimal behavior from system perspective

- No separate objective for households
- Varying minimum self-consumption restiction
- Prosumagers face wholesale prices



German scenario for 2035

- 66% renewables in electricity consumption
- 25% of PV capacity attributed to prosumage segment
- 2.6 million prosumage systems with 5.9 kWp each
- Endogenous investment only in central and prosumage storage

Source: scenario B1 2035 in BNetzA (2014), own assumption on prosumage

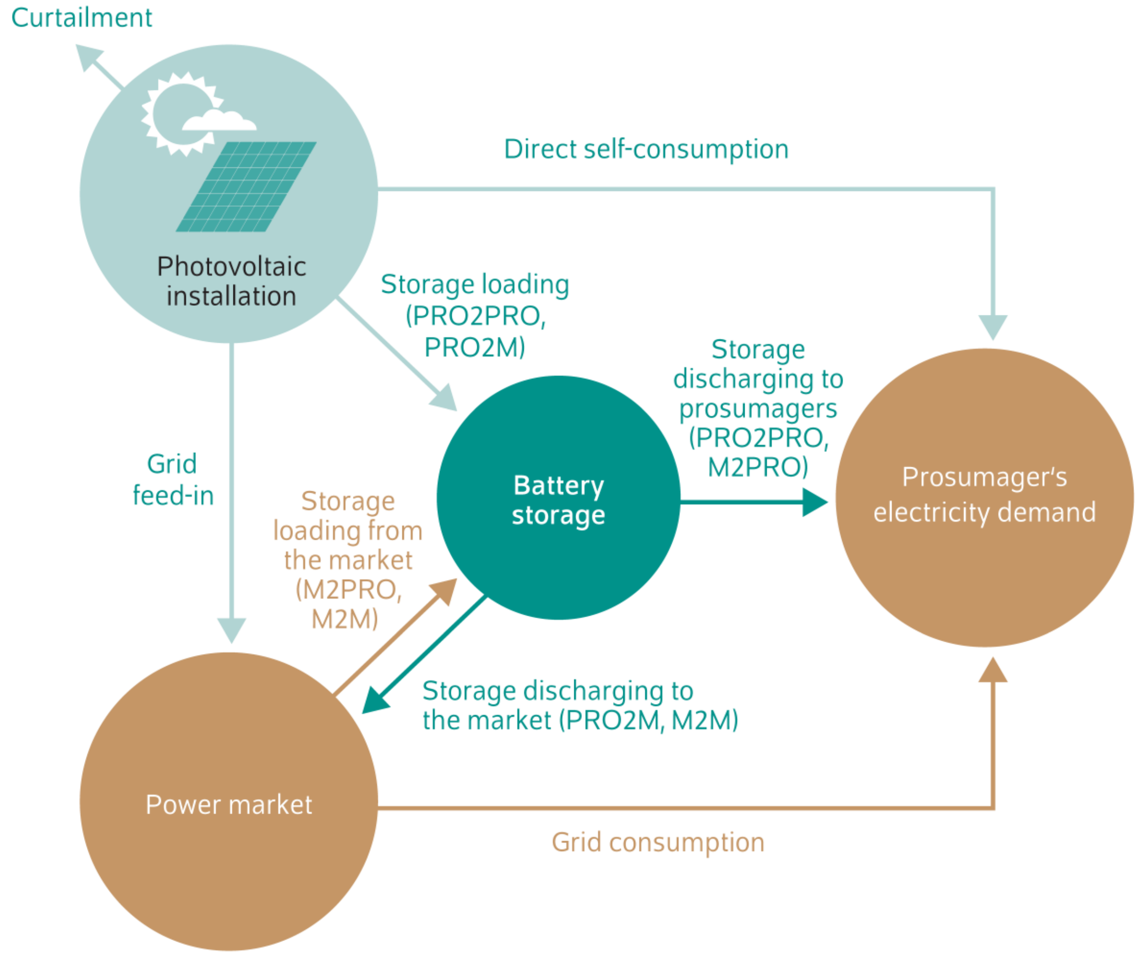
4 Interaction of prosumage with the electricity system

(i) ***Pure prosumage***
No interaction of prosumage storage with market

(ii) ***Grid consumption smoothing***
Only prosumage storage loading from market

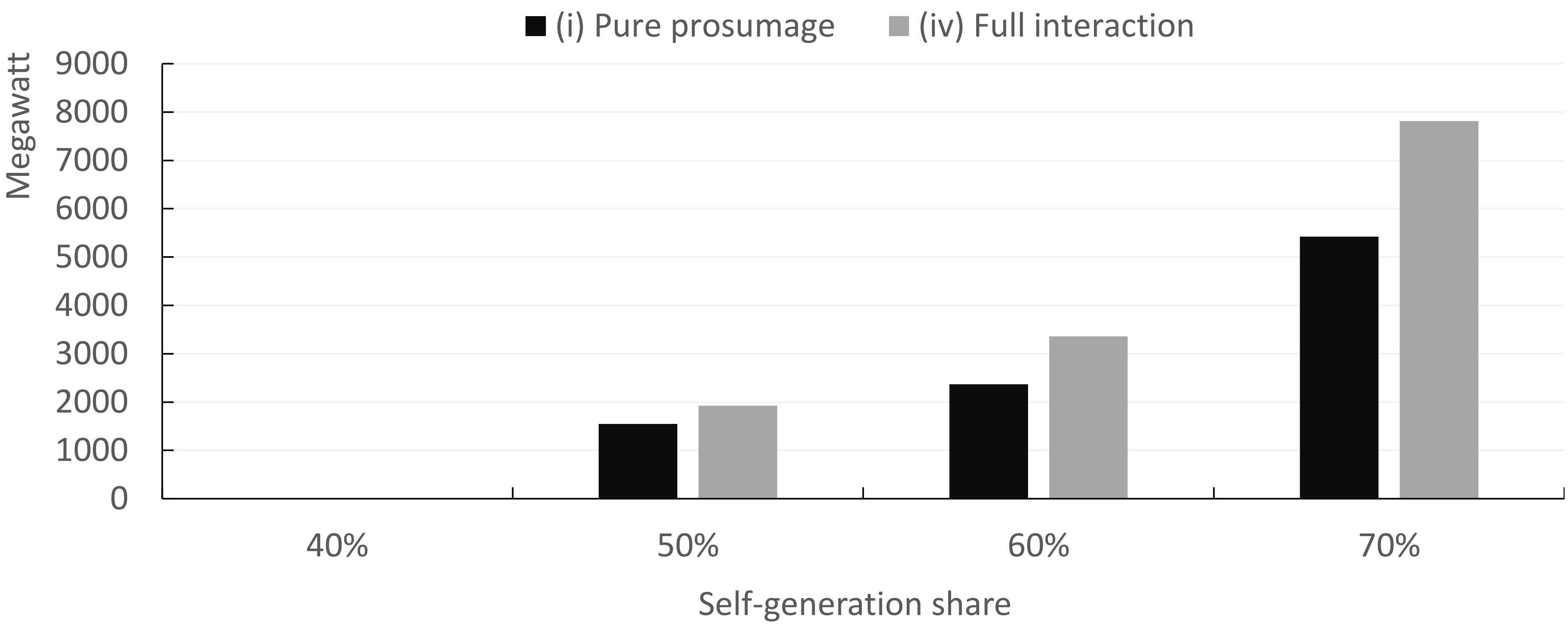
(iii) ***PV profiling***
Only prosumage storage discharging to market

(iv) ***Full interaction***
No restrictions on interaction of prosumage storage with market



Source: own illustration

4 Result: Additional storage capacity vs baseline

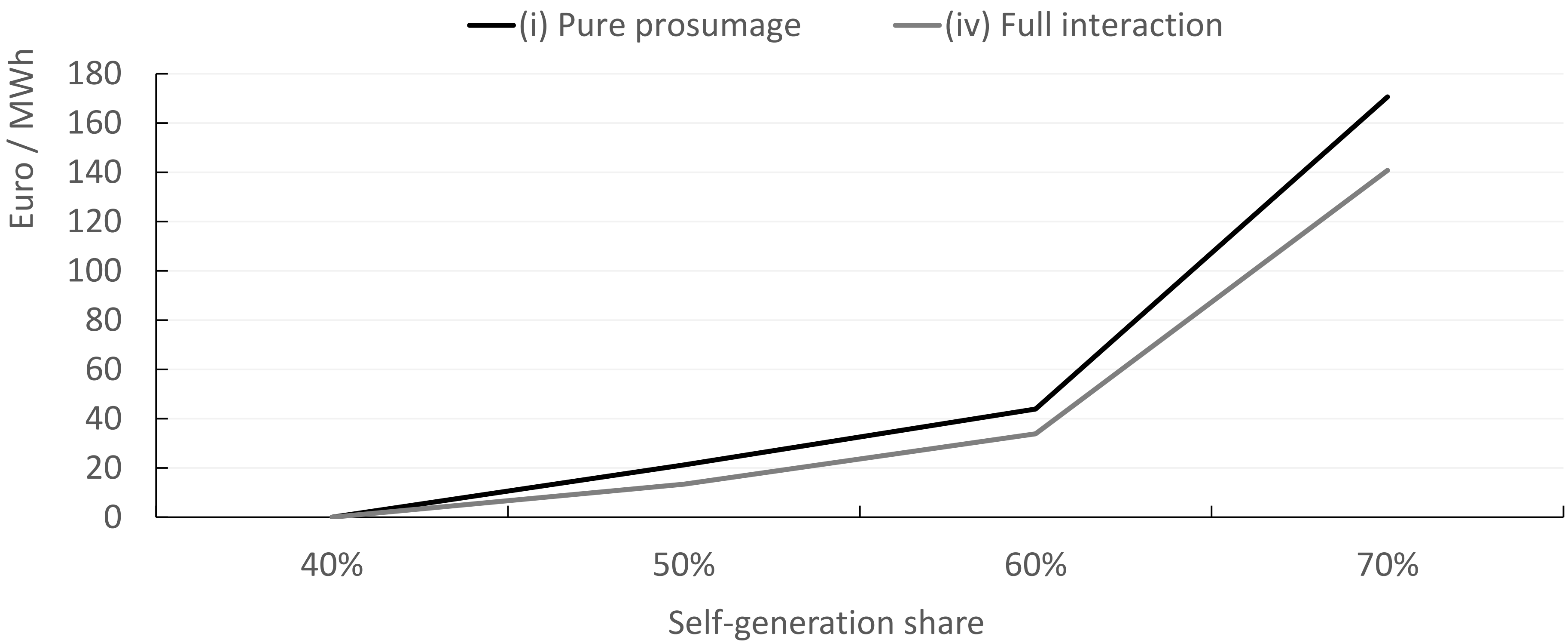


→ Moderate increase of prosumage storage capacities up to 65% self-consumption

→ If decentral storage is available to the system, substantially greater optimal capacities

Source: adapted from Schill et al (2017)

4 Result: Average additional cost per additional MWh self-consumption compared to baseline

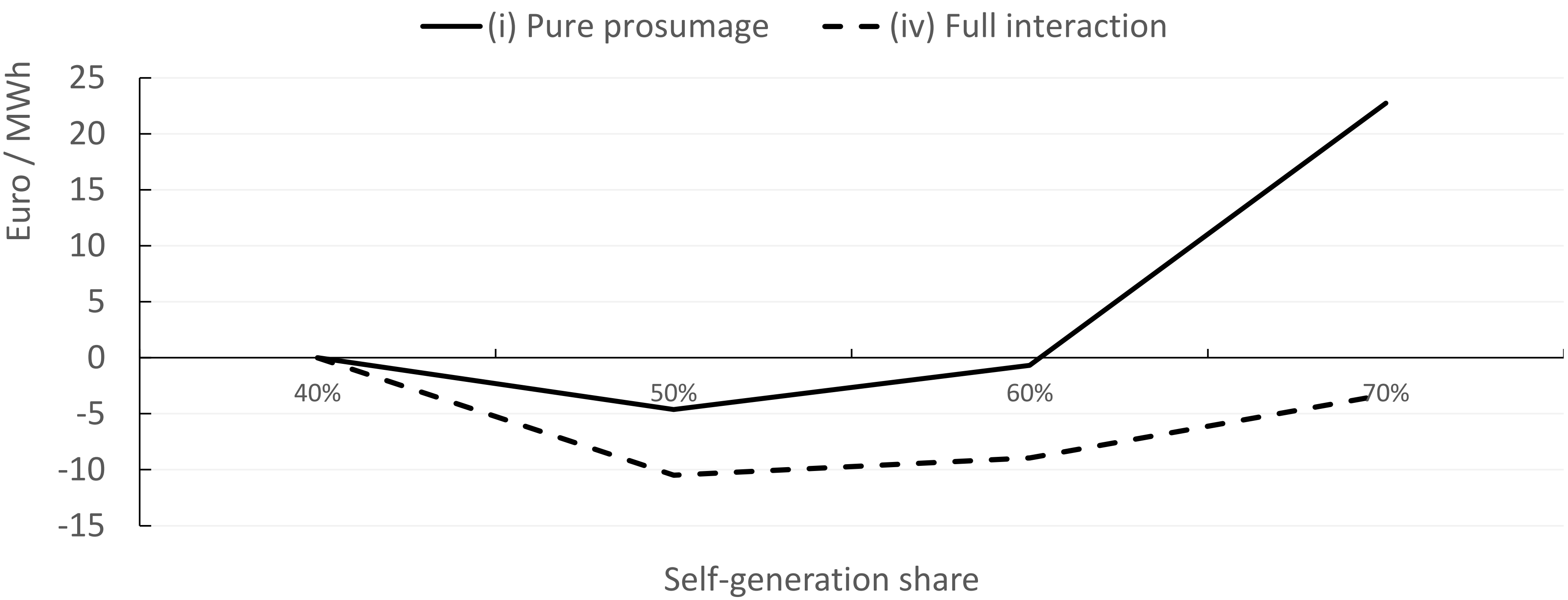


→ Lower cost increases in case of additional market interactions

→ Absolute cost increase: 170 – 210 million Euro or 0.5-0.6% of total system costs (Case (iv), 60%)

Source: adapted from Schill et al (2017)

Result: additional dispatch costs per additional self-consumption



→ If prosumage storage comes for reasons outside the model, ist flexibility can be beneficial

→ Especially if it is available to the entire system

Source: adapted from Schill et al (2017)

5 Prosumage and decentral sector coupling

5 Prosumage and sector coupling

Ambitious climate goals goals require decarbonization of heat and mobility

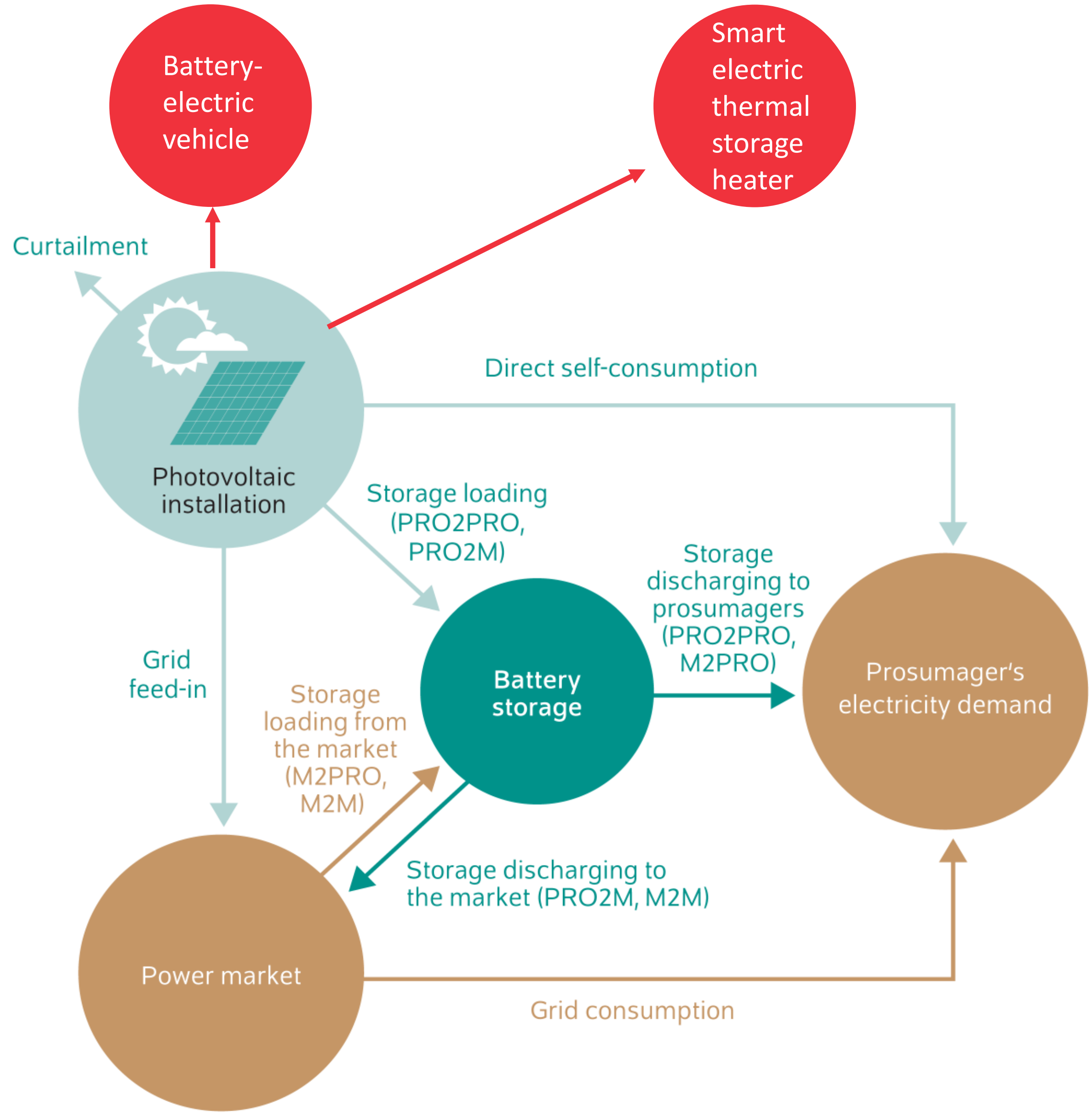
- Prosumage may play a vital role

Same model as above

- Plus decentral power-to-mobility
- Plus decentral power-to-heat

Findings in a nutshell

- If households wish higher self-consumption, increased sector coupling is likely (and desirable)



6 Findings and future research needs

1) Is it possible to develop blueprints (from lab to market) for smart RES integration?
2) Which R&D policy questions should be addressed now in order to lay the foundation of energy market (re-)design?
3) Which funding instruments are needed?

6 Conclusions so far – and research needs

Prosumage still a niche in Germany – but growing

- Ongoing (?) trend in battery cost reduction, favorable regulatory environment
- Large PV capacities drop out of support scheme before end of technical lifetime
- Prosumage is likely to grow for various reasons; vital to use its potential

→ Research needs on the role of prosumage in the energy transformation

- Clear estimation of rooftop area and flexibility potentials
- Effectiveness and efficiency of prosumage-related sector coupling for decarbonization
- Research on motivation and capital costs relating to private households
- Country studies

6 Conclusions so far – and research needs

Range of pros and cons

- Weight of arguments, relevance of perspectives

→ Research needs in social sciences

- Behavior: consumer preferences, data protection, acceptance, efficiency and rebound
- Look out for empirical ex-post analyses

6 Conclusions so far – and research needs

Quantitative model illustration shows benefit of system-friendly behavior

- If prosumage evolves, it is economically more efficient when system friendly
  - PV and storage investments: redundancy and dimensioning
  - PV and storage dispatch: orientation on current system scarcity and availability to the market

→ Research needs in the field of system analysis

- System models: strengthen actor representation to better reflect behavior (best of both worlds)
- Prosumage may not be efficient from a system perspective, but effective
- Design of regulation: fairness and cost-reflectiveness, tariffs incentivizing system-friendly behavior; also in relation to future sector coupling
- Market design: transmission of price signals

→ Research needs to make prosumage work efficiently in the energy system

- Standard software architecture for communication, data exchange and transactions
- Development of business models based on that

Thank you for listening

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Backup

BACKUP: Pros

Arguments in favor of prosumage

- Consumer preferences
- Lower and more stable electricity costs
- Participation/ acceptance of energy transition
- Activation of private capital
- Distribution grid relief

Consumer preferences

- Preferences for local renewable energy solutions or self-generation (IEA 2014)
  - Some empirical support for Germany (Gährs et al 2015, Oberst, Madlener 2015)
- Findings relevant for majority of consumers or for small niche?

BACKUP: Pros

Arguments in favor of prosumage

- Consumer preferences
- Lower and more stable electricity costs
- Participation/ acceptance of energy transition
- Activation of private capital
- Distribution grid relief

Lower and less volatile electricity costs

- Only valid from a consumer (prosumager) perspective
- Only true for self-generated share of electricity

BACKUP: Pros

Arguments in favor of prosumage

- Consumer preferences
- Lower and more stable electricity costs
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- Distribution grid relief

Participation and acceptance of energy transformation

- Preference to actively participate (Gährs et al 2015)
- Mitigate conflicts of “central” infrastructure (SPE 2015, 2016, Krekel, Zerrahn 2017)
- Realization of roof-top PV potential

BACKUP: Pros

Arguments in favor of prosumage

- Consumer preferences
- Lower and more stable electricity costs
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- Activation of private capital
- Distribution grid relief

Activation of private capital

- Mobilize “cheap“ capital (SPE 2015)
- Relevance now, in the future?
- Efficient investments from system perspective?

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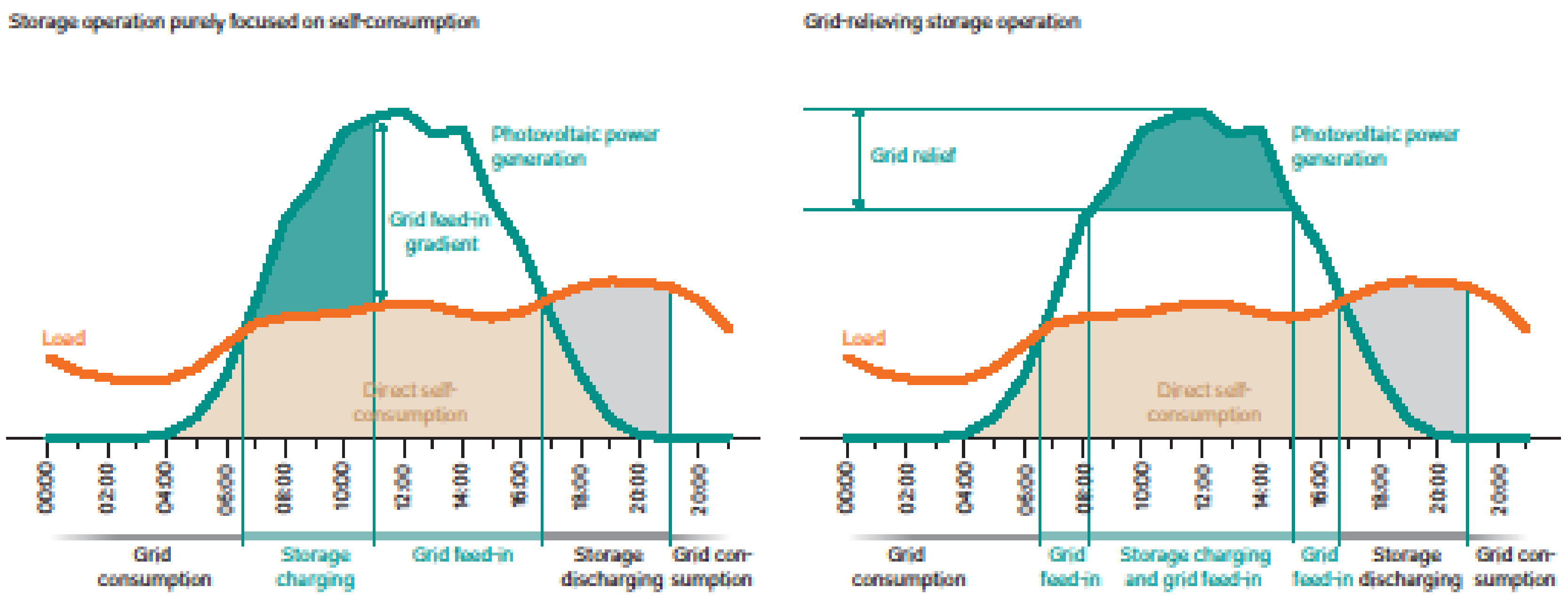

Source: own illustration

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BACKUP: Cons

Arguments against prosumage
• Increasing system costs • Distributional impacts

Efficiency losses (compared to a centrally optimized power system)

- Suboptimal investments
  - Less spatial balancing, redundant infrastructure
  - Sub-optimal siting and dimensioning of PV and storage systems (Borenstein 2015)
- Suboptimal dispatch

BACKUP: Cons

Arguments against prosumage

- Increasing system costs
- Distributional impacts

Distributional impacts

- Who can engage in prosumage?
- Regressive effect of volumetric grid charges and surcharges (Borenstein 2015)
- “Utility death spiral“ (Mayr et al 2015, Parag and Sovacool 2016)
- Size and relevance of effects? (Prognos 2016, Agora 2017)

BACKUP: Ambiguous

Arguments with ambiguous conclusion

- Transmission grid relief
- Flexibility
- Driver for sector coupling
- Energy efficiency vs rebound effect
- Local economic and macroeconomic benefits, increased competition
- Political economy, path dependency, policy coordination
- Data protection and security

Transmission grid relief

depends on spatial and temporal alignment of (PV) generation and load

- Favorable: smoothing due to good match of PV peak and peak load
- Neutral: bad match between PV peak and peak load
- Bad: high renewables and low prices incentivize storage use

BACKUP: Ambiguous

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Flexibility

- Unlocking untapped demand-side management potentials (Anda and Temmen 2014)
- Evidence on care about discomfort sparse and inconclusive (Kubli 2018, Palm et al 2018)
- Technical and regulatory prerequisites (CEER 2016)

BACKUP: Ambiguous

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Driver for sector coupling

- Sector coupling necessary to achieve climate targets; prosumage may unlock potentials (Prognos 2016, SPE 2016)
- Suboptimal sizing from system perspective (Bloess et al 2018), especially with respect to economies of scale (Schiebahn et al. 2015)

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Energy efficiency vs rebound effect

- Energy efficiency due to increased awareness (Luthander et al 2015)
- Rebound effect (Palm et al 2018)

BACKUP: Ambiguous

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Local economic and macroeconomic benefits, increased competition

- Local economic benefits due to local value added (IEA 2014)
- Mild evidence for small net macroeconomic benefits (Flaute et al 2016)
- Increased competition die to new players and smaller market size (SPE 2015, 2016)

BACKUP: Ambiguous

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Political economcy, path dependency, policy coordination

- Expansion of PV outside politically volatile support schemes
- Lower rent-seeking activities of well-organized incumbent lobby groups
- Solar/prosumage voters? (IEA 2014)
- Potential technological and policy path dependencies in hardware, software, and business models
- Policy coordination outside central control? Control over achievement of targets?

BACKUP: Ambiguous

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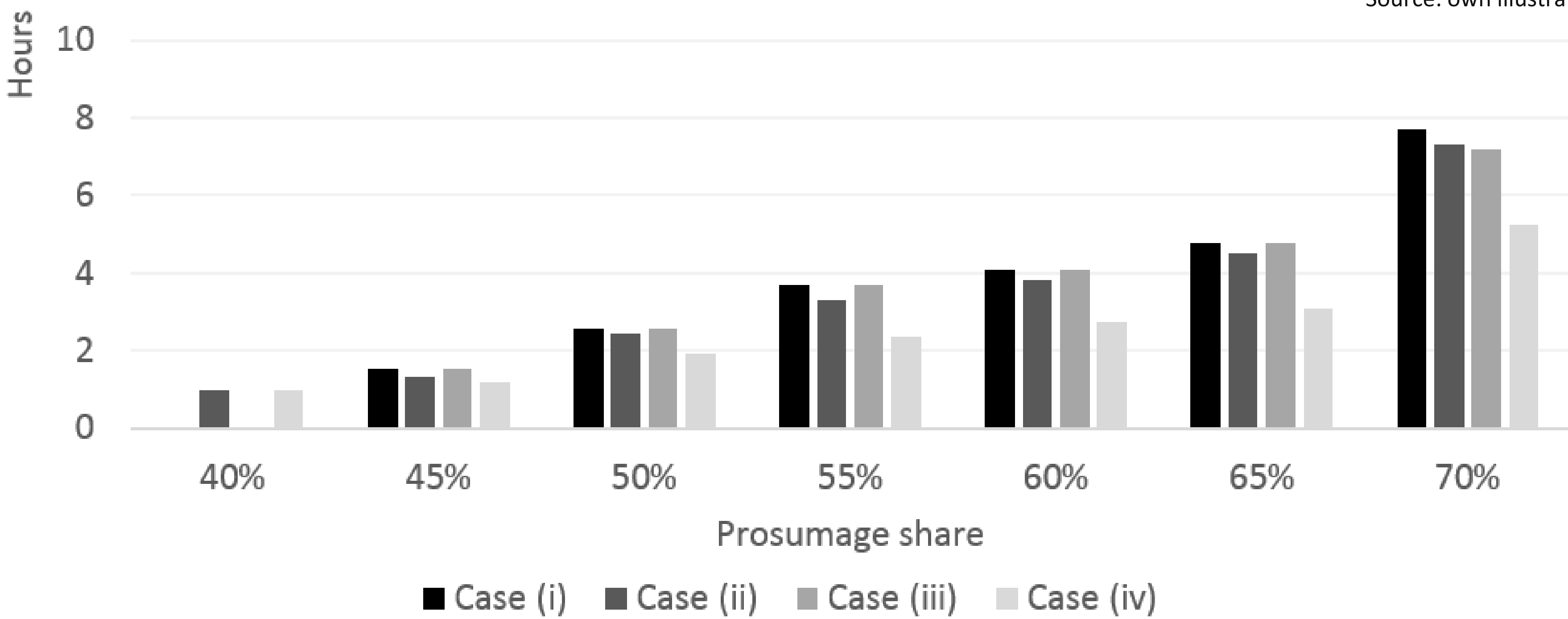
Data protection and security

- System-oriented prosumage requires communication interfaces and potentially remote control
- Ceding autonomy as well as data and privacy protection issues critical for residents (Gährs et al 2015, Michaels and Parag 2016, Wilson et al 2017)
- Greater resilience due to decentral infrastructure (Michaels and Parag 2016)

BACKUP: E/P ratios of prosumage storage

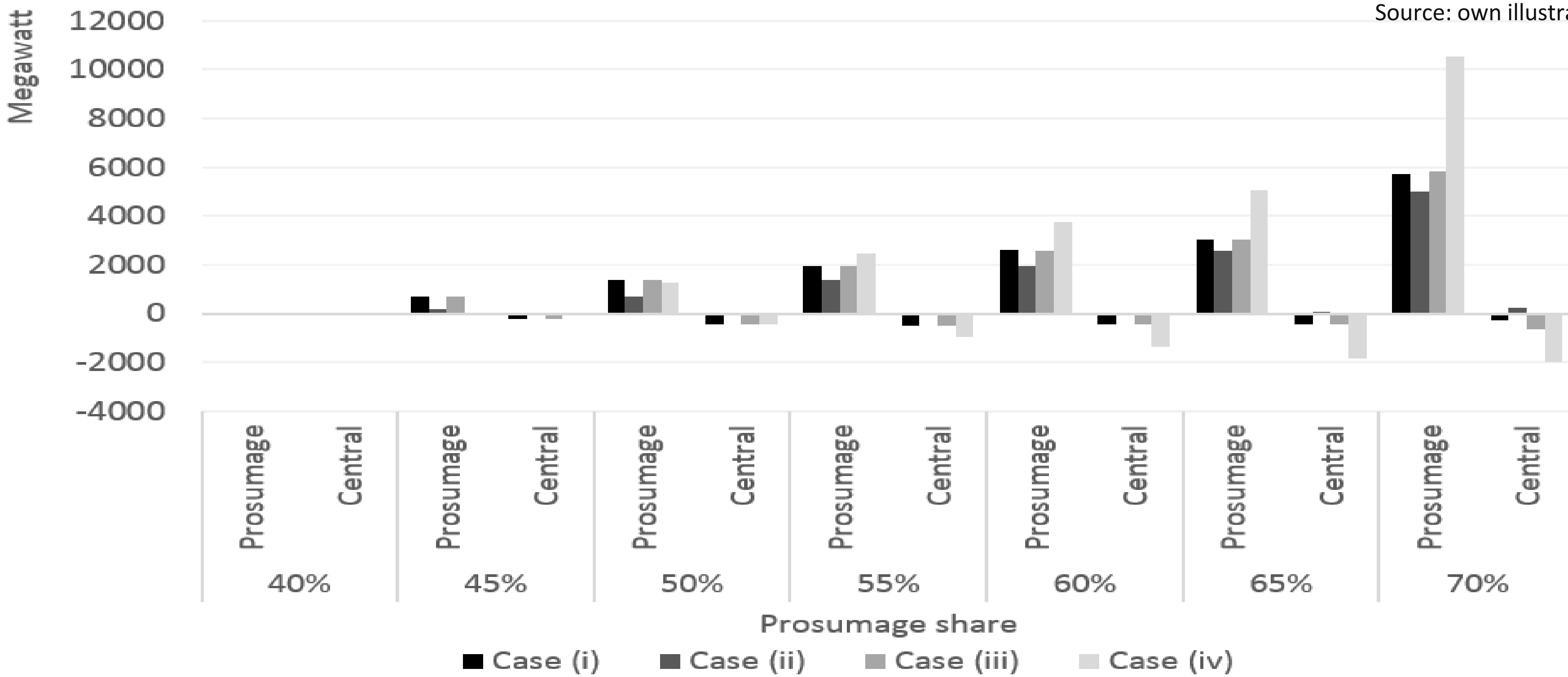
Source: own illustration



- E/P ratios increase in prosumage requirements
- Lower E/P ratios in Case (iv) driven by higher storage power capacities; energy virtually constant

BACKUP: Prosumage and central storage in a sensitivity w/o given storage capacities

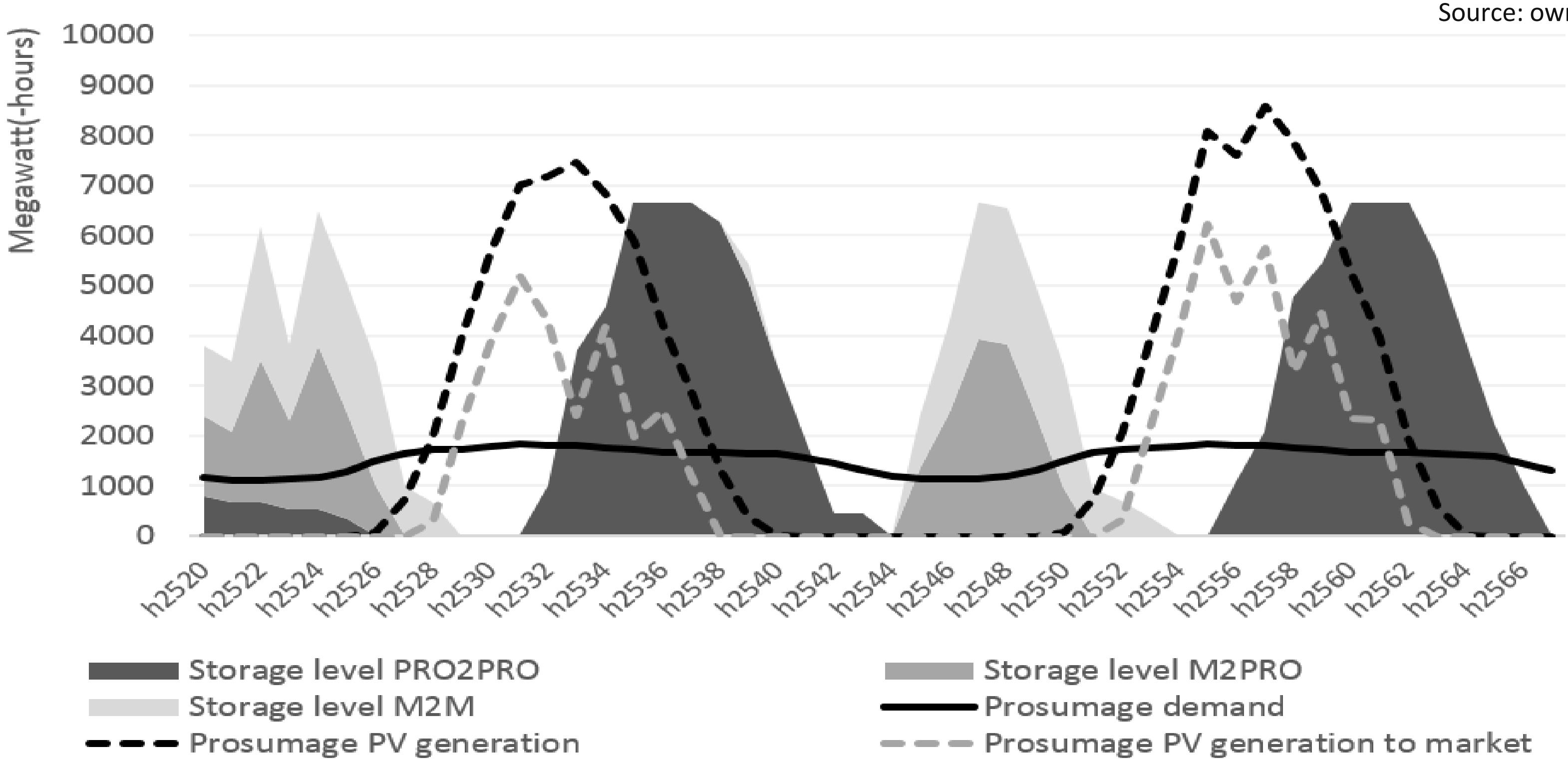
Source: own illustration



- Substantial substitution only under full market interaction

BACKUP: Storage patterns – Case (iv), 55% prosumage

Source: own illustration



- Excess PV (temporally) first sent to market, then to PRO2PRO storage
- No shifting of market exports
- Full market interaction does not help to fulfill self-generation requirements but bears efficiency potential

BACKUP: model limitations

Findings depend on a range of numerical assumptions

- Exogenous power plant park, potentially oversized
- PV and load profiles identical for prosumagers and entire system
- Direction of bias unclear

No direct incentives for prosumage

- No separate objective of prosumagers
- But system-optimal behavior
- Lower bound for efficiency losses

No intra-hourly variability