DIW BERLIN

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Prosumage of solar electricity: the role of power-to-heat

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Overview

1. Introduction
2. Qualitative arguments for and against prosumage
3. Prosumage in Germany
4. Analysis of system effects: batteries
5. Extension of the model: power-to-heat
6. Conclusions and next steps

1 Introduction

Background: Our recent article in EEEP (2017)

- Qualitative discussion of prosumage from an economic perspective
- Description of German situation
- Quantitative illustration of selected system effects
- Focusing on battery storage and different operational strategies
- https://doi.org/10.5547/2160-5890.6.1.wsch

Prosumage of solar electricity: pros, cons, and the system perspective

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ABSTRACT

We examine the role of prosumage of solar electricity, i.e. PV self-generation combined with distributed storage, in the context of the low-carbon energy transformation. First, we devise a qualitative account of arguments in favor of and against prosumage. Second, we give an overview of prosumage in Germany. Prosumage will likely gain momentum as support payments expire for an increasing share of PV capacities after 2020. Third, we model possible system effects in a German 2035 scenario. Prosumage batteries allow for a notable substitution of other storage facilities only if fully available for market interactions. System-friendly operation would also help limiting cost increases. We conclude that policymakers should not unnecessarily restrict prosumage, but consider system and distributional aspects.

Keywords: Prosumage, battery storage, PV, energy transformation, DIETER

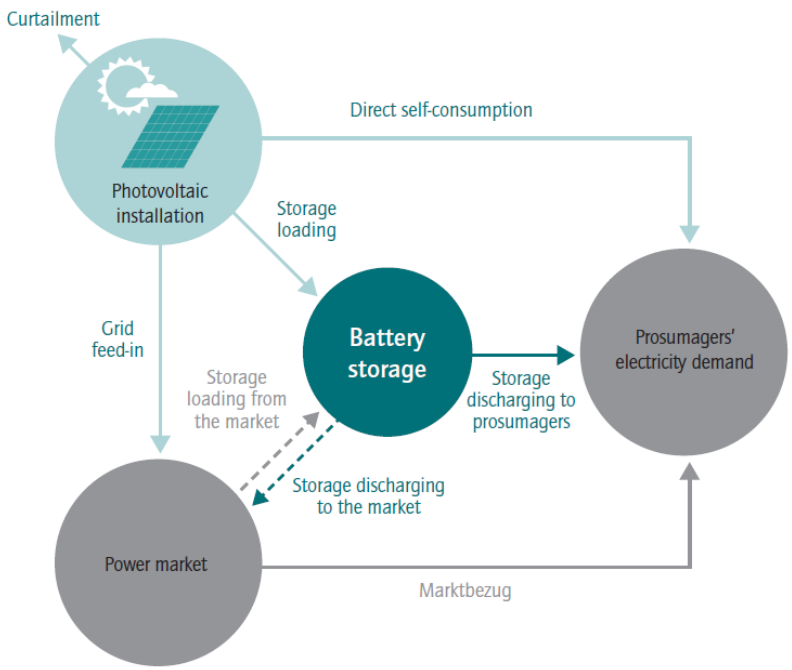
https://doi.org/10.5547/2160-5890.6.1.wsch

Extension: prosumage with power-to-heat

- People may increase self-consumption by electric heating
- More precisely, we look at electric storage heaters
- Evaluation of system effects compared to batteries

How we define PRO-SUM-AGE

- **PRO**duction of renewable electricity (PV)
- Con**SUM**ption of self-generated electricity
- Stor**AGE** to temporally align supply and demand



Source: own illustration

Prosumagers

- produce their own renewable (PV) electricity at times,
- draw electricity from the grid at other times,
- feed electricity to the grid at other times,
- and make use of storage (batteries or heat storage)

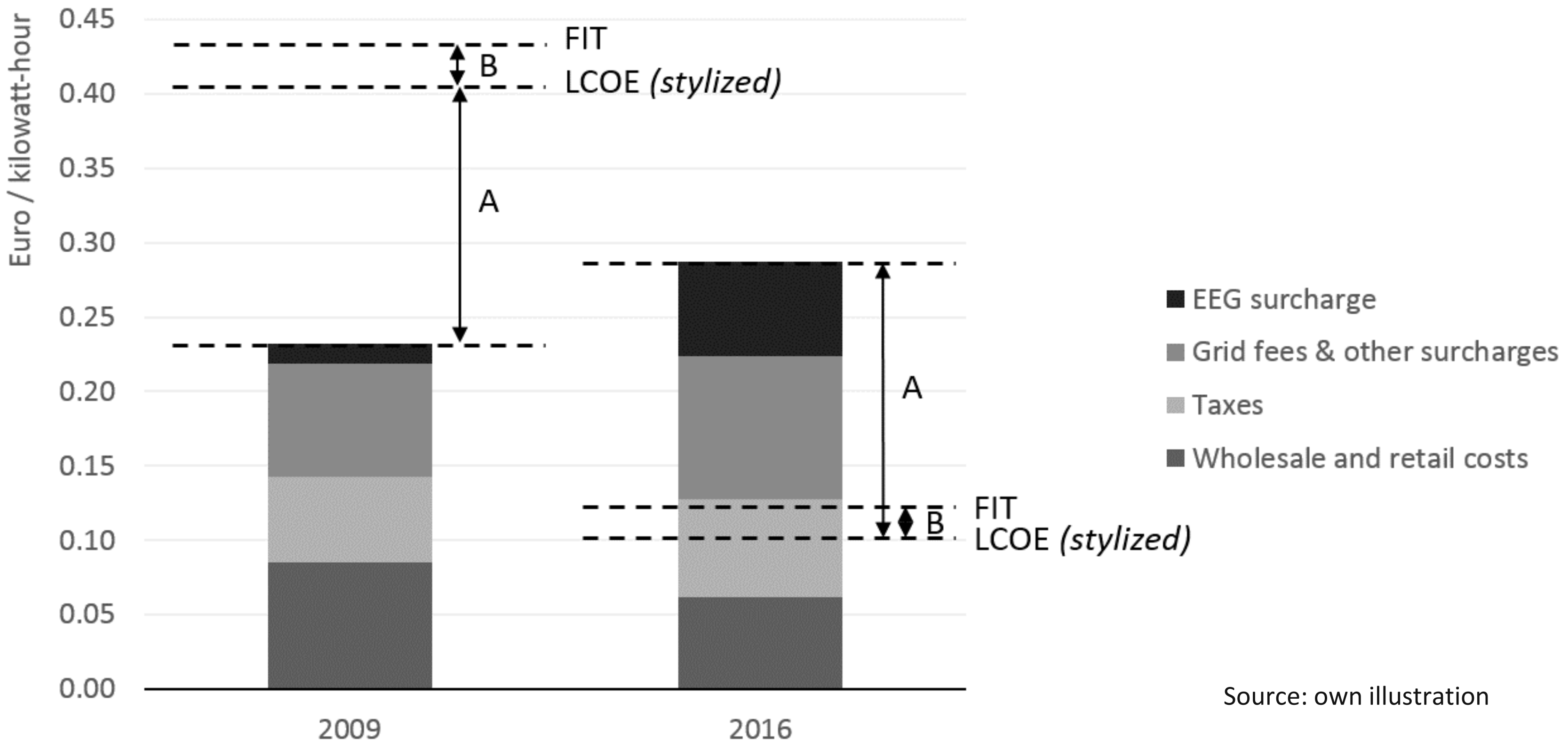
Pros and cons depend on the perspective

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

Arguments in favor of prosumage	Arguments against prosumage
• Consumer preferences	• Efficiency losses
• Participation and acceptance of energy transformation	• Distributional impacts
• Lower and less volatile electricity costs	• Rebound effects
• Activation of private capital	• Policy coordination and path dependency
• Flexibility, sector coupling, and energy efficiency	• Concerns about data protection and remote control
• Distribution grid relief	
• Transmission grid relief	
• Increased competition	
• Local benefits	
• Political economy and new institutional arguments	

Incentives for prosumage through FITs, LCOEs and household tariffs

- Volumetric grid charges and EEG surcharge – but not on self-generation
  - (40% surcharge on self generated electricity in EEG 2017 for PV > 10 kW)
- Strong decline of FIT compared to household tariff ("Socket parity")

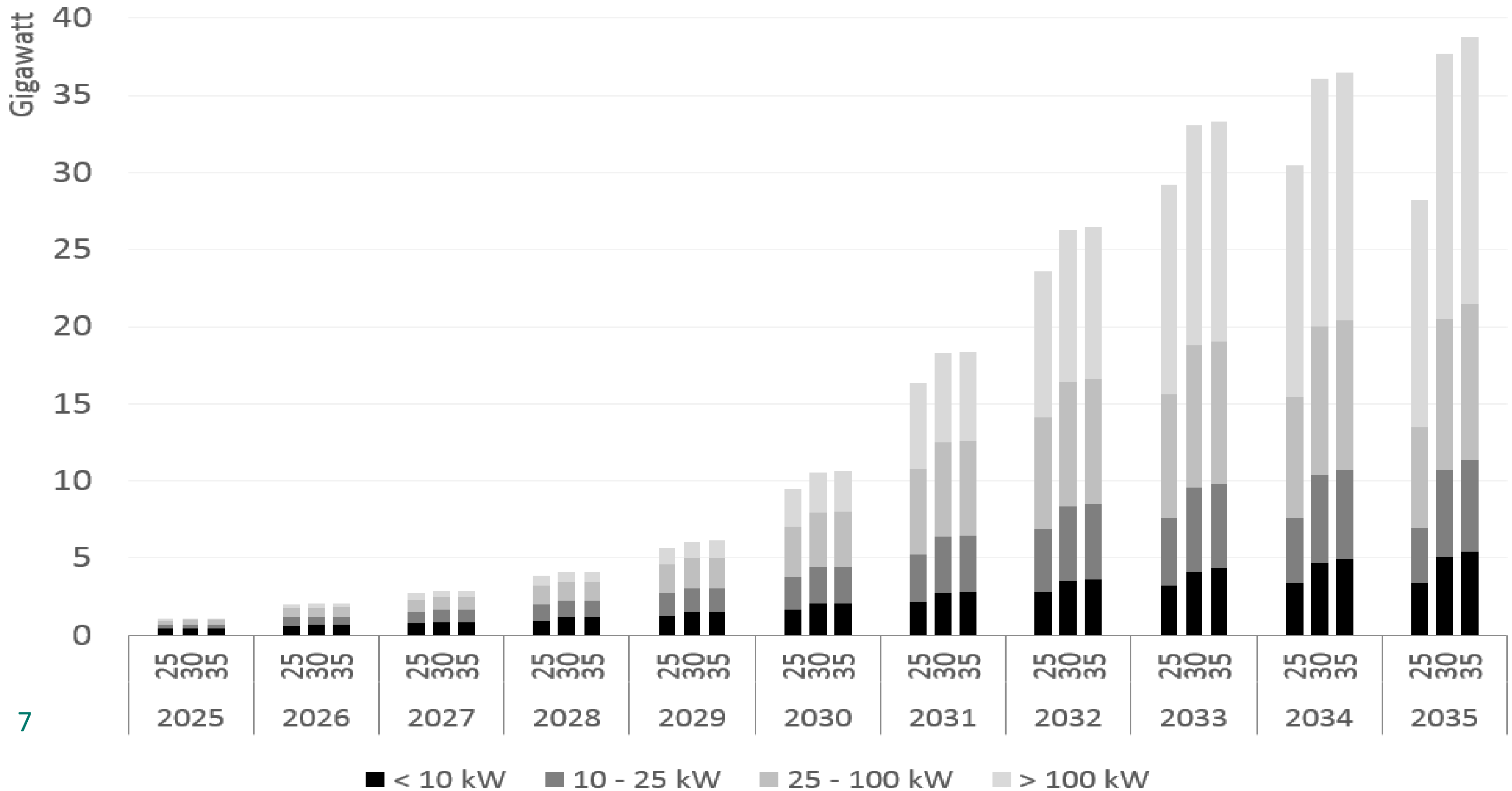


Source: own illustration

Deployment in Germany

- 2016: Every second small-scale PV system installed with battery
- April 2017: ~61,000 battery systems (~400 MWh)

Large additional potential when PV capacities drop out of support scheme



Source: own illustration based on Open Power System Data, http://open-power-system-data.org, Data Package Renewable power plants, version 2016-10-21

Analysis with an extended version of the DIETER model

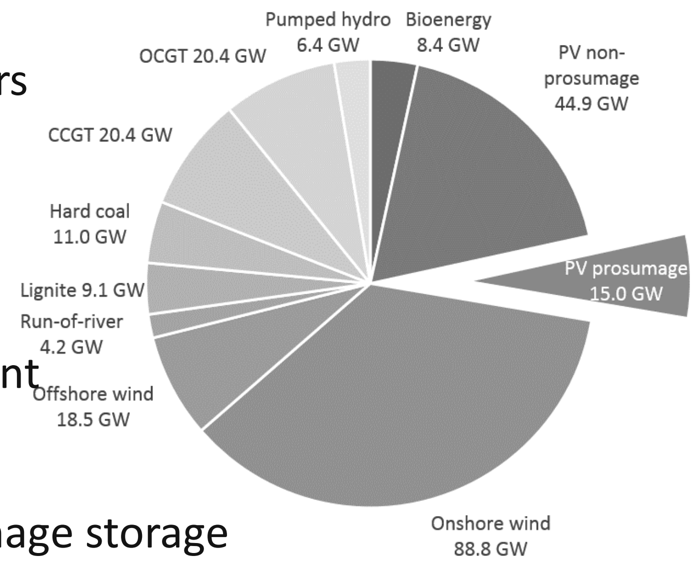
- Open-source electricity system model: www.diw.de/dieter
- Cost minimization for dispatch and investment in hourly resolution
- Loosely calibrated to German data

Prosumage segment

- Varying minimum self-consumption restictions
- Implicit assumption of system-oriented prosumagers

German scenario for 2035 (NEP scenario B1)

- 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



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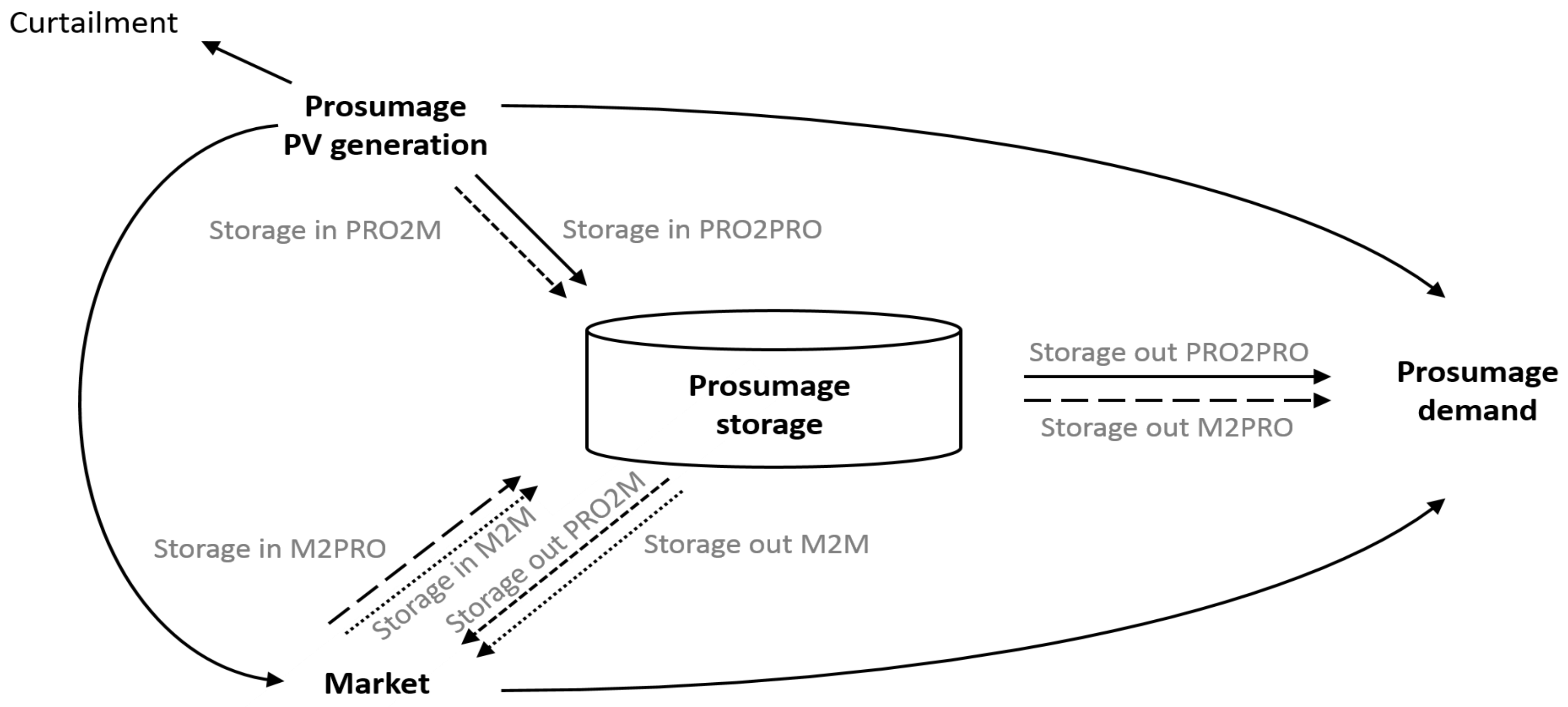
Scenarios differ with respect to market interactions



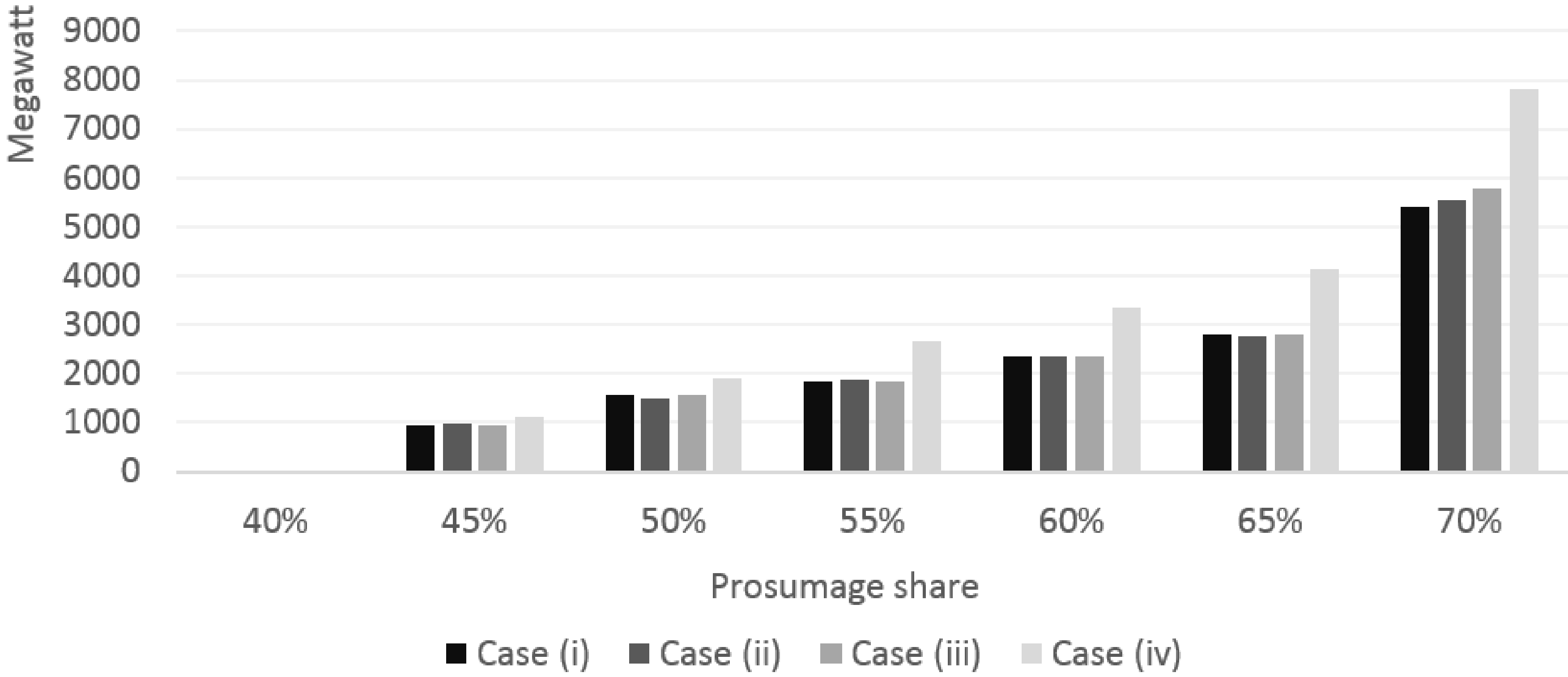
(i) ***Pure prosumage* -** No interaction of prosumage storage with market

(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

4 Storage deployment compared to baseline



- Moderate increase of prosumage storage capacities up to 65% self-consumption
- Substantially greater power rating in case (iv) with full market interaction

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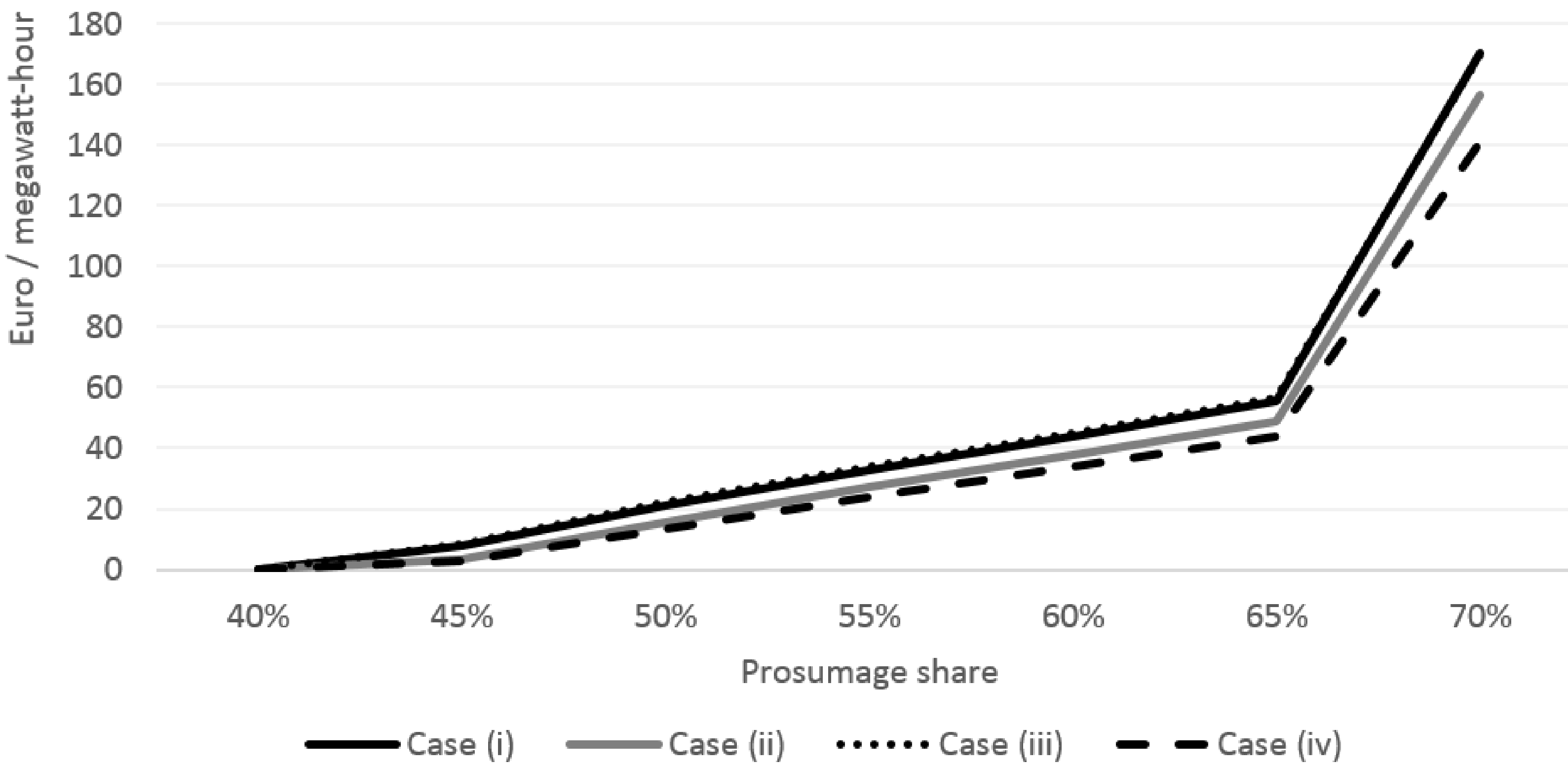
Average additional system cost per additional MWh self-consumption compared to baseline



- Lower cost increases in case of additional market interactions

Extension of the model: power-to-heat (work in progress)

Same framework, but electric storage heaters instead of batteries

- Households deploy additional storage heaters to increase self-consumption
- Storage heaters only use self-generated PV electricity
- Fixed E/P ratio of storage heaters (8 hours)
- No changes in generation portfolio
- Comparison: (i) only storage heaters, (ii) only batteries, or (iii) both

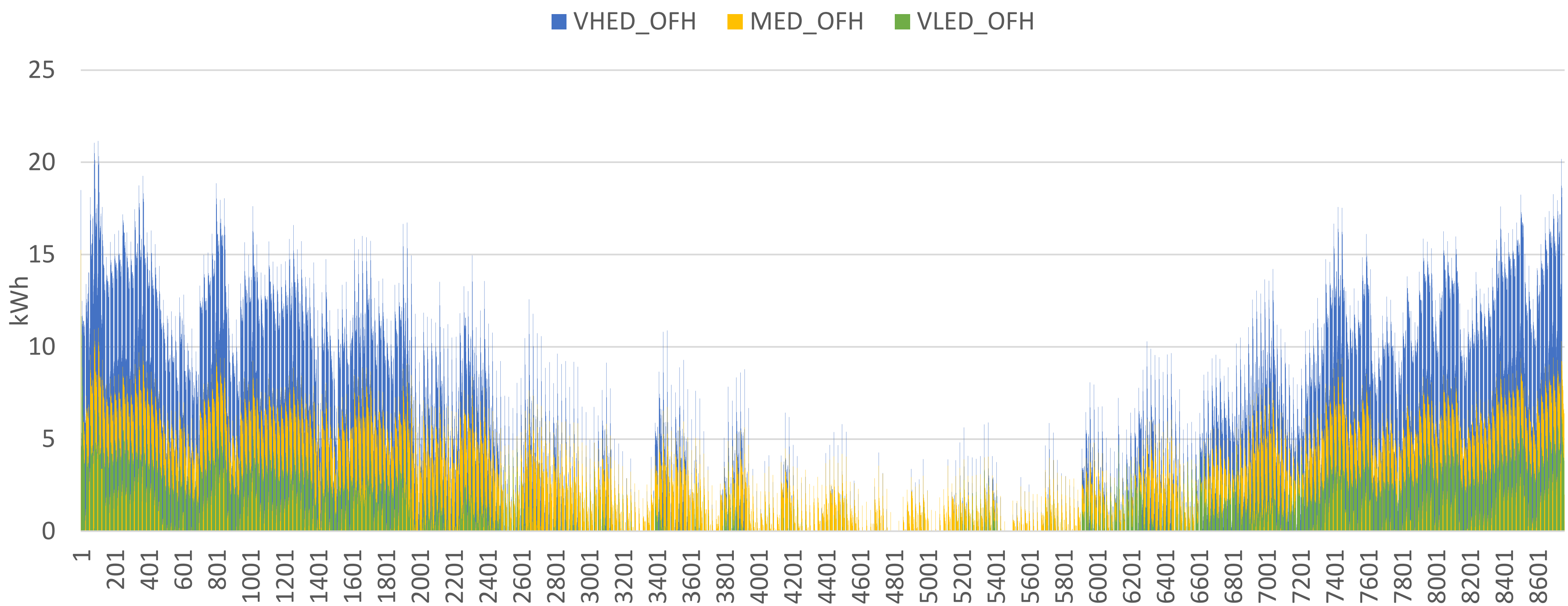
Implicit assumptions:

- Storage heaters backed up by other (existing) heating systems
- No induced change in size of PV systems or backup heating technology

Differences between storage heaters and batteries:

- Heat is stored instead of electricity
- Additional restrictions wrt. heat demand profiles
- Additional electricity demand → demand effect
- Lower investment costs → cost effect

5 Additional input parameter: hourly heat demand profiles



- Taken from ongoing European Horizon 2020 research project RealValue
- Derived from dynamic simulations with RWTH building model
- 12 building archetypes; here we pick one-family houses with low energy demand

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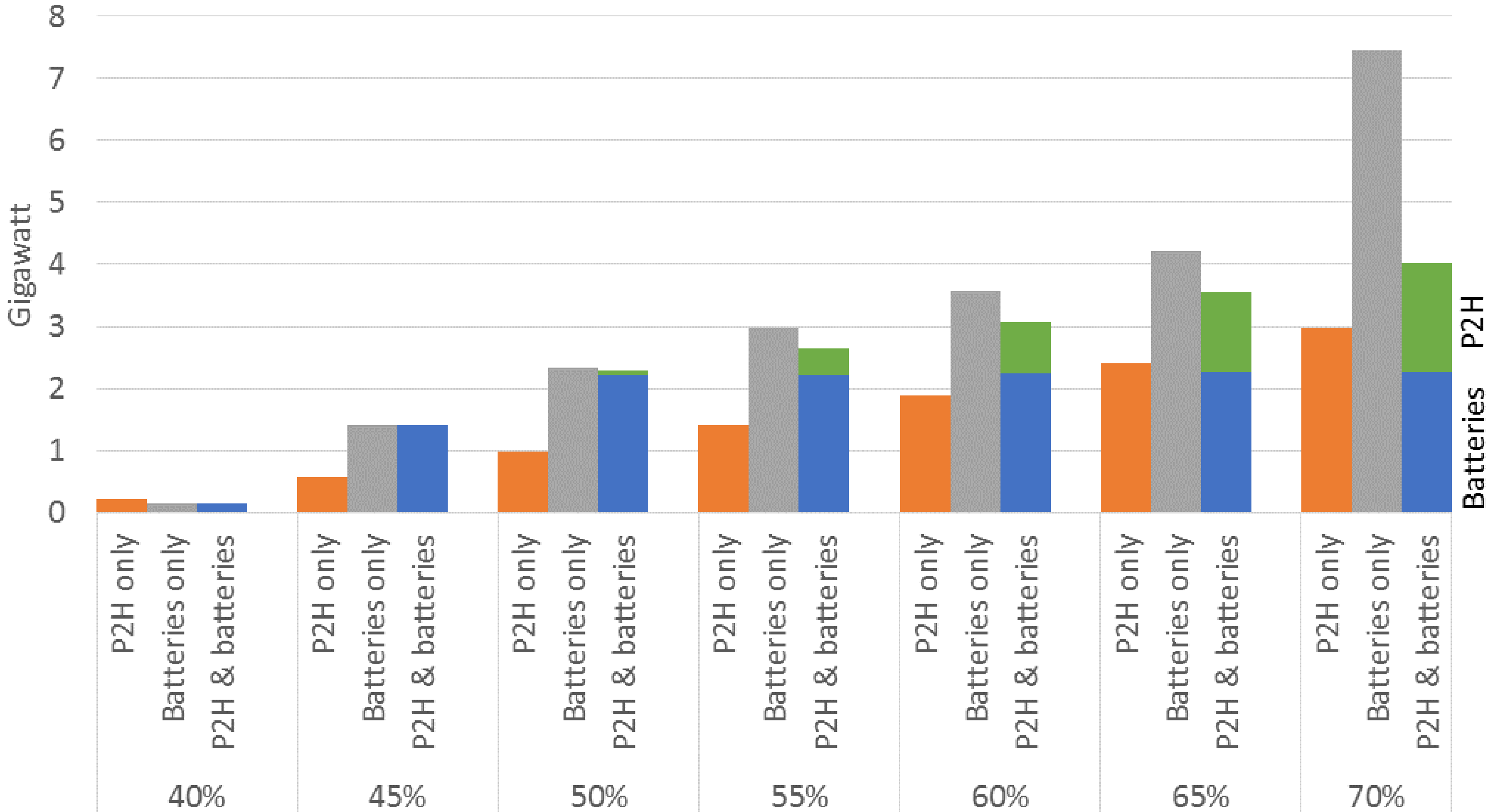
Storage heater capacity – power rating



- Moderate increase of P2H capacity even beyond 65% self-consumption
- Lower power rating cp. to batteries because of higher (low-cost) energy capacity
- If both options are available: P2H deployed beyond 50% → cost effect

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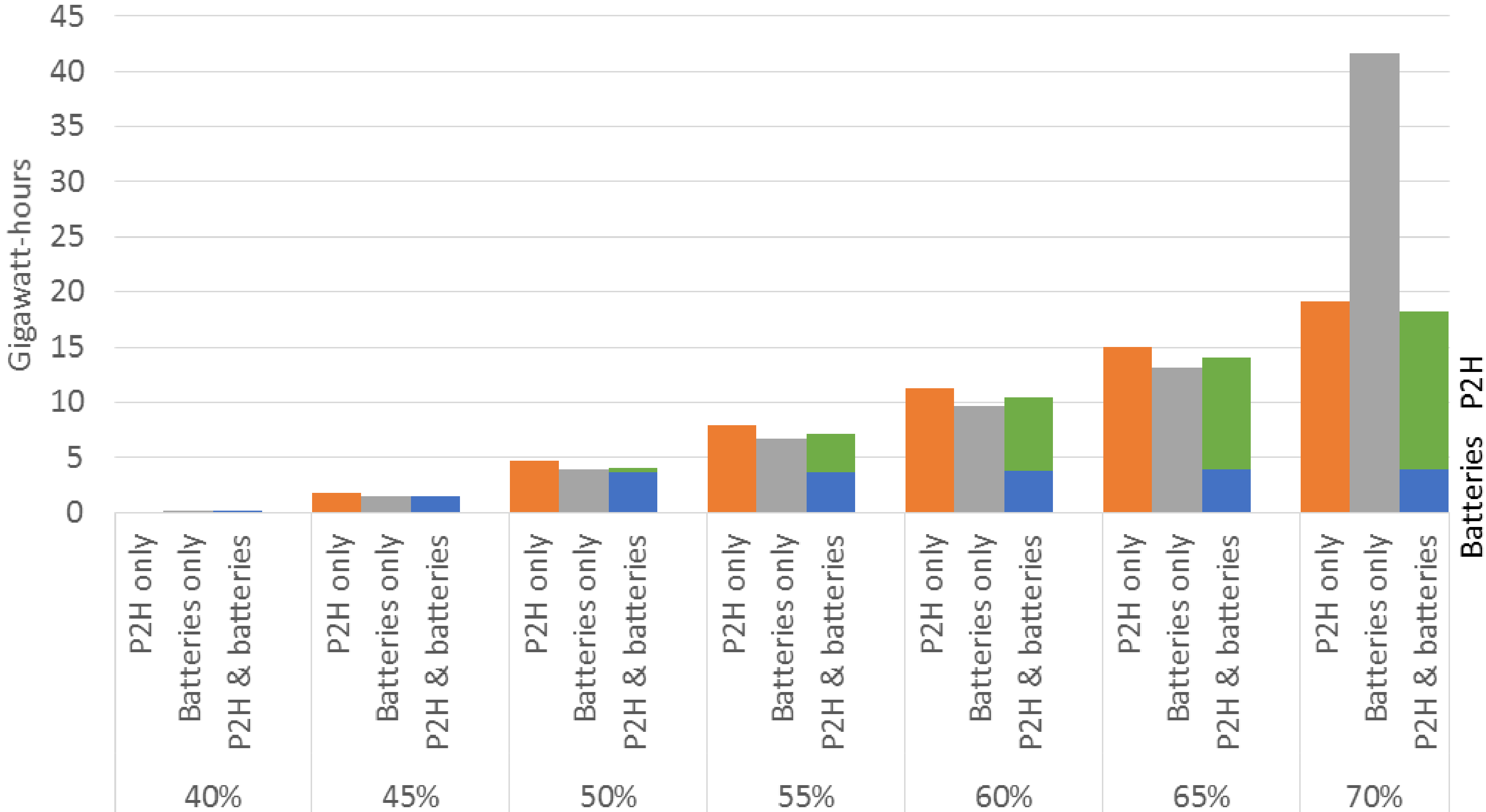
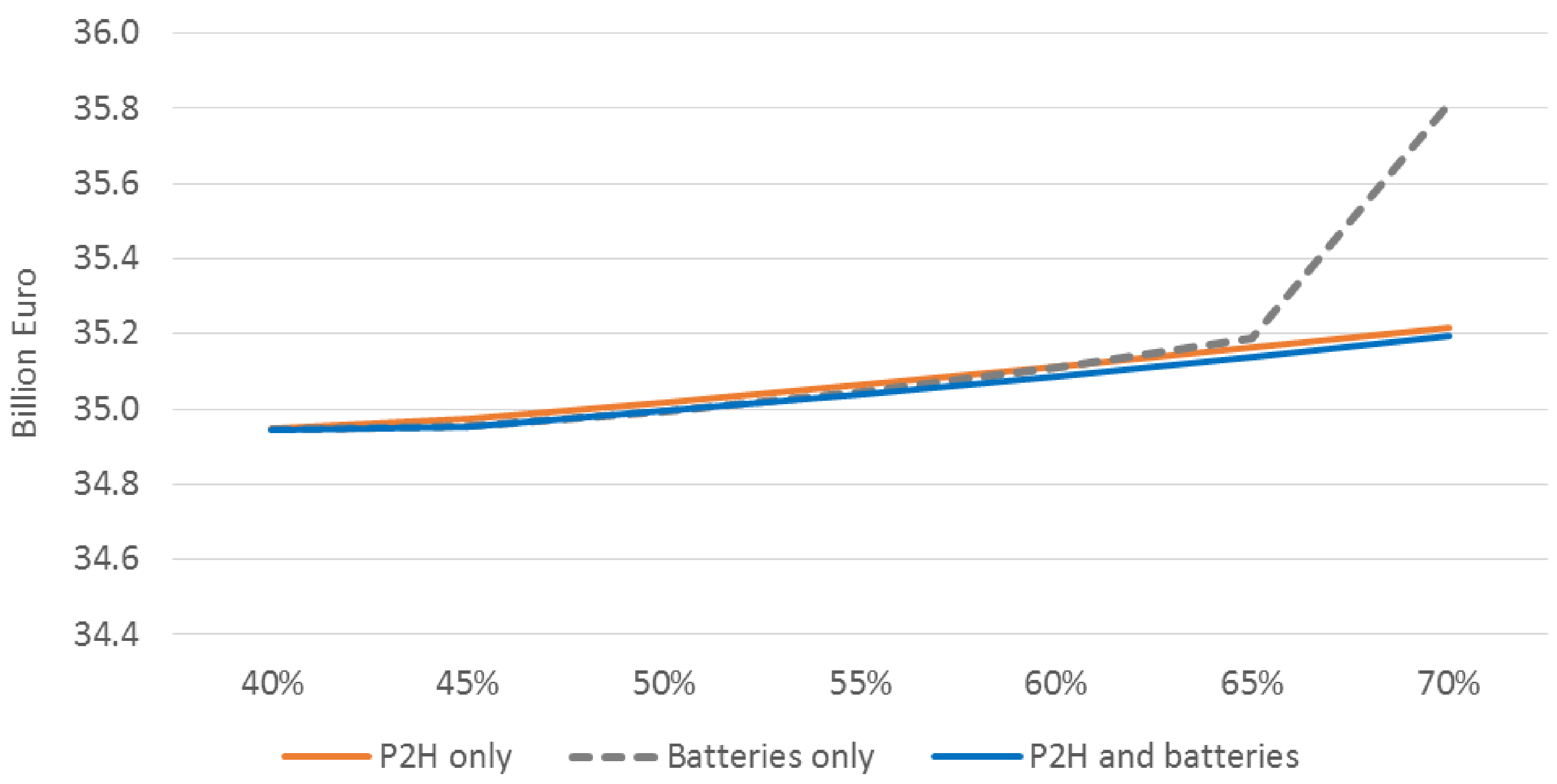
Storage heater capacity – energy capacity



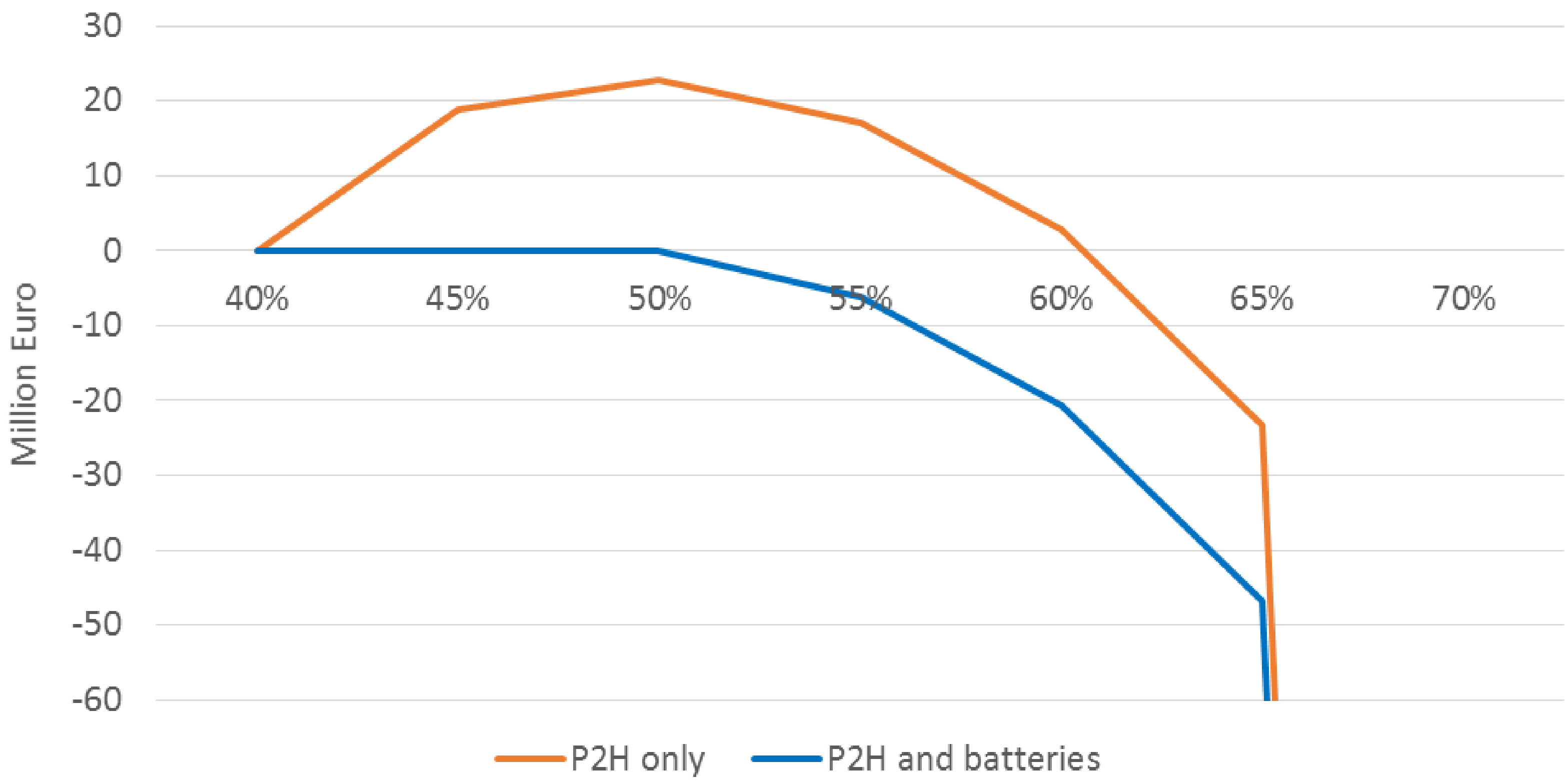
- Energy capacity of P2H comparable to batteries up to self-consumption share of 65%
- Much lower increase beyond 65% because of higher utilization

5 System costs - absolute



- Lower cost increases for high self-consumption shares through P2H

5 System costs – differences to „Batteries only“



- Up to ~60% self-consumption: additional demand effect dominates
- Beyond 60%: lower investment costs of storage heaters dominate

Prosumage: a growing niche

- Depends on consumer attitudes, technology costs and regulatory framework

Range of pros and cons

- Weight of arguments

Batteries: importance of system-friendly behavior

- Regulation should aim at making full flexibility potential available to the system

Potential role of power-to-heat

- May facilitate higher self-consumption shares than batteries
- Overlapping effects: investment costs vs. additional electricity demand

Next steps

- Investigation of potentially detrimental effect on RES shares and CO_2 emissions
- Additional model analyses:
  - Non-prosumage P2H, induced portfolio changes; maybe hot water, direct electric heating
- More detailed look at consumer incentives for power-to-heat

Thank you for listening

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Consumer preferences

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

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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

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Lower and less volatile electricity costs

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

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Activation of private capital

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

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Flexibility, sector coupling, and energy efficiency

- Unlock untapped DSM and sector-coupling potential (Anda, Temmen 2014, Prognos 2016)
  - Appropriate regulation, exposition to market prices
- Energy efficiency: awareness and behavioral changes (Luthander et al 2015)
  - Rebound?

2

Pros

Arguments in favor of prosumage	Arguments against prosumage

- Consumer preferences
- Participation and acceptance of energy transformation
- Lower and less volatile electricity costs
- Activation of private capital
- Flexibility, sector coupling, and energy efficiency
- **Distribution grid relief**
- Transmission grid relief
- Increased competition
- Local benefits
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- Efficiency losses
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- Policy coordination and path dependency
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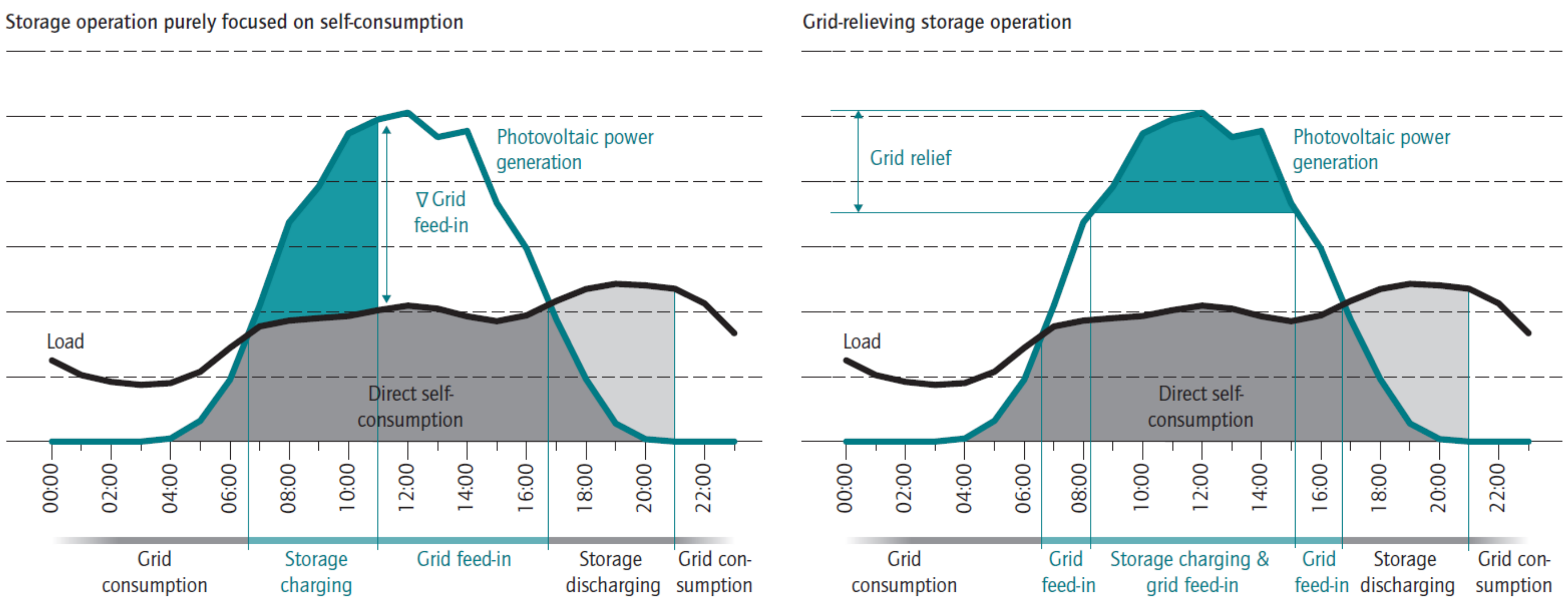

Source: own illustration

2 Pros

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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

2 Pros

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Increased competition and local benefits

- New players, but market may shrink
- Local economic spillovers?

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Political economy and new institutional economics

- Expansion of PV outside politically volatile support schemes
- Lower rent-seeking activities of well-organized incumbent lobby groups
- Innovation in hardware, software, and business models

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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

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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)

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Rebound effects

- Over-consumption of „cheap“ self-generated PV electricity?
- Particulalry in case of decentral sector coupling (power-to-heat, electric vehicles)

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Policy coordination and path dependency

- Control over achievement of targets
- Lock-in: technological and political path dependencies

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Concerns about data protection and remote control

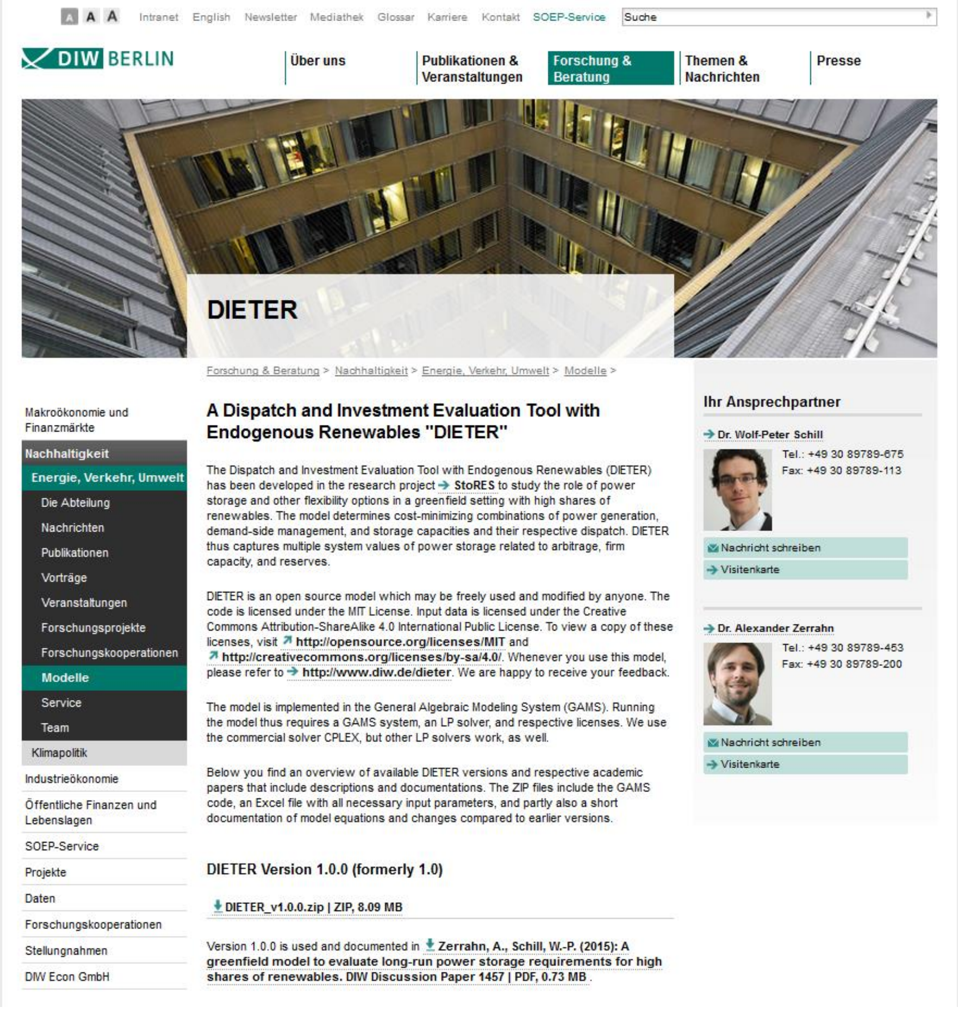
- …may hamper offtake of system-friendly prosumage (Michaels and Parag 2016)

DIETER

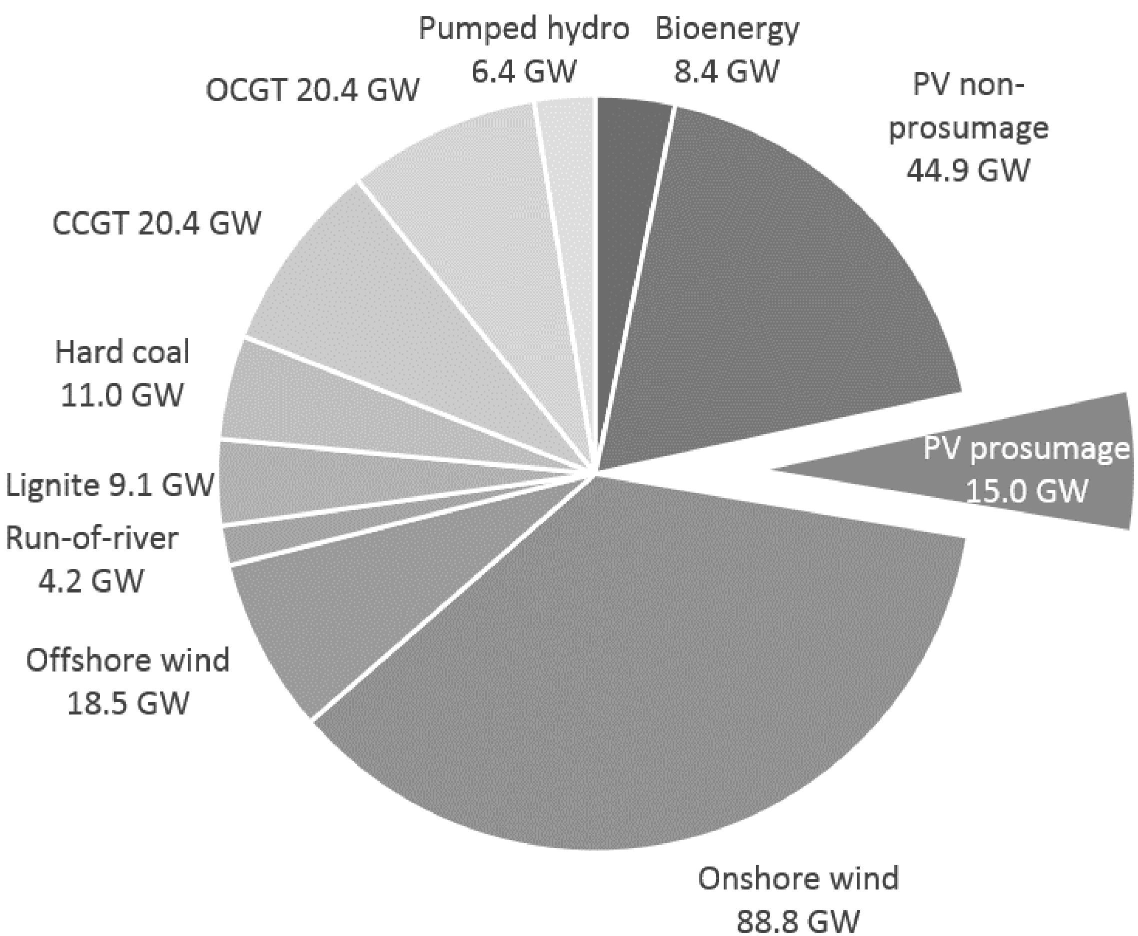
- Open-source electricity system model
- Cost minimization over dispatch and investment
- Hourly resolution, full year
- Loosely calibrated to German data

DIETER‘s website

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

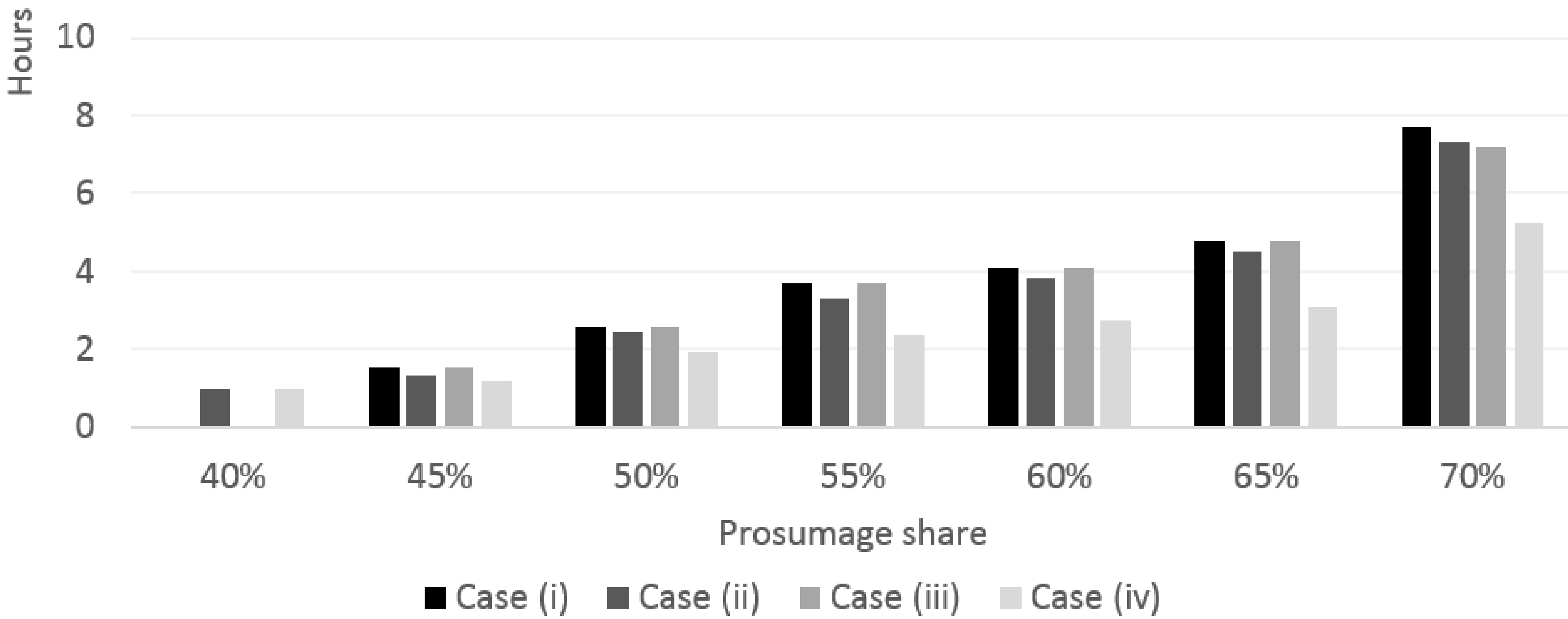


Brownfield data for 2035 (NEP scenario B1)



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

4 E/P ratios of prosumage storage



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

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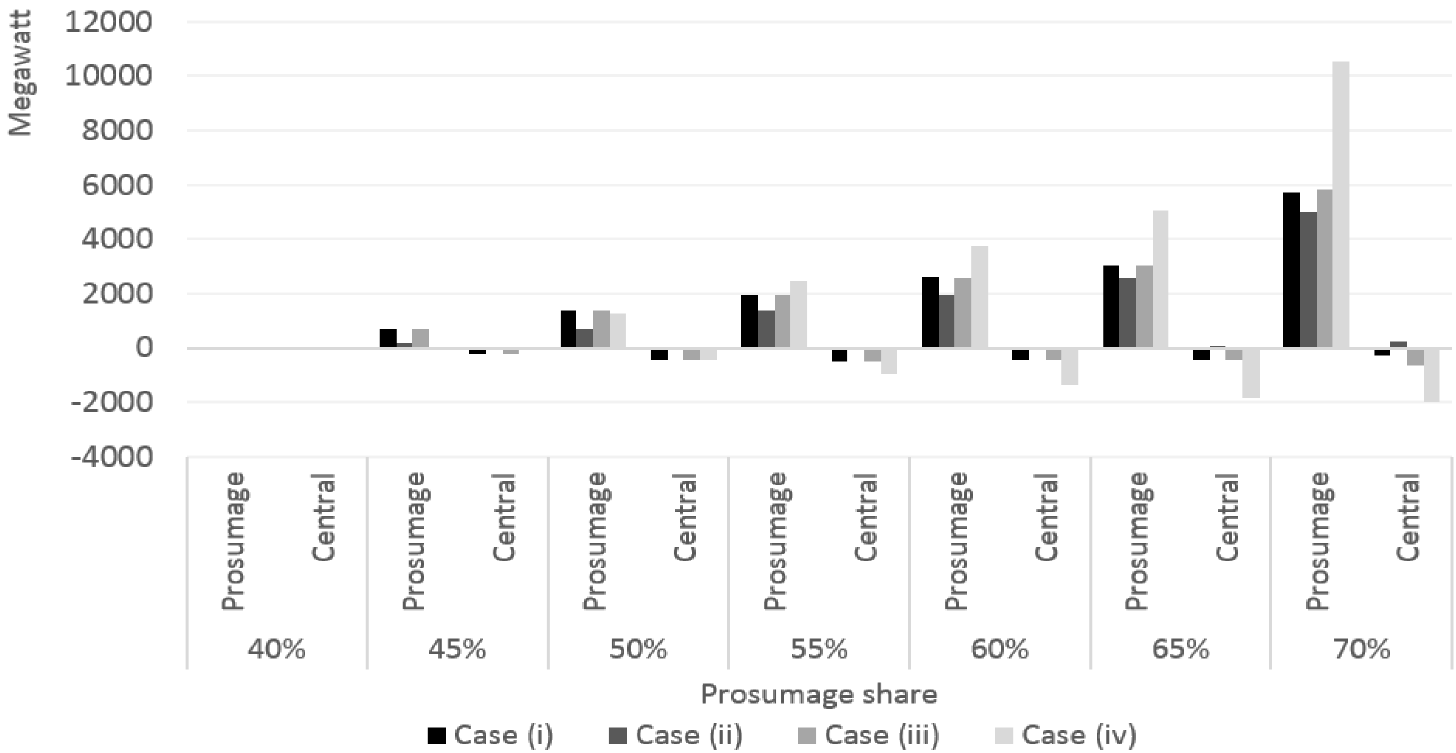
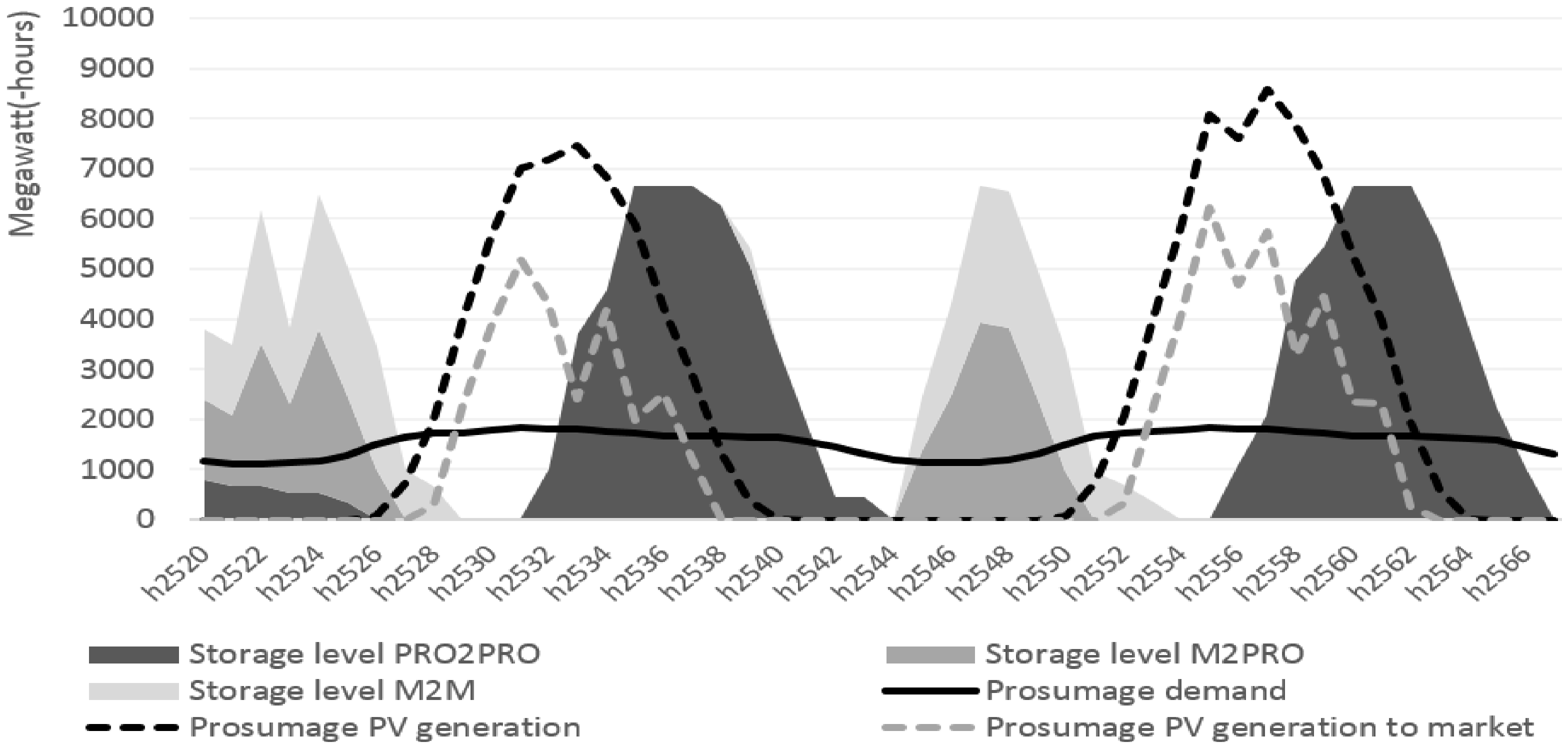
Prosumage and central storage in a sensitivity w/o given storage capacities



- Substantial substitution only under full market interaction

4 Storage patterns – Case (iv), 55% prosumage



- 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

APPENDIX: 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

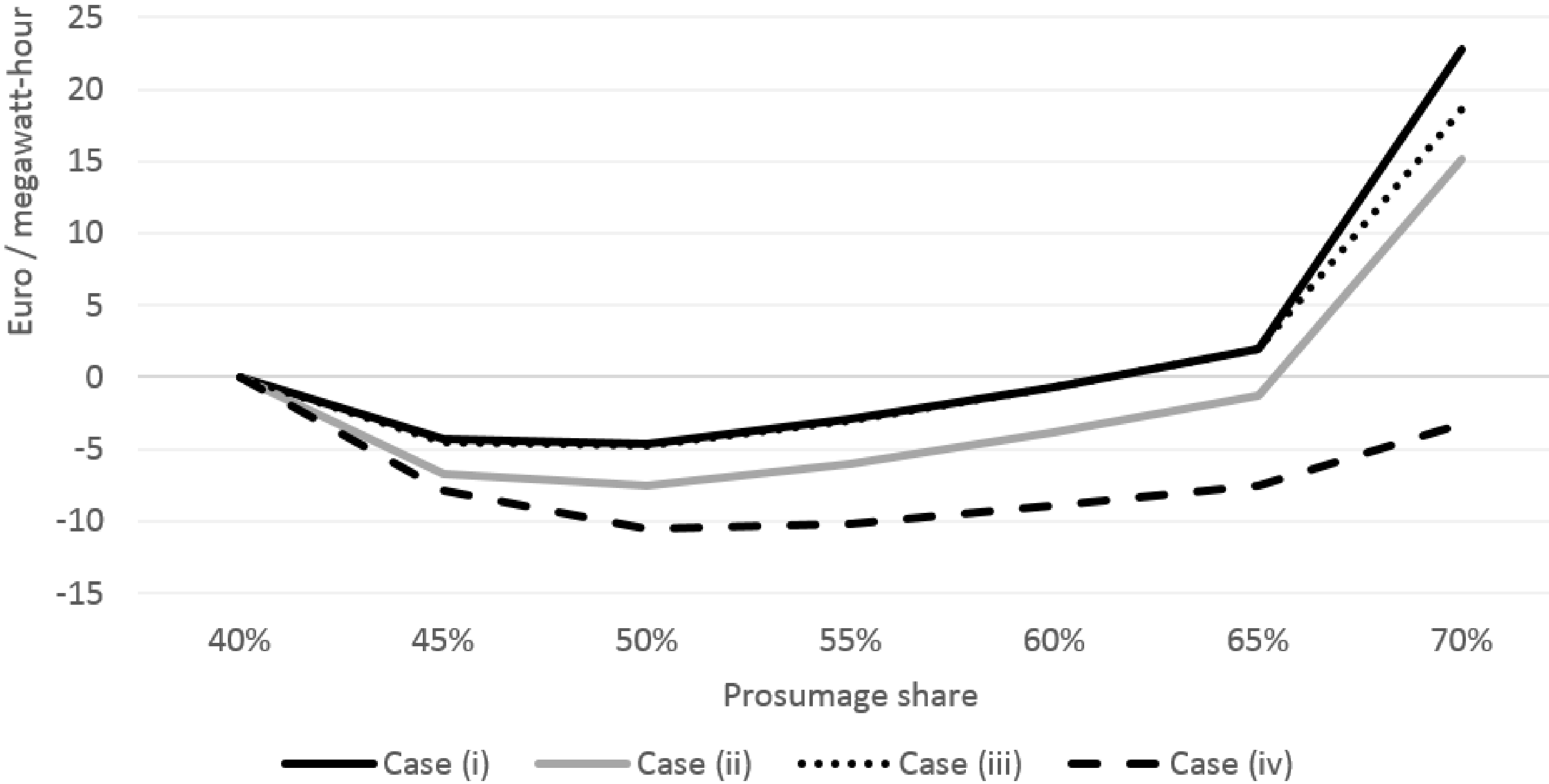
- No separate objective of prosumagers
- But system-optimal behavior
- Lower bound for efficiency losses

No intra-hourly variability

No other flexibility options (important especially in long-term perspective)

- DSM, sector coupling

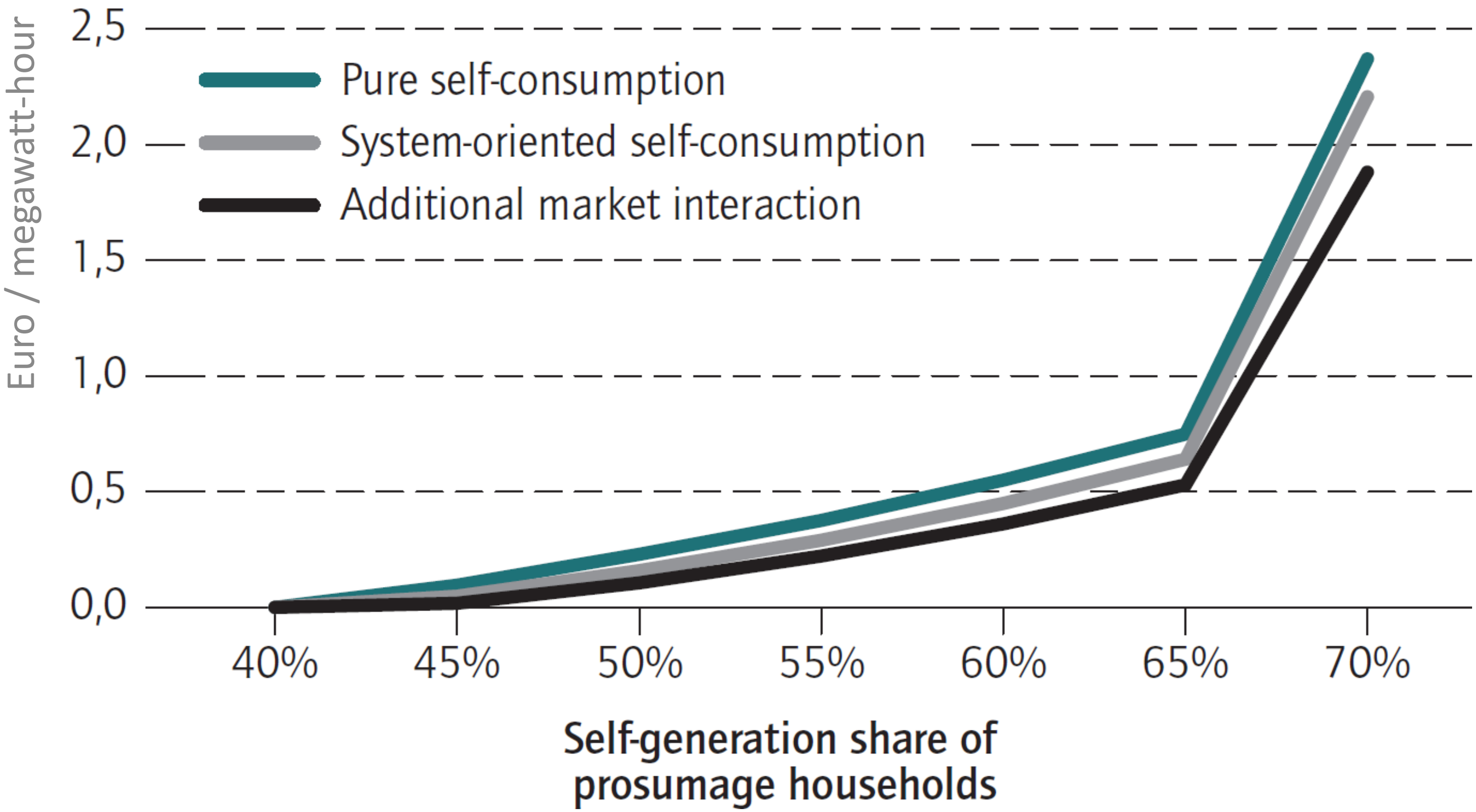
Dispatch effect (w/o storage investments)



- Positive value of additional flexibility

4 Additional system costs related to overall electricity demand

Additional calculations in DIW Wochenbericht / DIW Economic Bulletin



- Pure self-consumption (sligthly) worse than former Case (i)

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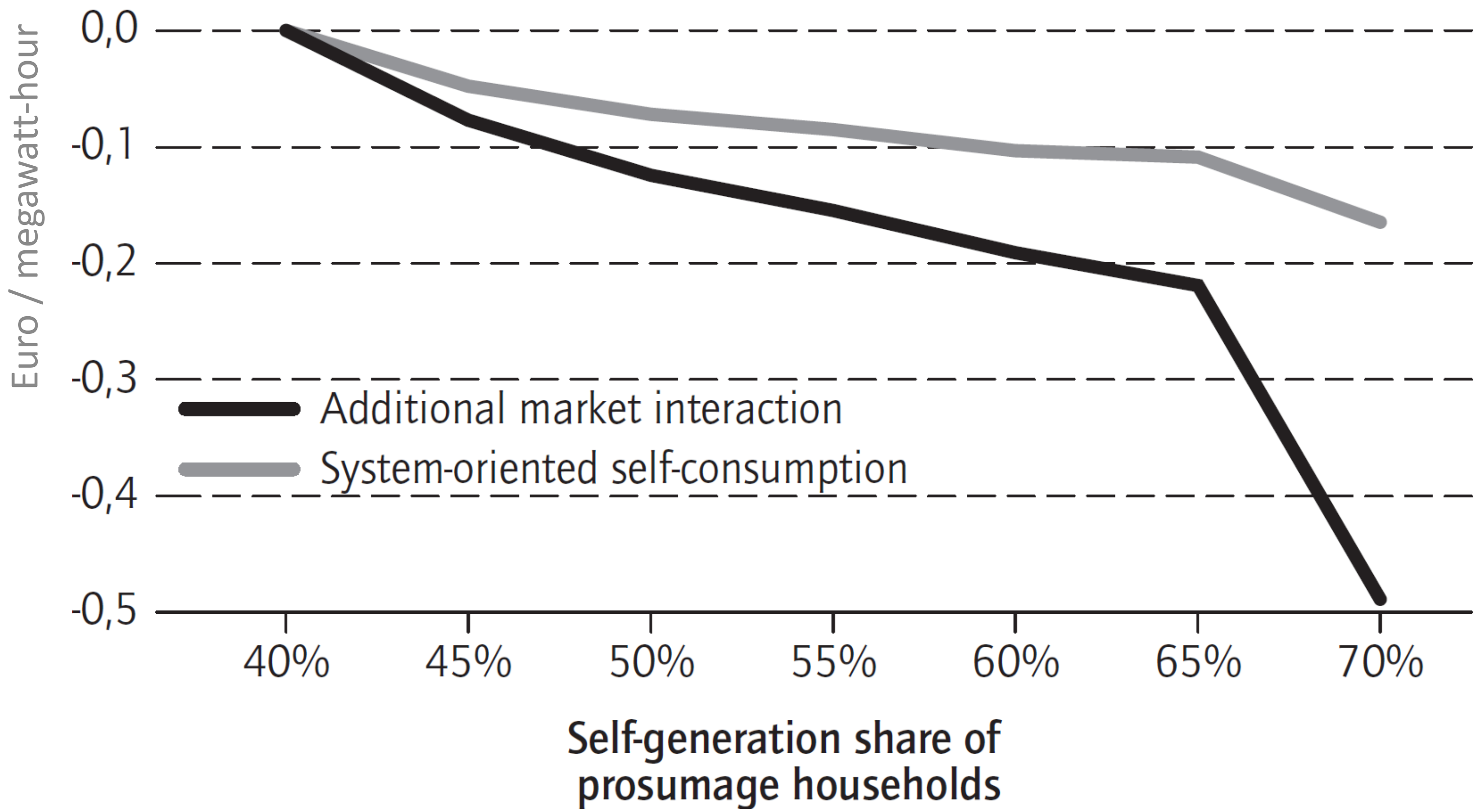
System cost reduction compared to pure self-consumption related to overall electricity demand

Additional calculations in DIW Wochenbericht / DIW Economic Bulletin



- System cost-decreasing effect of additional market interactions even larger