

**Flexibility options in electrical networks  
with high shares of fluctuating renewable energy systems**

3<sup>rd</sup> Good Governance to Energy Transition

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Valdivia, Chile

6 September 2017

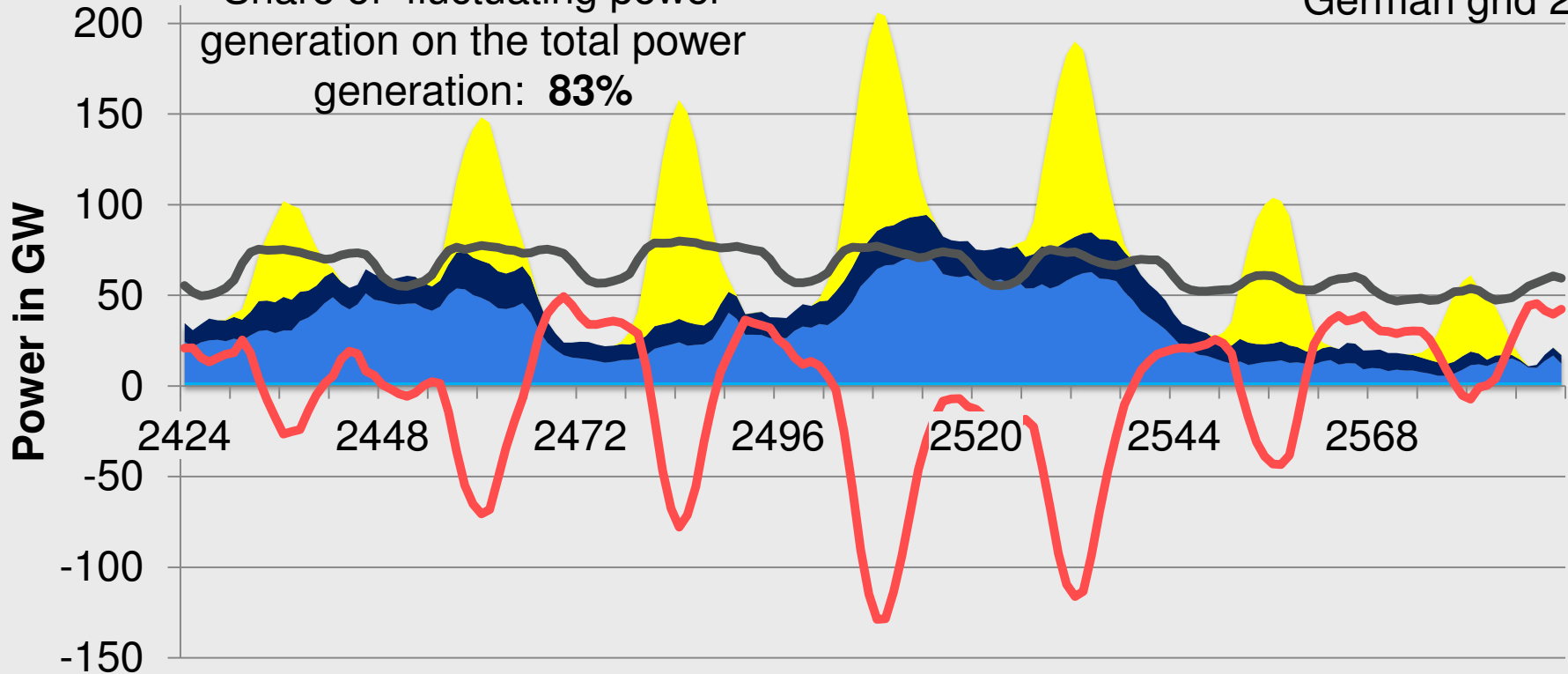
Qualitätsmanagement  
ISO 9001  
[www.dekra-siegel.de](http://www.dekra-siegel.de)



# Modelled development for the residual load Germany in 2050

Scenario:  
German grid 2050

Share of fluctuating power generation on the total power generation: **83%**



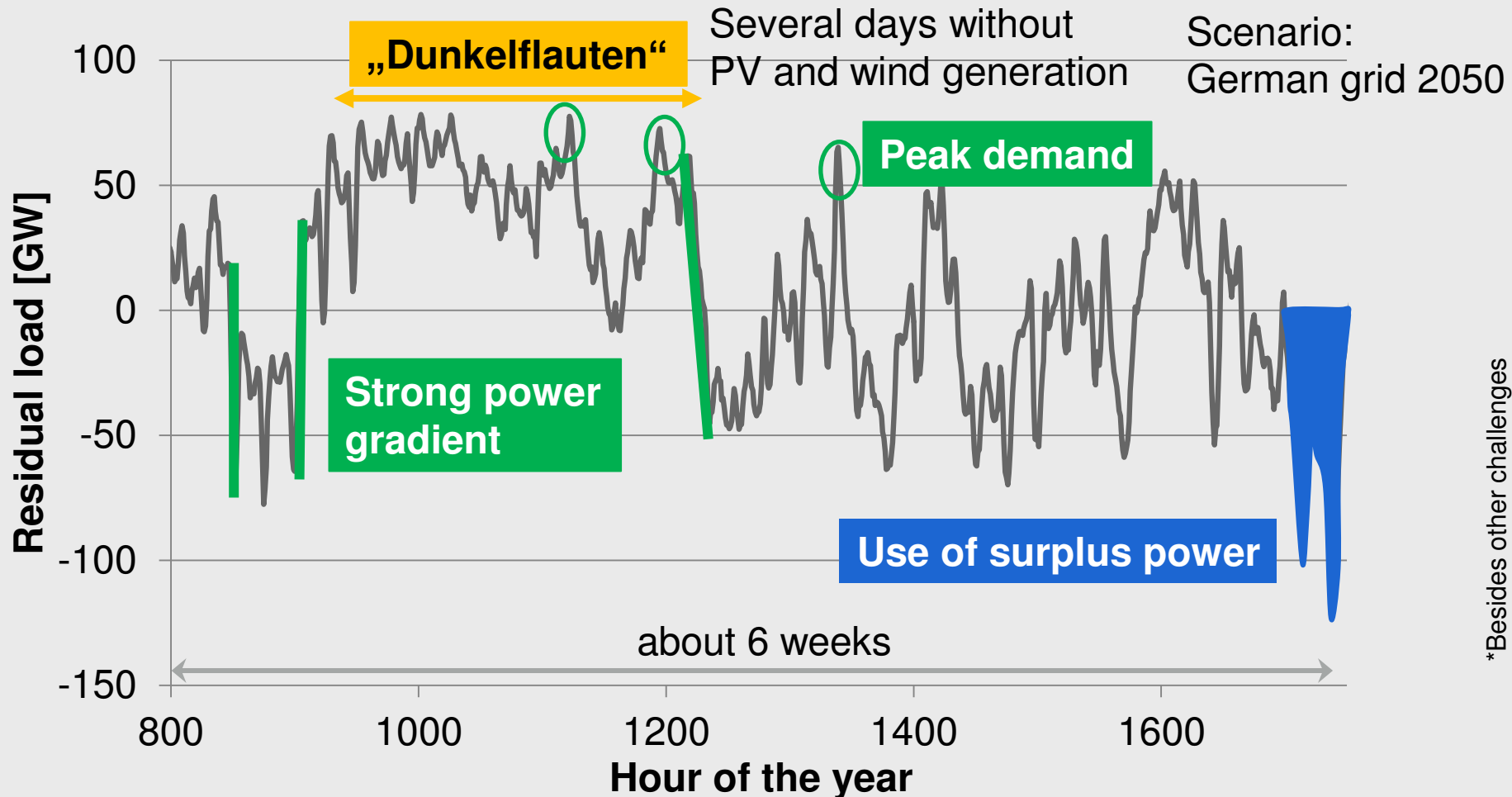
graph: Wuppertal Institut

■ Hydro Power   
 ■ Wind onshore   
 ■ Wind offshore   
 ■ PV   
 — Load   
 — Residual Load

PV: 151 GW, Wind onshore: 82 GW, Wind offshore: 20 GW, Electricity consumption: 602 TWh/year

# Energy system with high share of FEE

## 3 main challenges\*



\* Besides other challenges

Flexibilities in generation and consumption become necessary  
with high share of fluctuating renewables

# Different energy storage solutions for different challenges

**Peak demand**

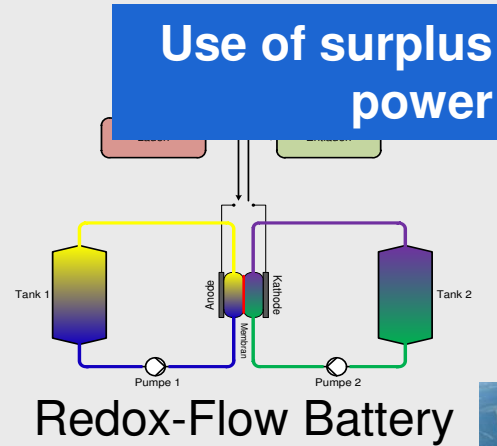
**Strong power gradient**

**Use of surplus power**

**„Dunkelflauten“**



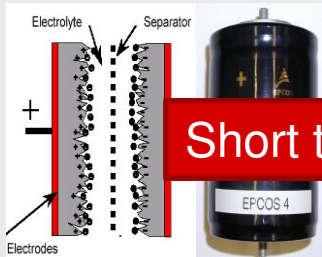
Ultraconductive Coils



Redox-Flow Battery



Hydrogen Storage



**Short to medium-term**

SuperCaps

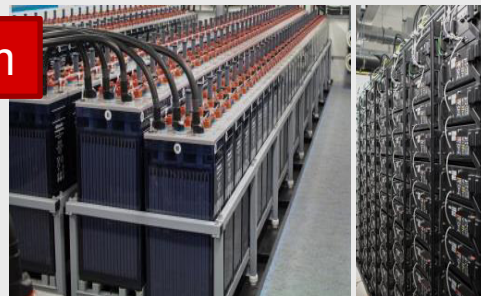


**Medium to long-term**

Pumped Hydro



Flywheel

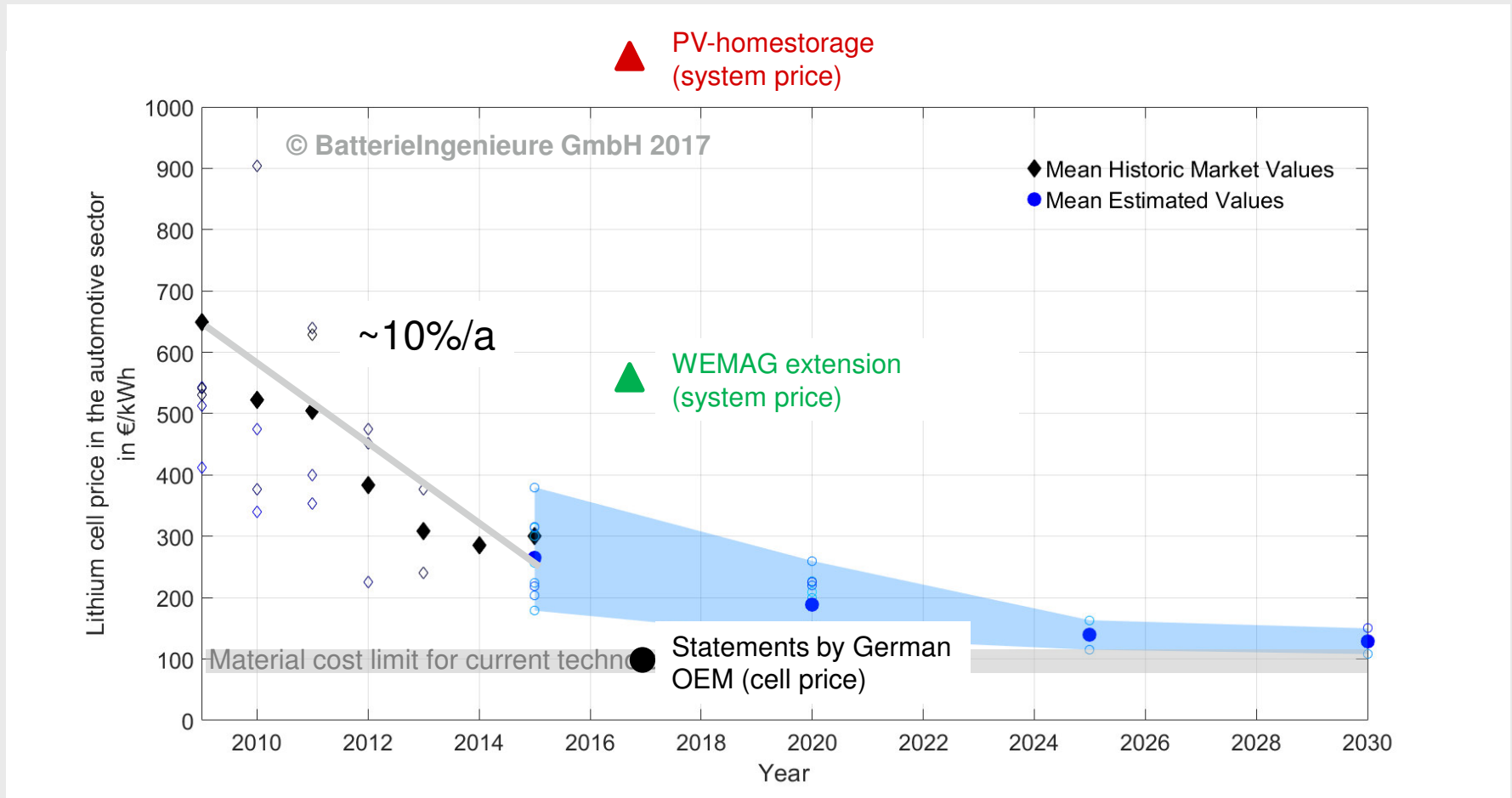


Batteries-  
Lead-Acid, Lithium, NaNiCl, ...



Compressed Air

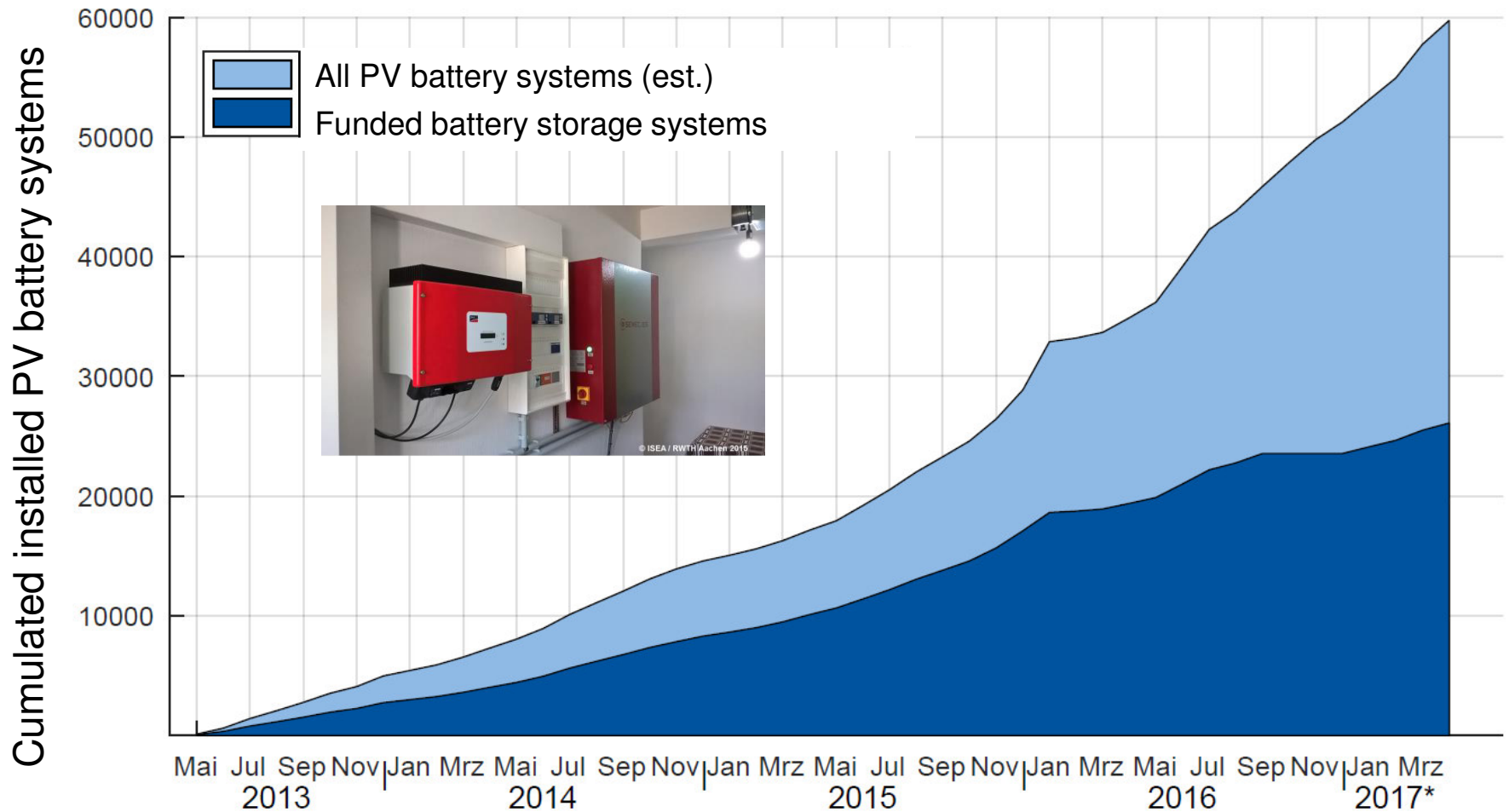
# Market development of Lithium-Ion cell prices



Considered were cell types used in the automotive industry (mostly NMC, NCA)

Sources: DB09, BCG10, RB10, TIA10, CED11, ATK12, RB12A, RB12L, EE12, Avi13, RB13, ISI13, MWG13, ISI15, UBS14, UBS14-A

# Market development of PV battery storage systems in Germany



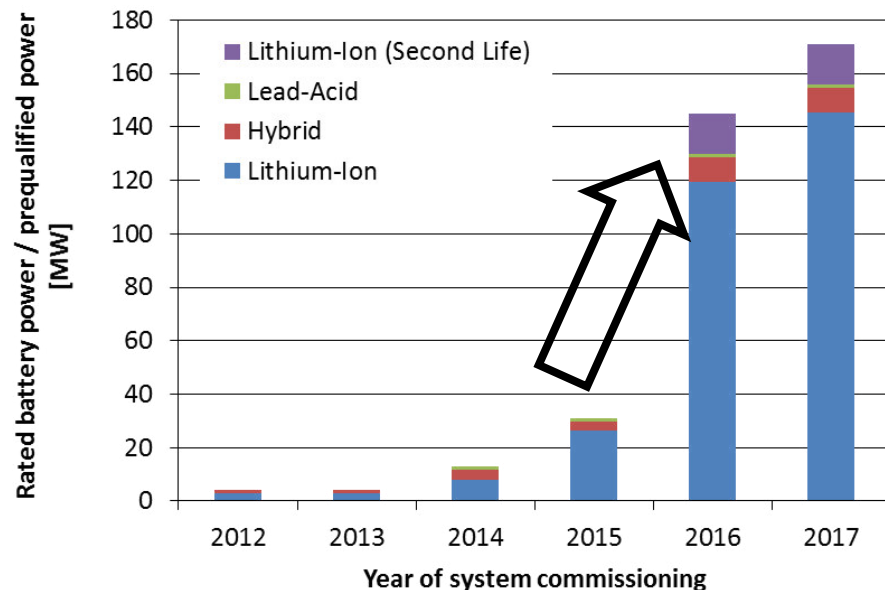
Source: Speichermonitoring program, ISEA, RWTH Aachen University, [www.speichermonitoring.de](http://www.speichermonitoring.de)



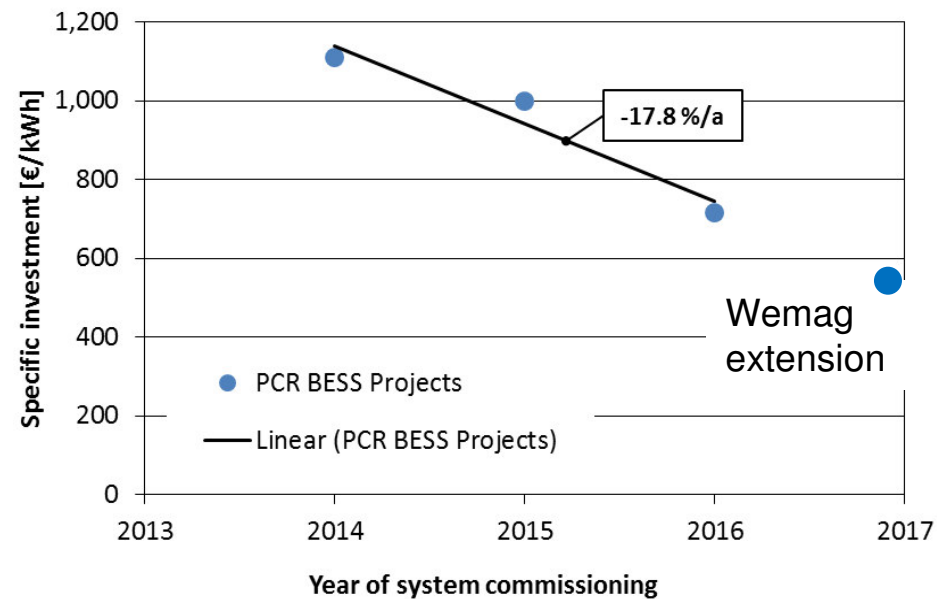
# Market development of MW storage systems in Germany



- Large scale storage systems for Frequency Containment Reserve
- Until the end of 2017: ~171 MW battery storage systems for FCR (~28% of the German market)
- System price development ~-17.8%/a
  - Through cell price development and learning effects

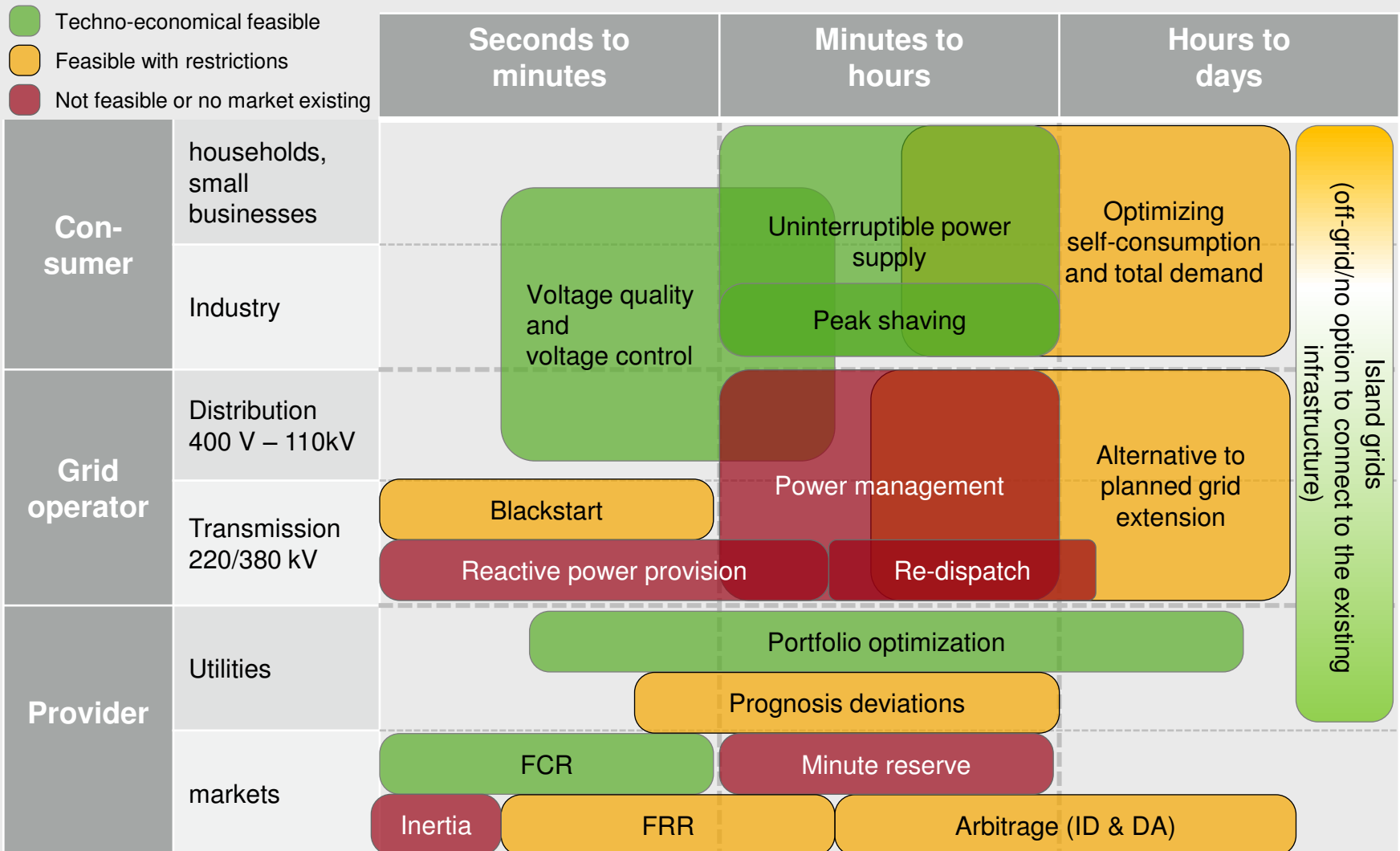


Source: Fleer et al. IRES 2017



Source: Fleer et al. IRES 2016

# Stationary battery storage application Markets and potentials (Germany)

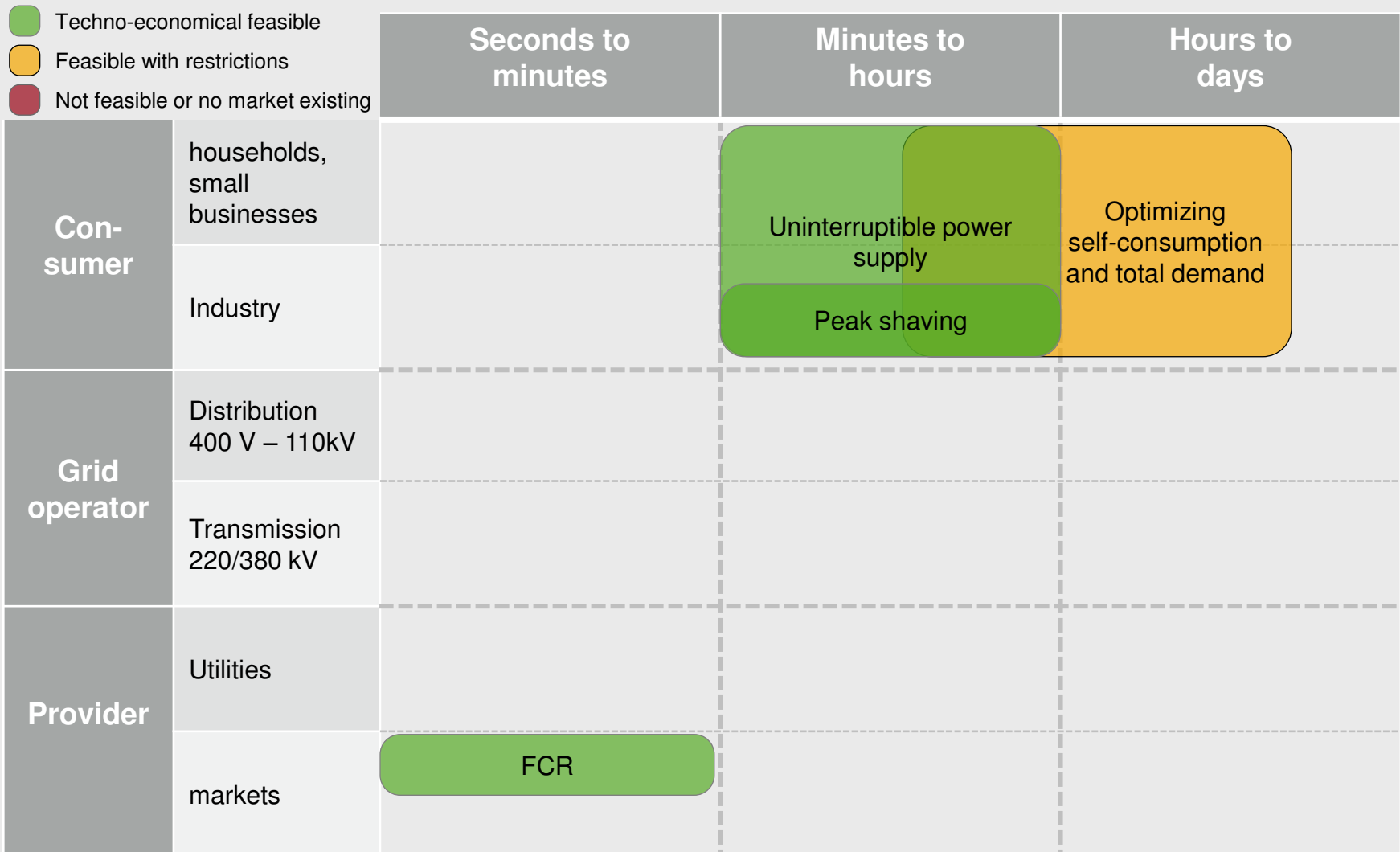


Source: own illustration based on Wasowicz B., Dissertation, 2015 and Gerhard, Vattenfall, 2017



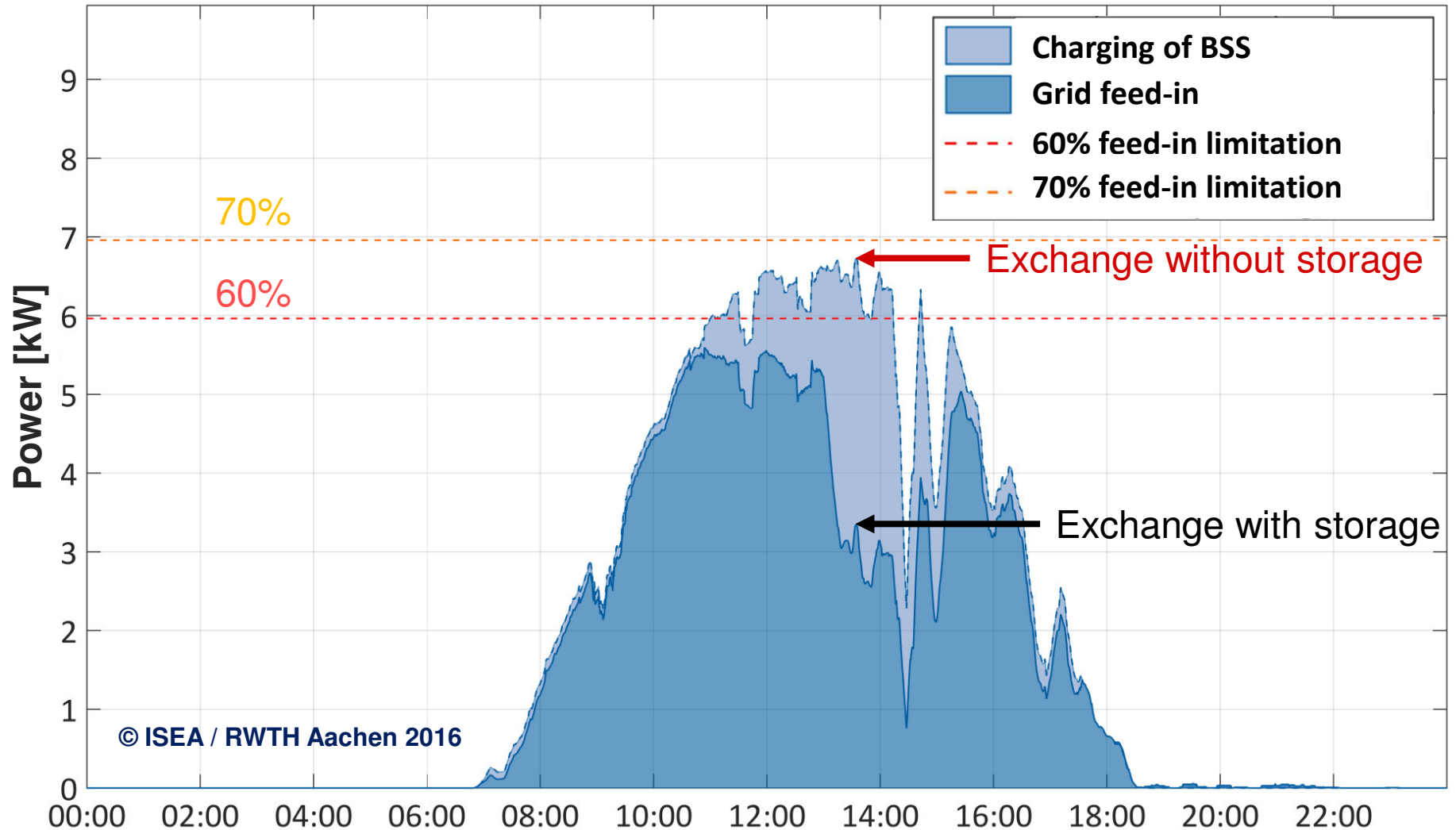
# Stationary battery storage application

## Currently most important markets



Source: own illustration based on Wasowicz B., Dissertation, 2015 and Gerhard, Vattenfall, 2017

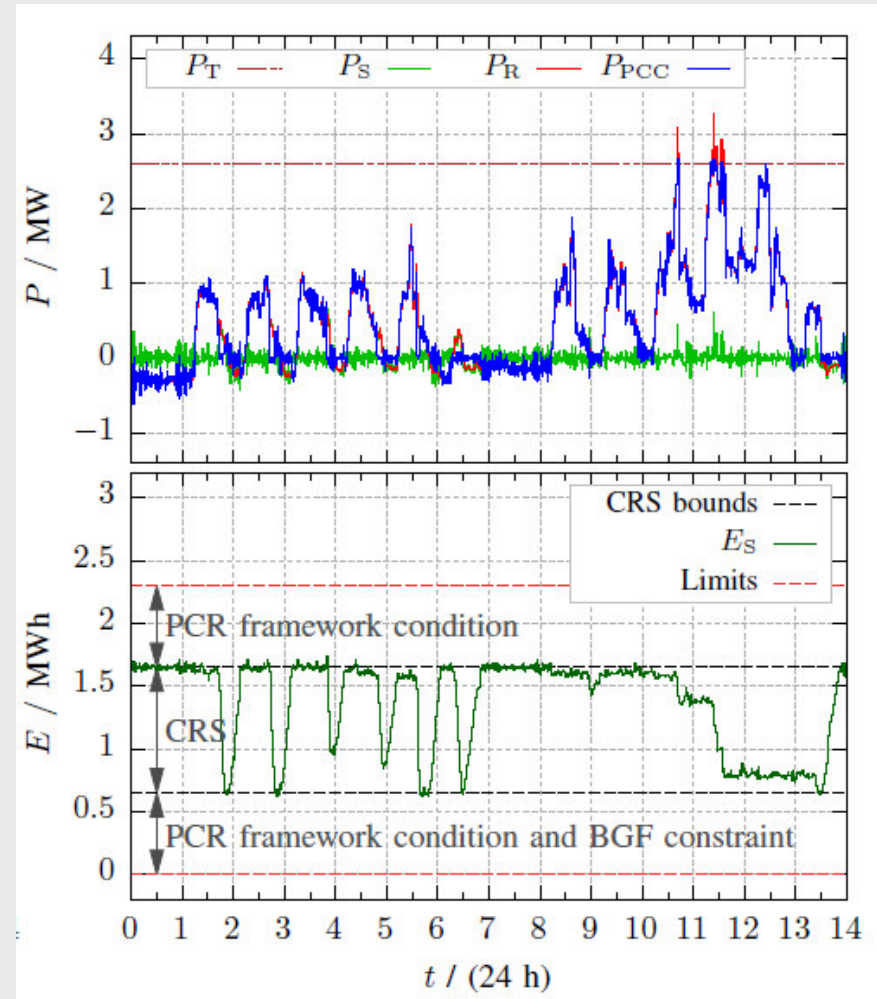
# Optimizing of self-consumption with PV-Battery Systems in households



© ISEA / RWTH Aachen 2016

# Combination of different market applications for industrial microgrid

- Combination of
  - Increased self-consumption
  - Peak Shaving
  - Frequency Containment Reserve
  - Uninterruptible Power Supply
- All constraints can be met and synergies allow for smaller battery size
- Payback period between 3-5 years possible within the existing German markets



Source: Vogt & Badeda et al., PEDS, 2017

# Next step: interconnection of energy markets

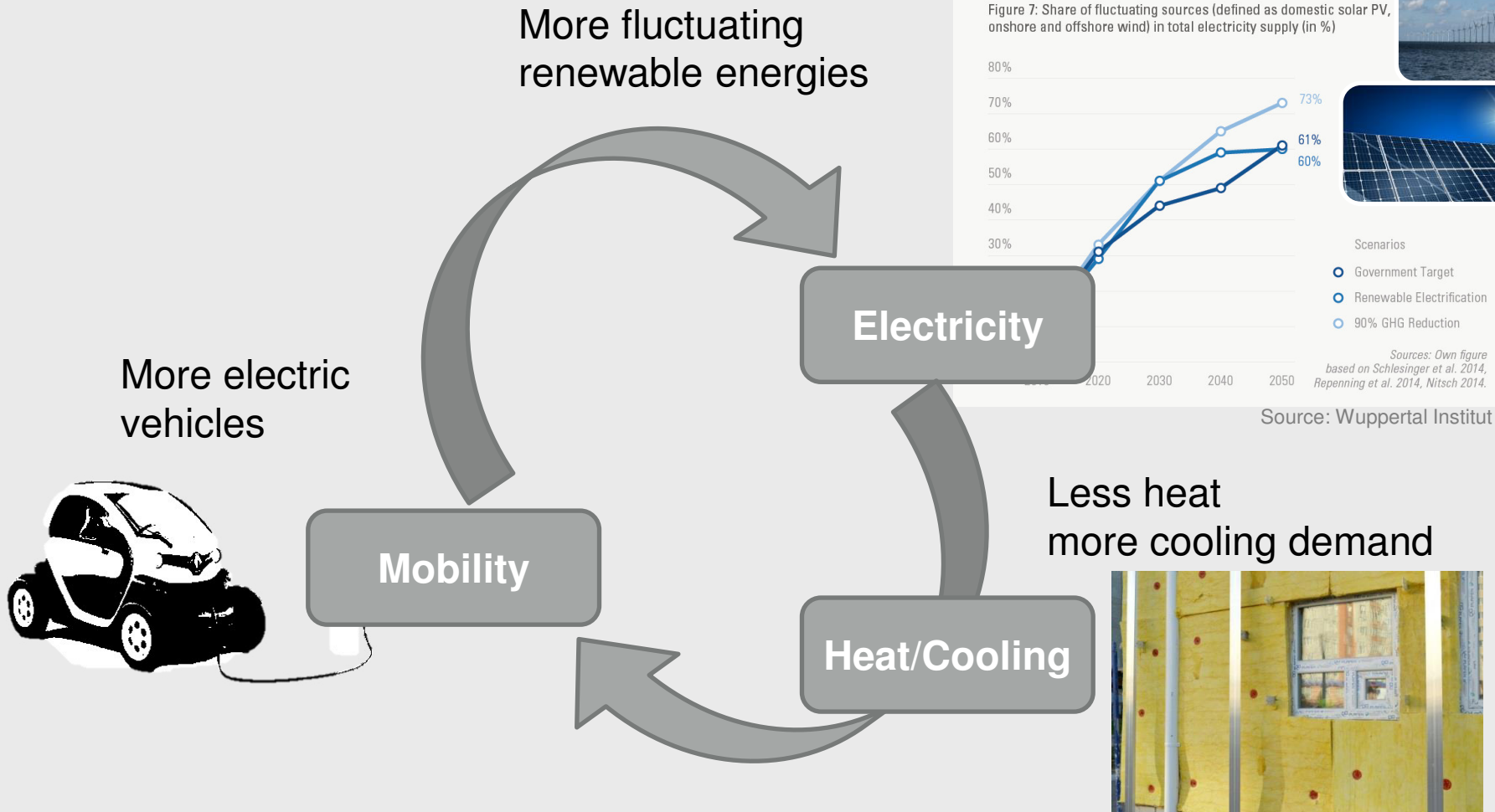
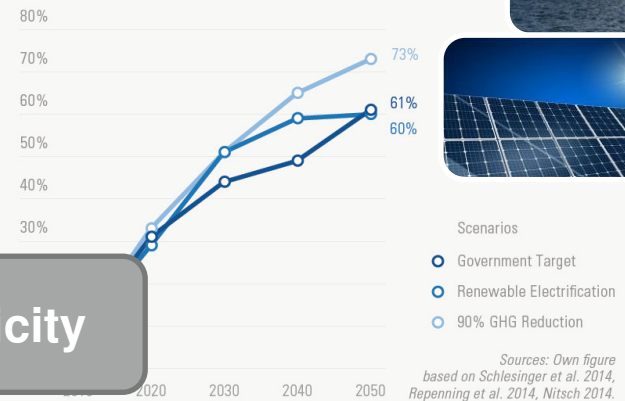
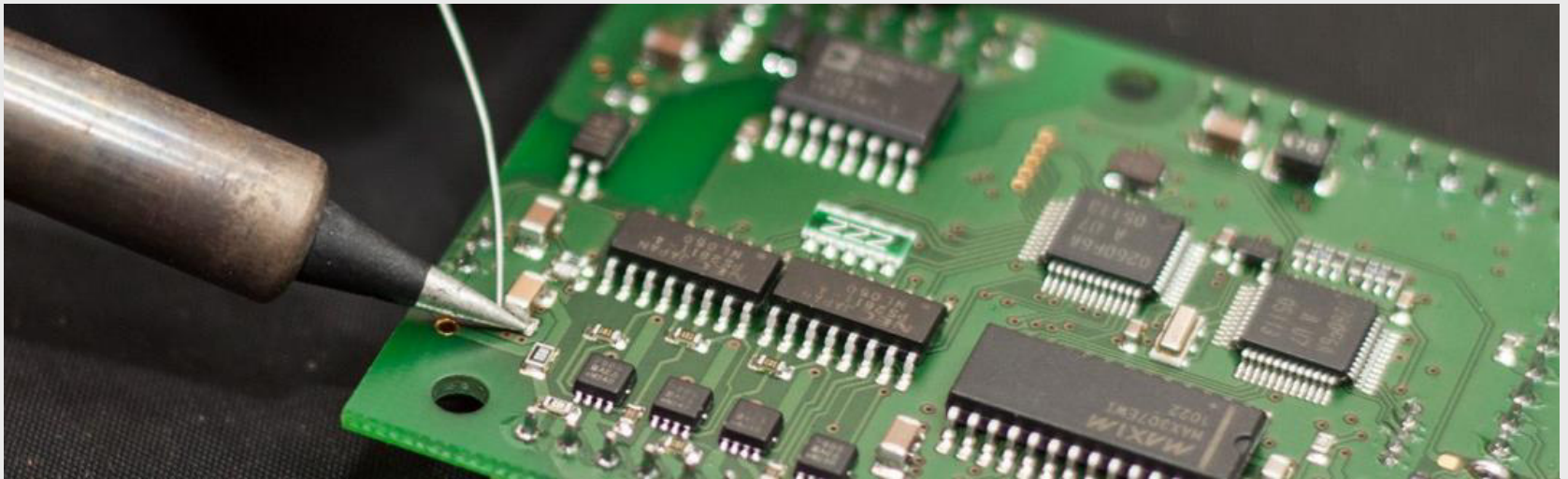


Figure 7: Share of fluctuating sources (defined as domestic solar PV, onshore and offshore wind) in total electricity supply (in %)



Source: Wuppertal Institut

More electricity will be utilized within the other energy markets



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# Sources for Lithium cell price meta analysis



Abrev.	Short Name for Reference	Titel	Author	Editor
DB09	2009 Deutsche Bank	Electric Cars: Plugged In 2 - A mega-theme gains momentum	R. Lache, D. Galves, P. Nolan	Deutsche Bank
BCG10	2010 BCG [Din10]	Batteries for Electric Cars, Challenges, Opportunities, and the Outlook to 2020		Boston Consulting Group
RB10	2010 Roland Berger	Powertrain2020: Li-Ion batteries – the next bubble ahead?	k.A.	Roland Berger
TIA10	2010 TIAX 18650	PHEV BATTERY COST ASSESSMENT		TIAX
CED11	2011 CE Delft	Impacts of Electric Vehicles - Deliverable 2 Assessment of electric vehicle and battery technology	Gopalakrishnan Duleep (ICF) Huib van Essen (CE Delft) Bettina Kampman (CE Delft) Max Grünig (Ecologic)	ICF, Ecologic, CE Delft
ATK12	2012 AT Kearney	Überspannung im Batteriemarkt für Elektrofahrzeuge	Klink, G., Krubasik, S., Rings, T. Schindler, M.	ATKearney
RB12A	2012 Roland Berger Automotive [Ber12a]	Technology & Market Drivers for Stationary and Automotive Battery Systems	k.A.	Roland Berger, batteries 2012
RB12L	2012 Roland Berger Lithium [Ber12]	The Lithium-Ion Battery Value Chain	Pavoni, F., Bernhart, W.	Roland Berger, Istanbul
EE12	2012 Element Energy [Clu12]	Cost and performance of EV batteries Final report for The Committee on Climate Change	Element Energy	For Committee on Climate Change
Avi13	2013 Avicenne	Li-ion battery material market review and forecasts 2012-2025	Pillot, C.	Avicenne, 3rd Israeli Power Sources Conference
RB13	2013 Roland Berger	Market and Cost Drivers for Automotive and Stationary Batteries	Bernhart, W., Kruger F. Thielmann, A.; Sauer, A.; Isenmann, R.; Wietschel, M.	Roland Berger, Energy Storage Conference Düsseldorf
ISI13	2013 ISI	Technology-Roadmap Energiespeicher für die Elektromobilität 2030		Fraunhofer ISI
MWG13	2013 MW Group	Large scale Factories for Li-Ion Batteries IPVEA PV Production and Battery Forum at PVSEC, Paris, 2013	Eberhardt, Klaus	M+W Group
NAV14	2014 Navigant	The Lithium Ion Battery Market: Supply Demand	Sam Jaffe	Navigant
ISI15	2015 ISI	Produkt-Roadmap Energiespeicher für die Elektromobilität 2030	Thielmann, A.; Sauer, A.; Wietschel, M.	Fraunhofer ISI
UBS14	2014 UBS	Global Utilities, Autos & Chemicals Will solar, batteries and electric cars re - shape the electricity system?	Hummel, P. et al	UBS
UBS14-A	2014 UBS-A	Expert Call: Electric Vehicle Batteries Sowing the seeds of an energy revolution	Dewhurst, J. et al	UBS