Concept Symposium 2018
Governing Megaprojects – Why, What and How

Digitalisation and Consumer Demand – the Empirical Evidence

Dr. Andreas Löschel
Professor of Economics
University of Münster
Germany

With the advancing energy transition, the integration of renewable energies into the energy market is becoming increasingly important. In order to avoid overloading the grid, the supply of electricity must always correspond to the demand for electricity. Fluctuating generation and grid feed-in from renewable energies with relatively rigid demand at the same time presents problems that can be addressed with various flexibility options on the supply and demand side. These include grid expansion, storage or a more flexible demand for energy. The digitalization of the energy industry, summarized under the term "Smart Energy", provides approaches to such a flexibilization and reduction of energy consumption.

Smart metering technologies enable flexible pricing of energy consumption for demand management. With the help of digital feedback technologies, more informed energy consumption decisions can be made, e.g. by informing about benchmark consumption. However, these opportunities associated with digitisation go hand in hand with many open questions: Which factors influence the energy demand behaviour of households and companies? How do households and companies react to variable prices and real-time feedback? What savings potential and degree of demand flexibility can be realized? The presentation will present some empirical evidence on these questions.

The Concept Symposia on Project Governance
The Norwegian Ministry of Finance and the Concept Research Program hosts every second year a symposium on project Governance. Project governance, in brief, is concerned about investments and their outcome and long-term effects. In view of the problem at hand, the aim is to ensure that the best conceptual solution is chosen, that resources are used efficiently and anticipated effects realized. Resource persons from ministries, governmental agencies, academia, international organizations, and industry are invited. In order to facilitate professional exchange and direct communication between participants, the number of individuals is restricted. The aim is to initiate further international cooperation and research on important issues related to project governance.

Digitalisation and consumer demand – the empirical evidence

Andreas Löschel

Virtuelles Institut Smart Energy

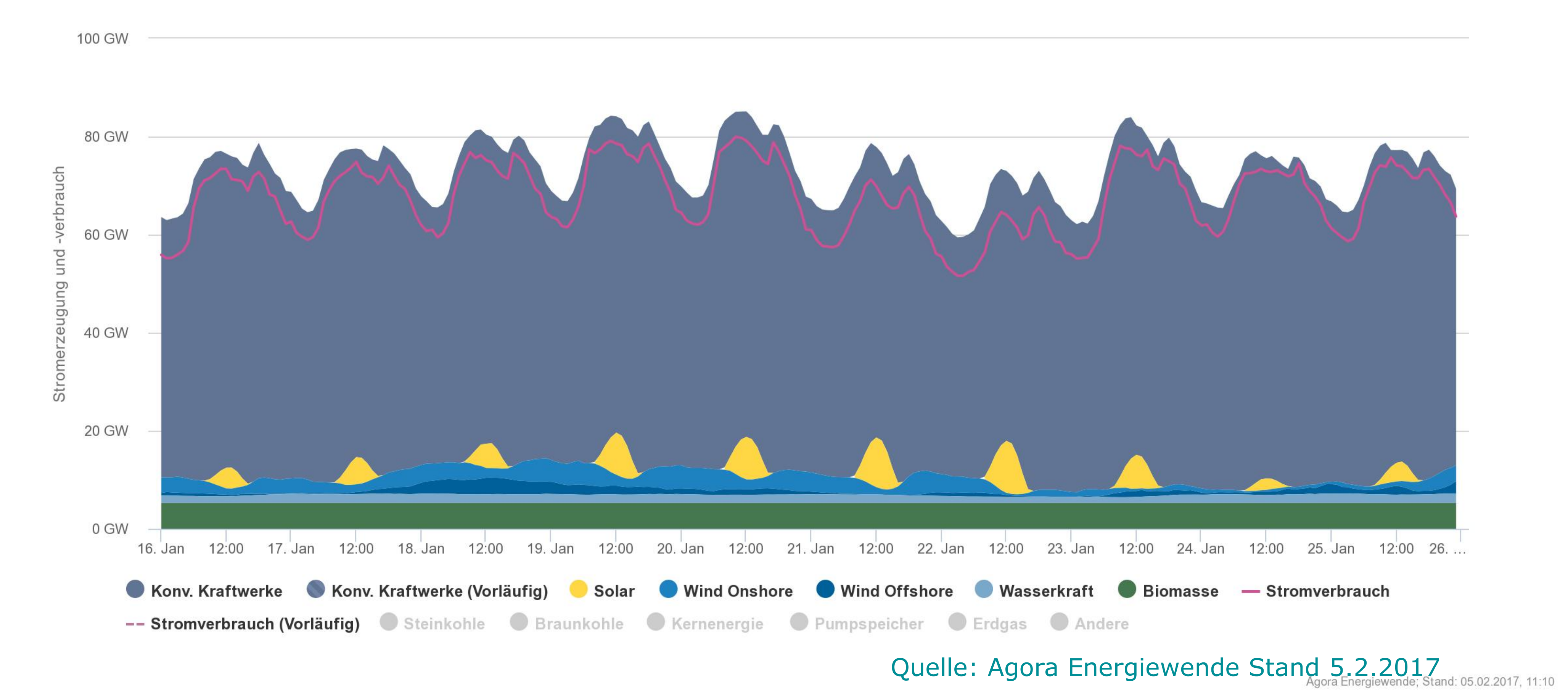
Andreas Löschel,
University of Münster
Virtual Institute Smart Energy NRW

Future visions and necessary paradigm changes

- Reaching the Paris goals (well below 2 degrees temperature change) reguires net-zero gobal emissions in the second half of the century with electricity generation likely to decarbonise first
  → **future vision**: 100 % renewable electricity by mid of the century
- Integration of renewable energy sources is a huge challenge given the current electricity system infrastructure → high renewables penetration requires **paradigm change** (from supply follows demand to demand follows supply)
- equating demand and supply calls for all flexibility option to address stronger degree of exogeneity of production including (curtailment, grid extension,) strorage and demand side options

WWU MÜNSTER

Current situation: German electricity market in January 2017

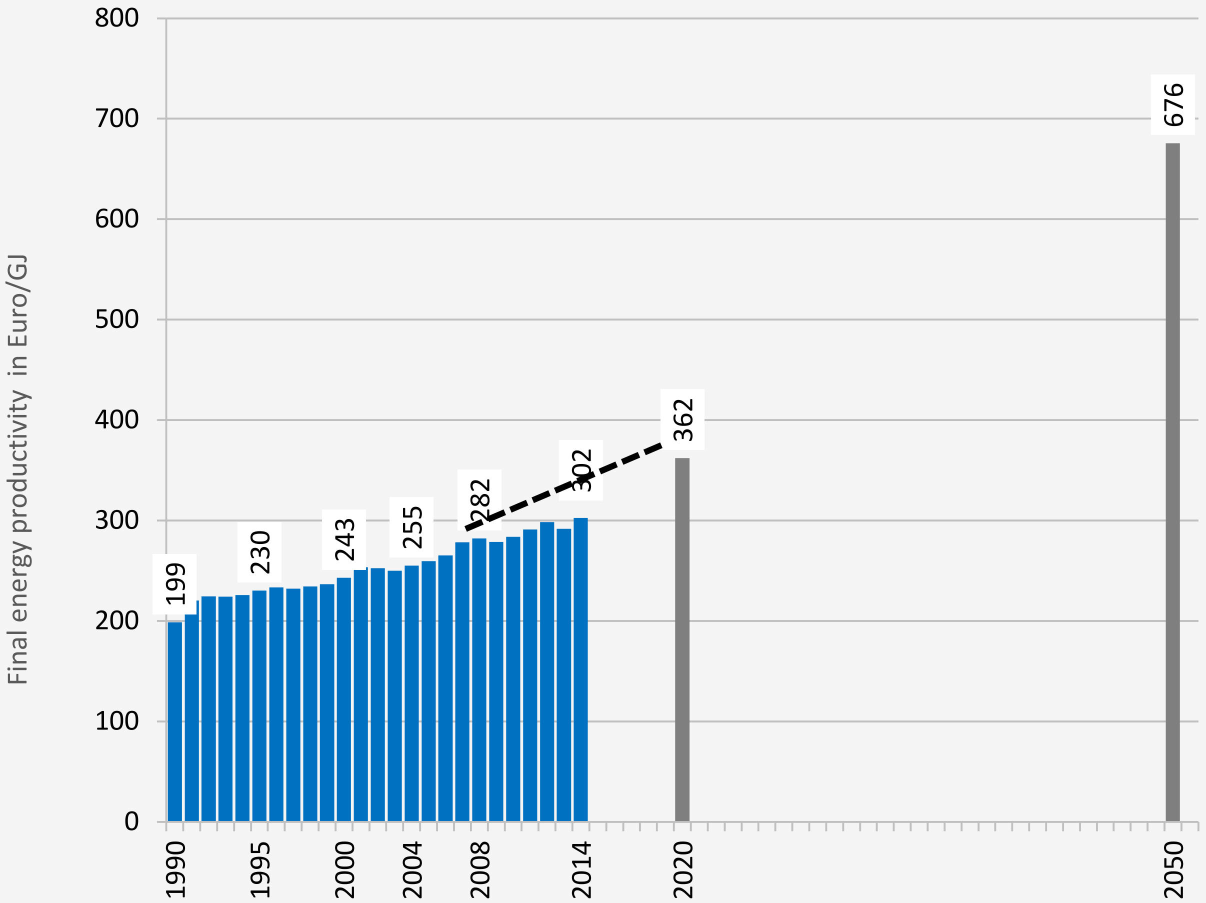


Quelle: Agora Energiewende Stand 5.2.2017

Options: storage and demand

In general one can think of two options

1. Supply side mechanisms in the form of storage technologies. This restores the endogeneity of production, but is expensive and challenging.
2. Demand side mechanisms that enable adjusting households' choices and reduce energy consumption. This could be less expensive and could 'pay' a double dividend by stabilizing the system and helping households making better choices.



Source: Löschel et al. (2015)

WWU MÜNSTER

Virtual Institute Smart Energy NRW (VISE)

VISE Virtuelles Institut Smart Energy

- Weiterentwicklung VISE
- Energienachfrageverhalten Haushalte
- Smarte Technologien für Unternehmen
- (Regionale) Virtuelle Kraftwerke

Westfälische Wilhelms-Universität Münster

VKU Verband Kommunaler Unternehmen e.V.

Technology Arts Sciences

EnergieAgentur.NRW klimaschutz made in nrw

Jülich Forschungszentrum

ewi Energy Research & Scenarios gGmbH

BVMW Bundesverband mittelständische Wirtschaft

Universität Duisburg Essen

PALUNO The Ruhr Institute for Software Technology

CPS.HUB /NRW Competence Center for Cyber Physical Systems

Bergische Universität Wuppertal

Wuppertal Institut

ERCIS European Research Center for Information Systems

Smart Meter Rollout as a large scale investment project

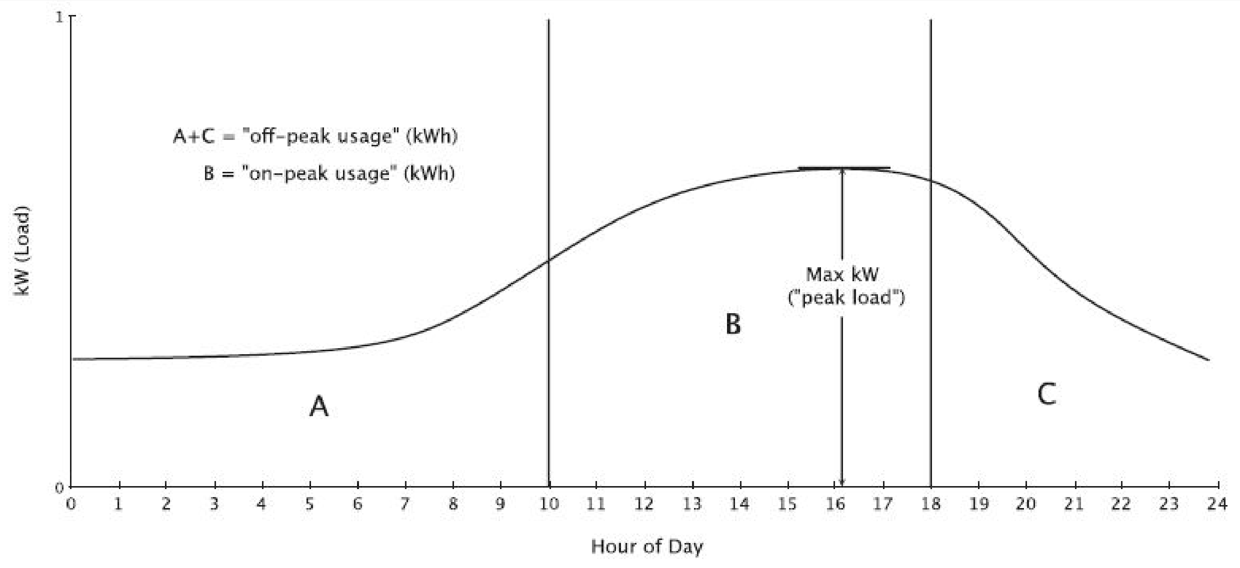
- Smart meter rollout: >6000 kWh from 2020, completed in 2032
- Initially high costs and low benefits (EU COM CBA for Germany):
  2022/32 investment 6.5/14.5 bn€, benefit 5.9/17 bn€, per meter cost 550€, benefit 490 €
- Main costs: meter procurement (24%), investment in ICT (10%), ICT operating costs (9%)
  Main benefits: energy savings (33%), load shifting (15%), avoided grid investment (13%)
- Digital technologies facilitate implementation of policy tools to flexibilize demand in terms of time varying prices, information & behavioral aspects for a dynamic adjustment of demand
- What is the empirical evidence on digitalisation and consumer demand?

How to assess effectiveness: Experimental Methods

- Goals of experiments: identify and quantify causal effects of verifiable factors (e.g. policy measures) on individual decisions
- Core is the counterfactual analysis: how would have the individuals behaved, if the policy measures had not been carried out
- Counterfactual analysis requires a randomized division of experiment participants in treatment and control group. The treatment group receives an intervention/ policy measure.
- Example: Impact of price flexibility, information or social norms
- Field experiments substantiate potential estimates with empirical evidence and create generalizable results with appropriate control group instead of case studies (but trade-off external vs. internal validity)

Demand Side Mechanisms: Dynamic Pricing

- The most straightforward way to make energy demand more flexible is to implement dynamic pricing and let households adjust to price hikes.
- Instead of adjusting supply, household's demand adjusts to production.
- In peak times prices increase and households would decrease energy demand and stabilize the energy infrastructure.



Source: Jessoe und Rapson (2015)

Demand Side Mechanisms: Dynamic Pricing

- Problem: price responses of households tend to be small.
- Moreover, richer households tend to have a higher responsiveness to (average) price changes (up to three times larger).
- Experimental study by Wolak (2011): comparison of electricity demand reductions under flat rate tariffs, hourly pricing (HP), and critical peak pricing (CPP) scheme

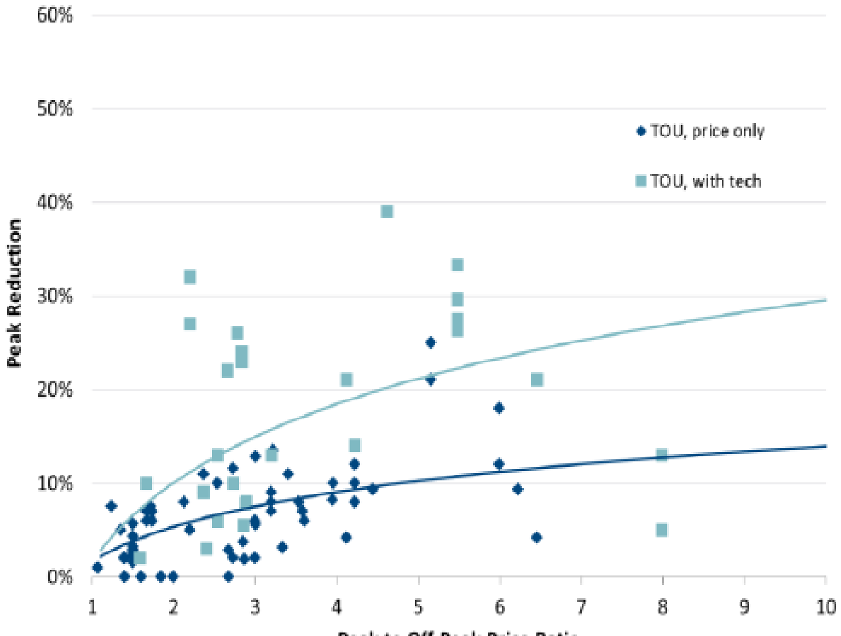
TABLE 1—ESTIMATION RESULTS FOR R CUSTOMERS

Parameter	Estimate	SE
Full sample results		
HP_PER	−0.030	0.011
CPP_PER	−0.090	0.007
Summer sample results		
HP_PER	−0.026	0.013
CPP_PER	−0.089	0.008
Winter sample results		
HP_PER	−0.008	0.018
CPP_PER	−0.055	0.014

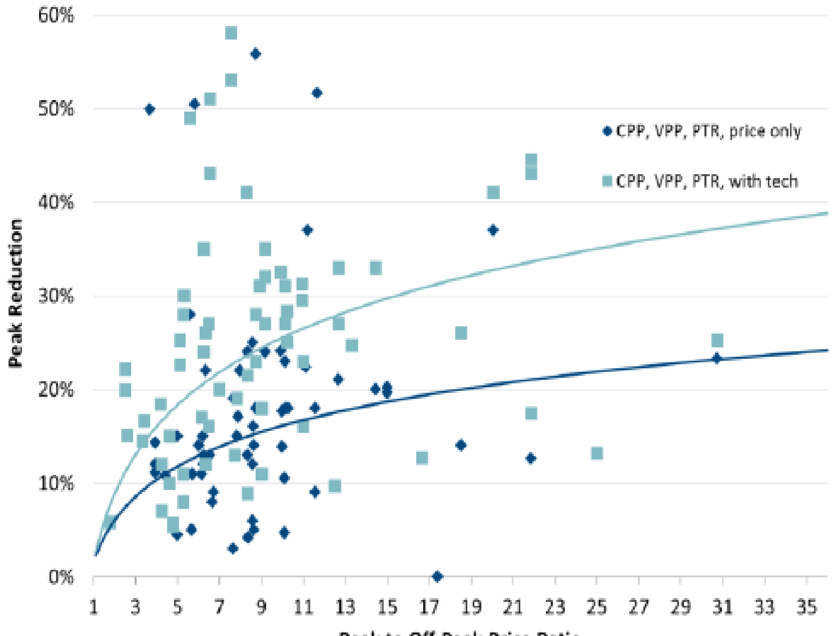
Source: Wolak (2011)

Demand Side Mechanisms: Dynamic Pricing

- HH might react very negativ on price hikes
- and might not accept control over some appliances



Source: Faruqui, Ahmad. "Arcturus." The Brattle Group.
Notes: Chart includes 67 data points from TOU pricing treatments without enabling technology and 30 data points with enabling technology.



Source: Faruqui, Ahmad. "Arcturus." The Brattle Group.
Notes: Chart includes 68 data points from dynamic pricing treatments without enabling technology and 70 data points with enabling technology.

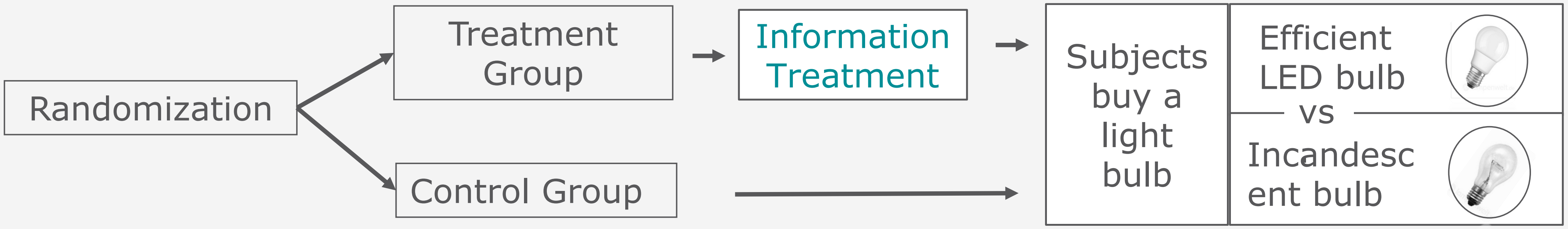
Quelle: Faruqui (2016)

Demand Side Mechanisms: ‘Soft’ Interventions

- But not only price changes affect the way households choose their demand for energy.
- There also exist a number of ‘behavioural’ effects that have an impact such as
  - Social norms
  - Providing information and helping to process these information
  - ‘Psychological’ effects: goals
- These soft interventions could be easier to implement, but it is not clear if and how these work.

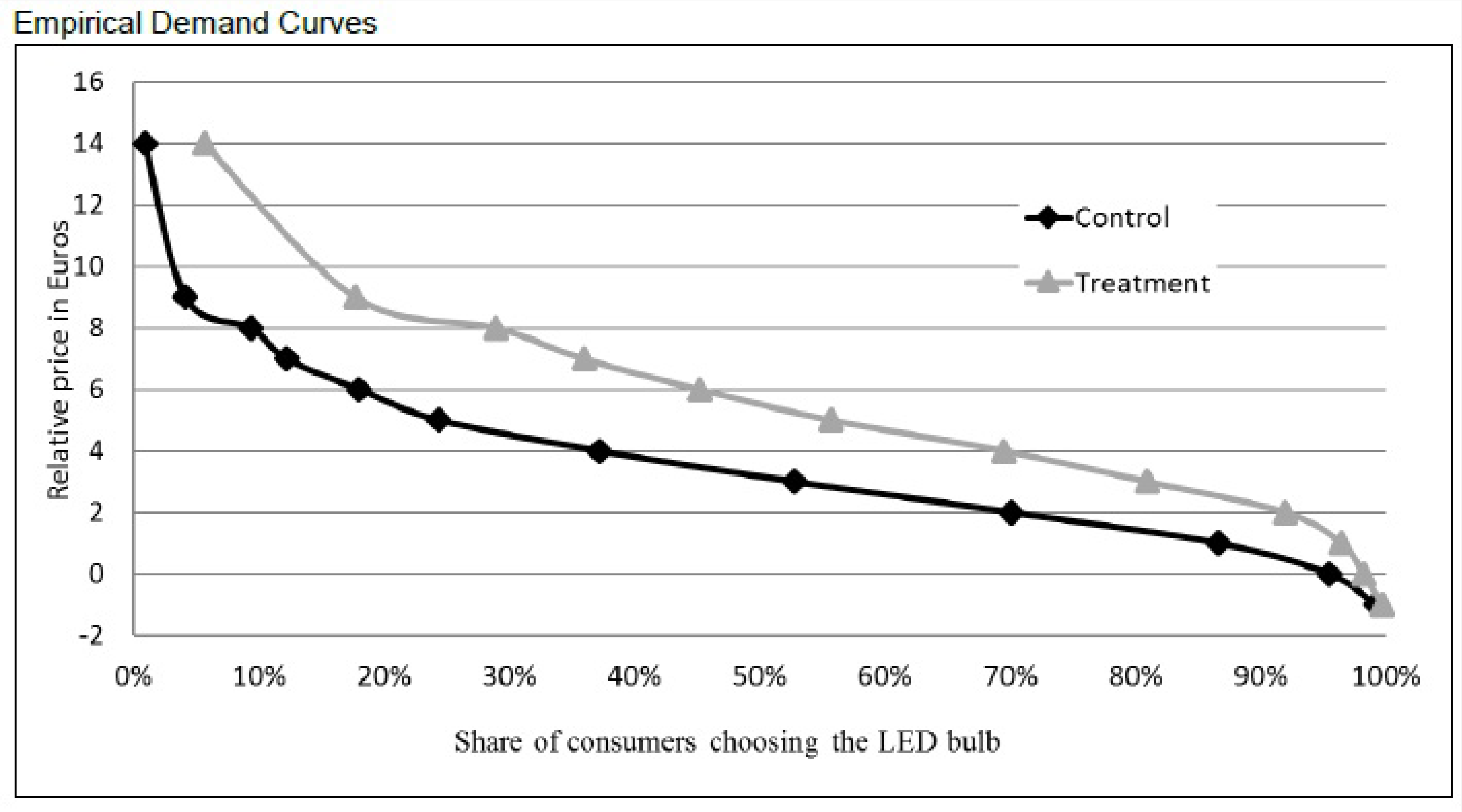
Consumer Inattention and Imperfect Information

- Experimental study by Rodemeier/Löschel/Kube (2017): Can we increase the adoption of energy-efficient light bulbs when we inform consumers about the financial savings of energy efficiency?



Source: Rodemeier, Löschel & Kube (2017)

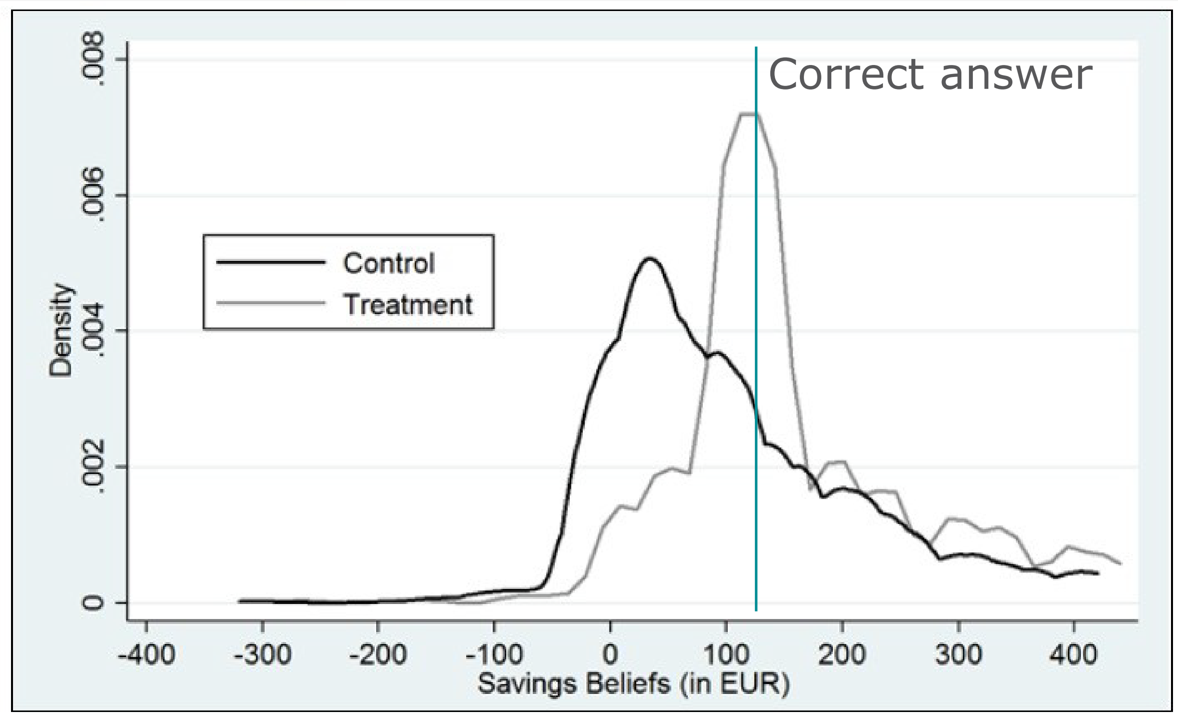
Results: Demand Curves



Source: Rodemeier, Löschel & Kube (2017)

Why do we observe these results?

- Question: How much does the energy-efficient LED bulb save over its lifetime compared to an incandescent?
- The treatment has significantly increased the level of energy literacy among subjects

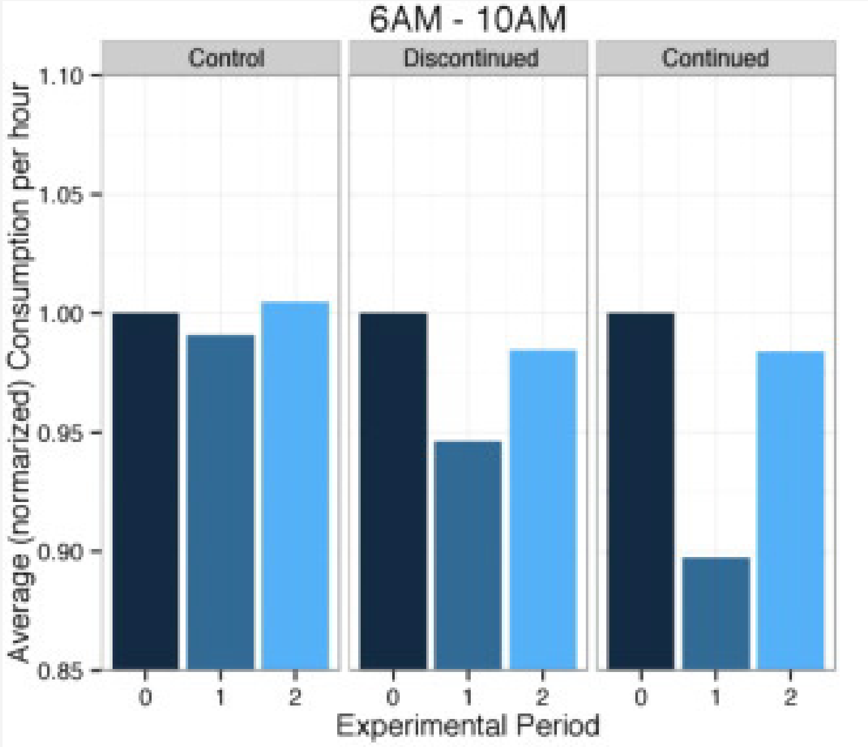


Source: Rodemeier, Löschel & Kube (2017)

Further Effects from Information Provision

- Note that information provision could in general backfire: depending on whether households initially over- or underestimate the costs of electricity consumption
- Experiments, however, show that more information (through in-Home displays) decreases electricity consumption (1% to 8%).
- These effect do not seem to be sustainable

Further Effects from Information Provision



Quelle: Lynham et al. (2016)

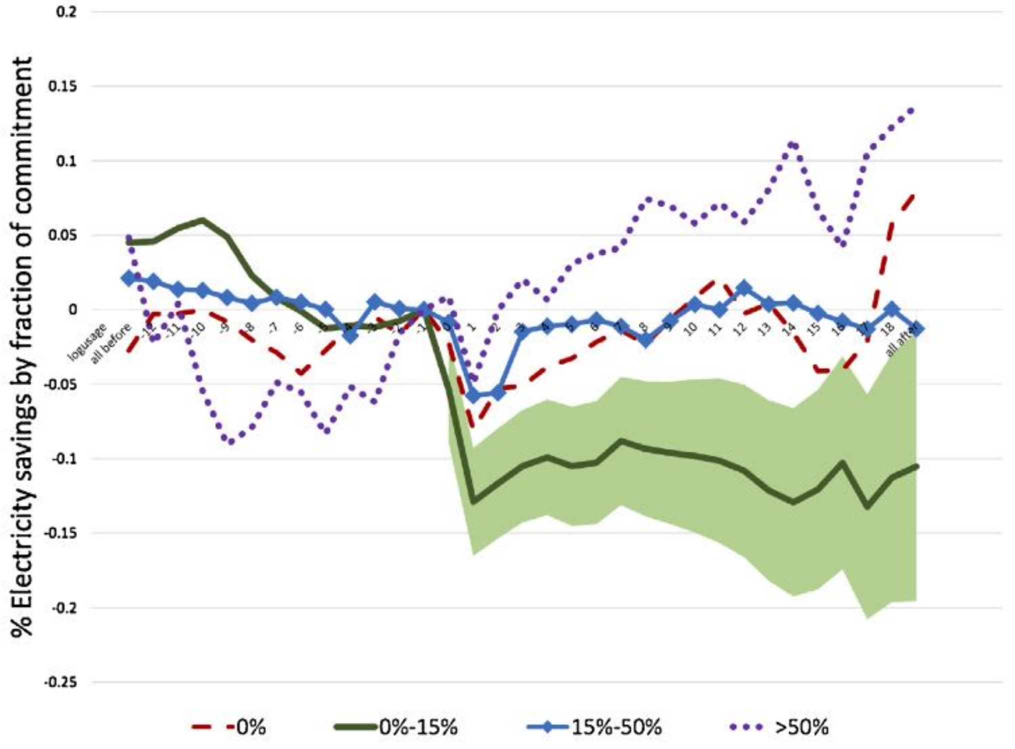
- Experiment by Lynham et al. (2016): one group has access to IHD for 1 month (discontinued), second group has access for 2 months (continued)
- Average reductions of 7,5-11% from period 0 to period 1
- Discontinued Group: (decreasing) learning effect (on consumption) → significant
- Continued Group: no evidence of salience effect (from display)

The Effect of Nudges: Goal Setting

- Empirical study by Harding and Hsiaw (2014): participating households are asked to set a goal on their electricity consumption
- Hypothesis: The endogenously chosen goals form a reference point to which actual electricity consumed is compared
  - Consumption higher than goal: Psychological Loss
  - Consumption lower than goal: Psychological Gain
- Hypothesis: The endogenously chosen goals form a reference point to which actual electricity consumed is compared
- Average yearly energy savings of 4,4% for all participants, 8% within first months

Results: Influence of Goal Level

- Decline in electricity consumption by 11 % for consumers with realistic goals (0% - 15%)
- No significant consumption restraints for participants with very low or very high goals



Shaded area corresponds to the 95% confidence bounds for the estimated mean savings of the 0%-15% goals group.

Source: Harding, Hsiaw (2014)

In which direction does research move?

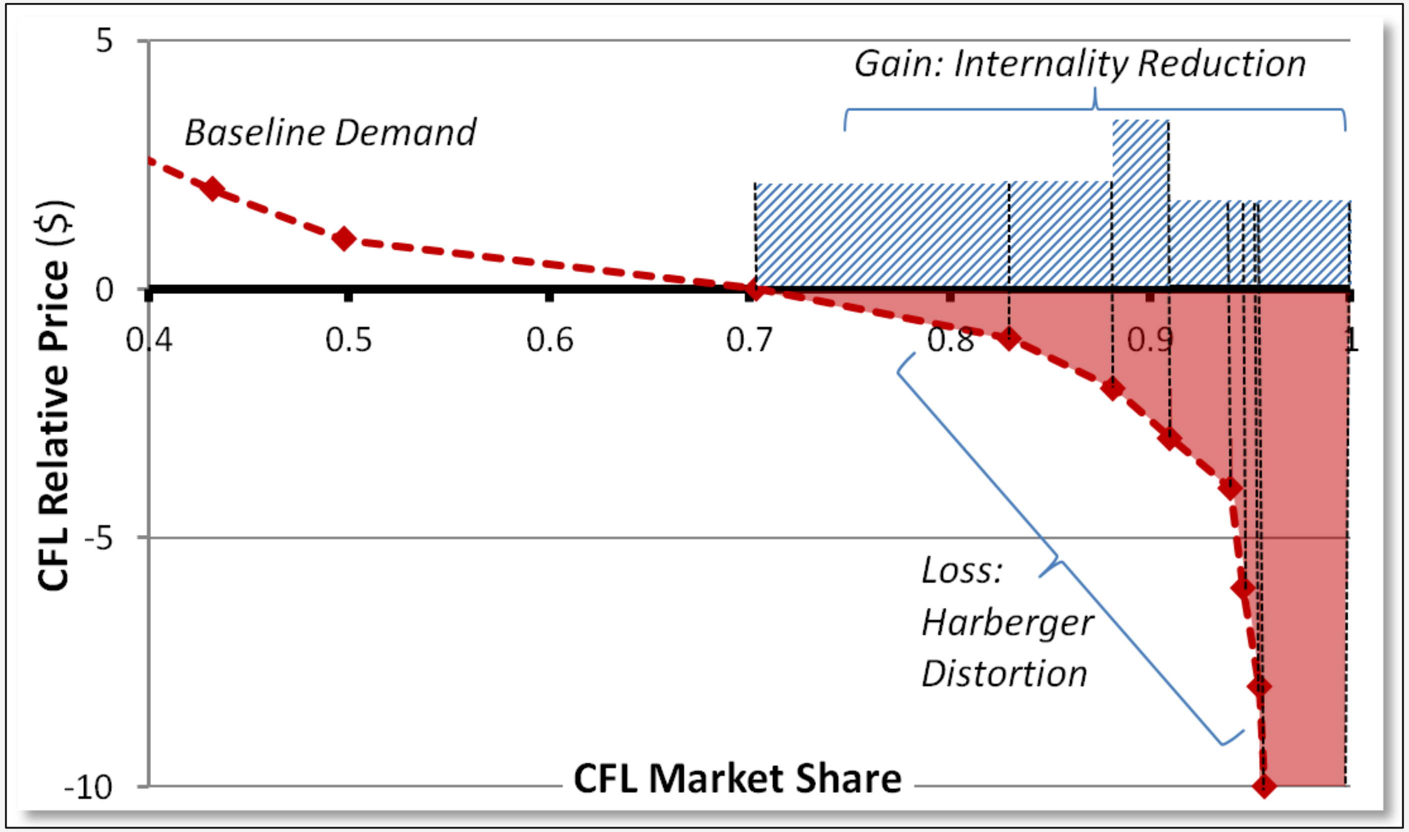
- Previous experimental research has mostly focused on two questions:
    - *Does* the intervention have an effect?
    - What is the *average* treatment effect?
- Additional questions of current and future research:
    - Does intervention (substantially) increase *welfare*? (→ not all interventions increase welfare)
    - Are treatment/welfare effects heterogeneous?

→ **Behavioral welfare economics**: theory-driven experiments which attempt to elicit consumers (possibly heterogeneous) preferences

- Consumers maximize "decision" utility instead of "experienced" utility: difference **Internality** (as analogy to externality) → welfare rationale for interventions through nudges, taxes or legal mandates.

Famous example

Welfare effect of different subsidy levels for a CFL light bulb



Source: Allcott & Taubinsky, 2015, AER

- For instance, Allcott & Taubinsky (2015) find that consumers undervalue compact fluorescent lamp (CFL) light bulbs
- Current relative market price of products offered in experiment lies at $p = 0$.
- Any subsidy under $3 increases welfare since internality reduction is larger than classical Harberger distortion.
- For subsidy levels above $3, the Harberger distortion exceeds the internality reduction
- optimal subsidy of $3 per CFL

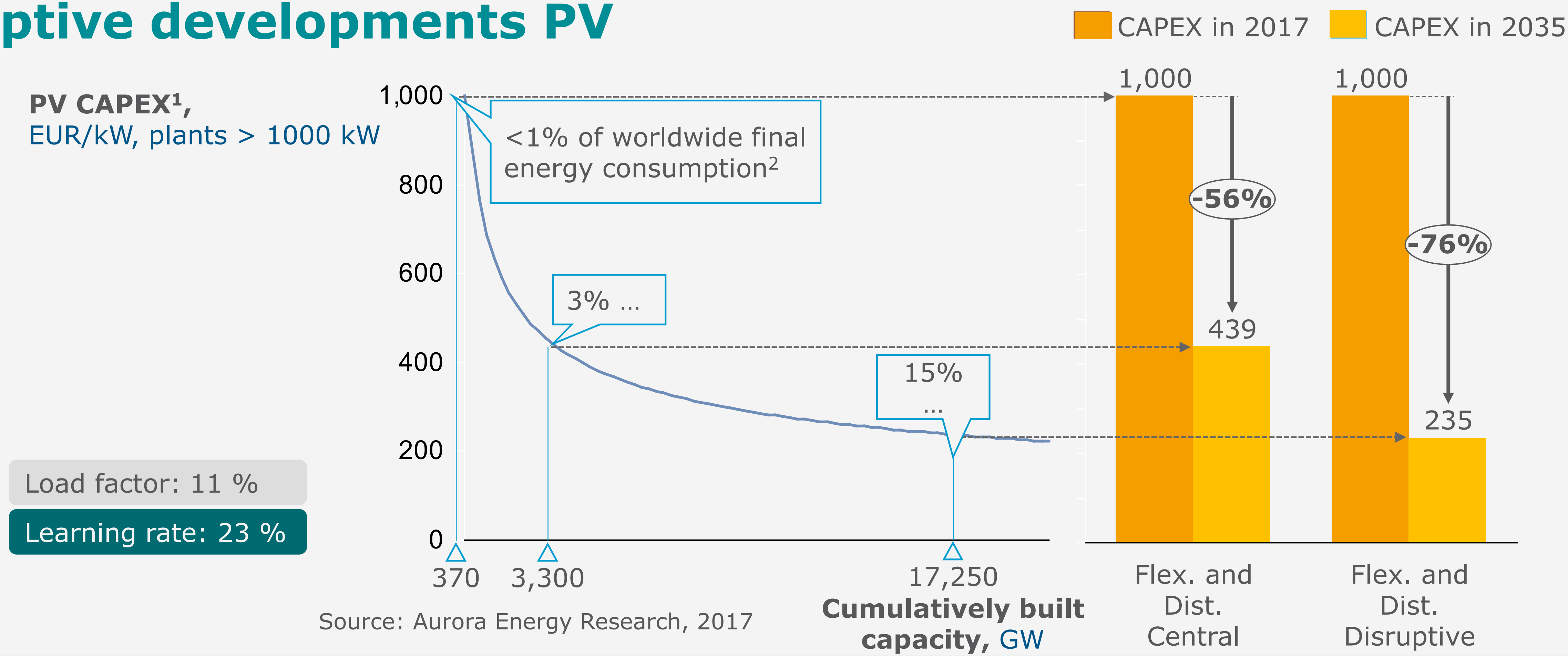
Summing Up

- Inflexible electricity demand with respect to price changes (and income)
- Flexible prices, information, nudges affect electricity demand; but rather mildly (HH and SMEs)
- More conceptual research on how household's choose electricity demand
- More (experimental) evidence on the strength of these effects and welfare impacts
- Especially a more internationally diverse approach is needed:
  many studies rely on US data; BUT demand structure is different compared to other parts of the world (think of heating and cooling with electricity which is not too common in (northern Europe)
- Consumer preferences are crucial: willingness to pay for climate protection, willingness to pay for self-generated electricity - electricity (battery) and heat (PtH)

What do we need to know?

- We also need more evidence on the effects of digitalization (Smart Homes) on making electricity demand more flexible.
- Prosumers play an increasingly important role, crucial are technology developments, regulatory framework and the intention of self-provision
- Dynamic development in the digitalization of the energy transition (Smart Meter etc.) open new possibilities – the **tyranny of the status quo should not be trusted** too much

Disruptive developments PV



Source: Aurora Energy Research, 2017

1) incl. BoS & installation, 4 hour duration 2) For simplicity reasons, one learning rate has been applied to the entire battery since cell costs constitute 83% of 2017 CAPEX.

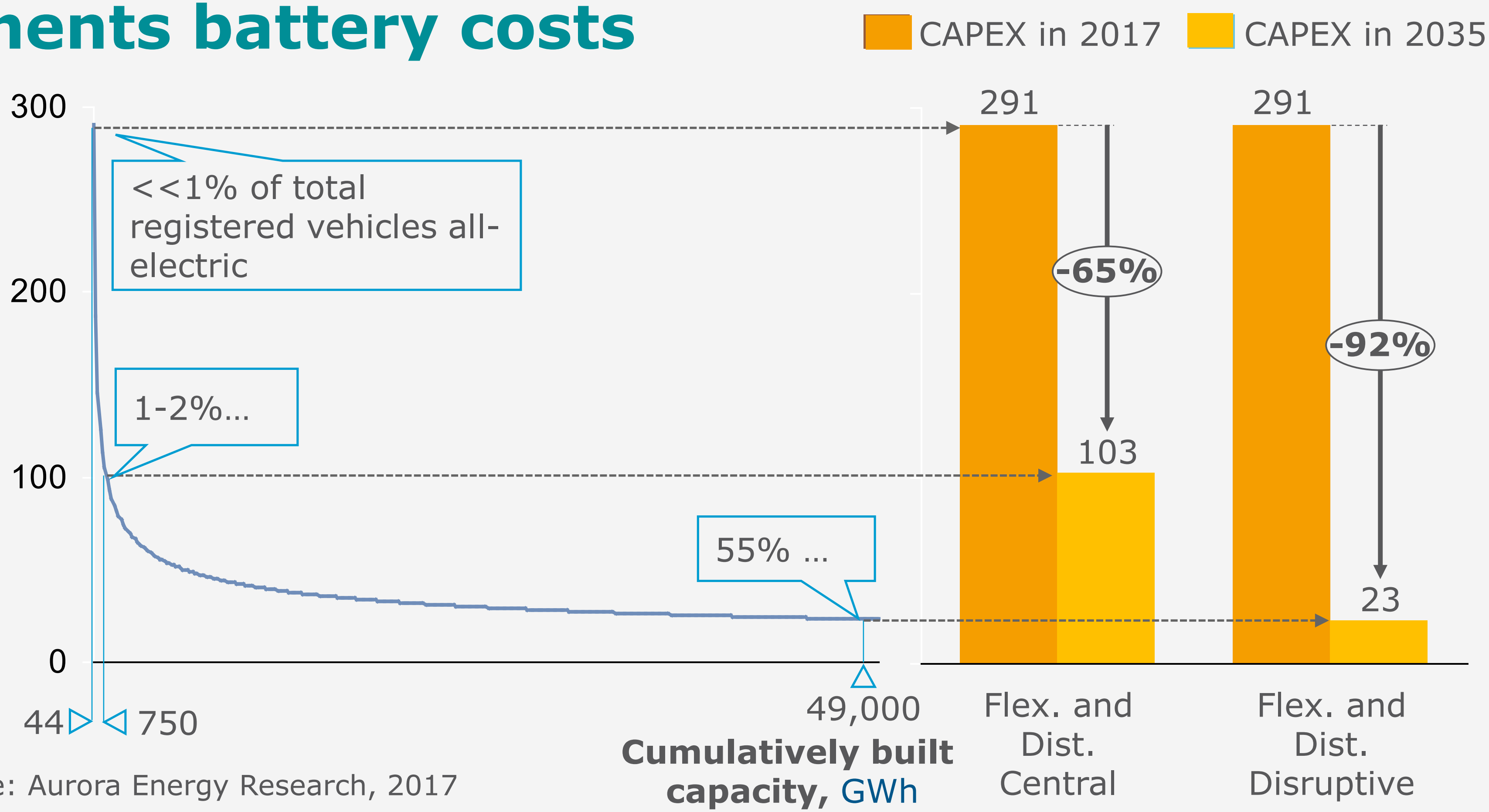
Disruptive developments battery costs

Li-ion battery CAPEX[1], EUR/kWh

worldwide diffusion of electric vehicles would trigger a disruptive decline in battery cost

Vehicle's battery: 20-50 kWh

Learning rate[2]: 22 %

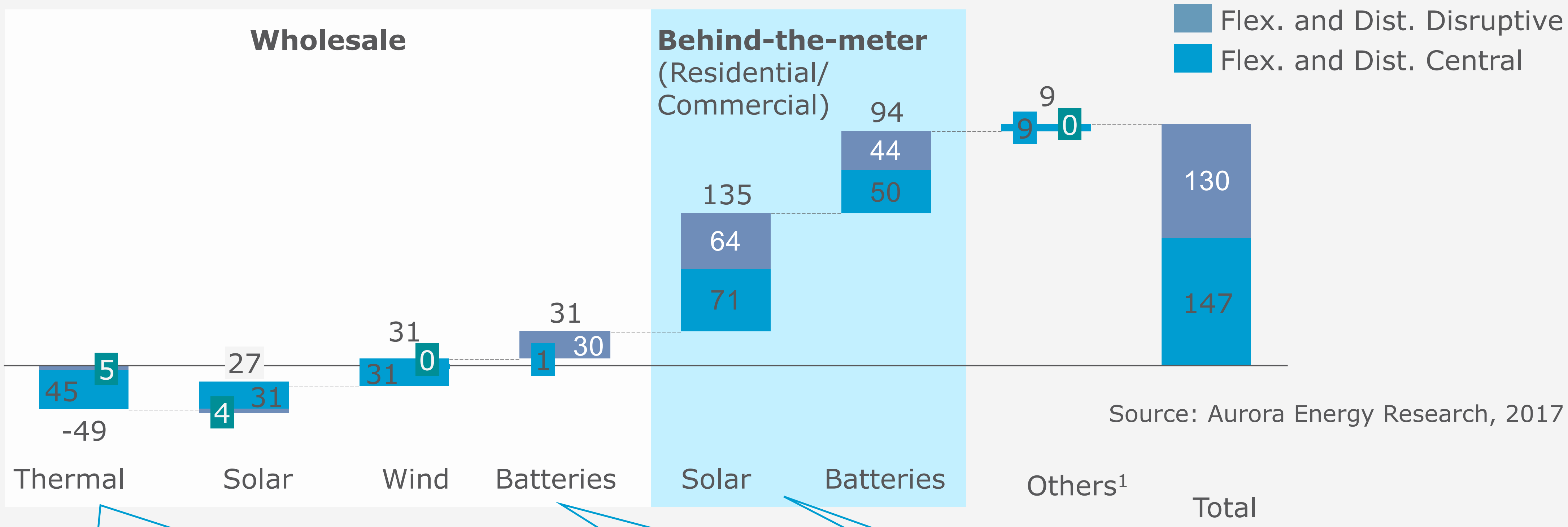


Source: Aurora Energy Research, 2017

1) incl. BoS & installation 2) Final energy consumption in 2014

Buildout installed capacity Germany

Buildout between 2017 and 2035,
GW



Source: Aurora Energy Research, 2017

In the Disruption scenario, only 5 GW more thermal capacities exit – thermal capacities continue to be needed when the sun doesn't shine

Grid-scale batteries become investible in the wholesale market at CAPEX below 100 EUR/kWh

Behind-the-meter solar and batteries displace grid-scale solar due to self-consumption privileges

1) Includes small-scale CHP, applications in the industry sector (Batteries, DSR) and for ancillary services

Prof. Dr. Andreas Löschel

Chair of Microeconomics, esp. Energy and Resource Economics

University of Münster

Web: www.loeschel.eu

Twitter: andreasloeschel