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German Network Planning, Operation, and Costs Allocation

US-System Operator Tour to Germany

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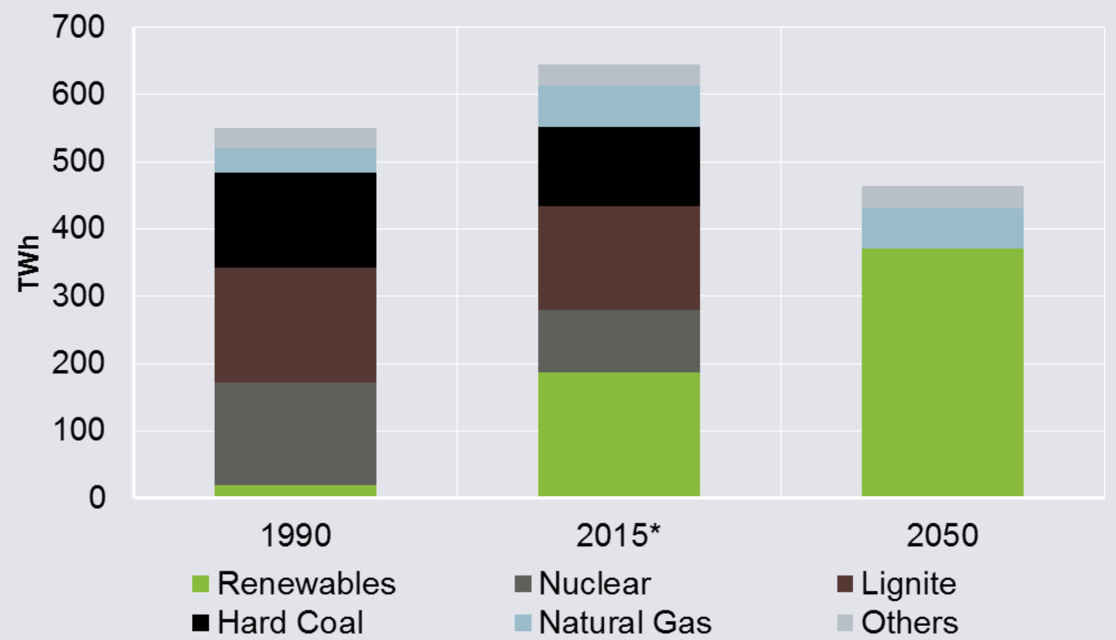
Agenda

Electricity market design for the energy transition

- Key challenges for the Energy Transition
- German power market design
- Network costs and cost allocation/tariff design
- Effect of PV self-consumption to system costs
- How could “Energiewende markets” look like?

Energiewende in the power sector

Gross electricity generation 1990, 2016 and 2050



AGEB (2016), BReg (2010), EEG (2014), own calculations
* preliminary

Phase out of nuclear power
Gradual shut down of all nuclear power plants until 2022

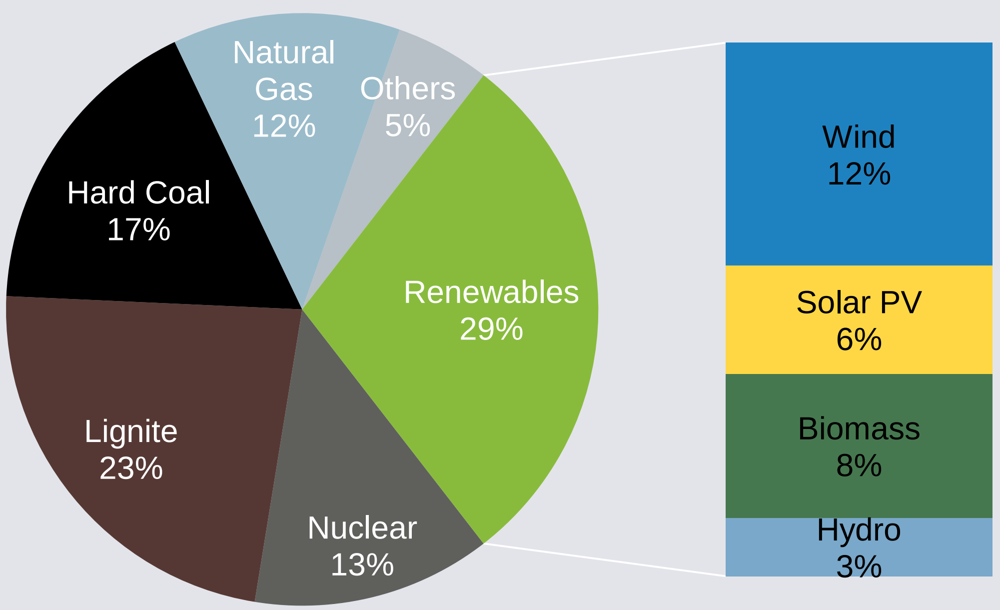
Reduction of greenhouse gas emissions
Reduction targets below 1990 levels: - 40% by 2020; - 55% by 2030; - 70% by 2040;
- 80% to - 95% by 2050

Development of renewable energies
Share in power consumption to increase to: 40 - 45% in 2025; 55 - 60% in 2035; ≥ 80% in 2050

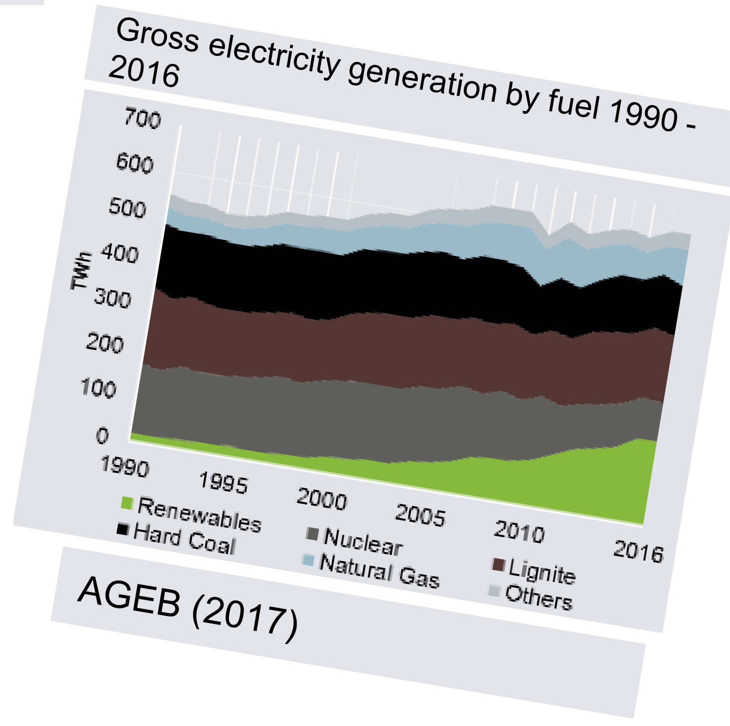
Increase in efficiency
Reduction of power consumption compared to 2008 levels: - 10% in 2020;
- 25% in 2050

Renewables are the most important source in electricity generation, followed by lignite and hard coal

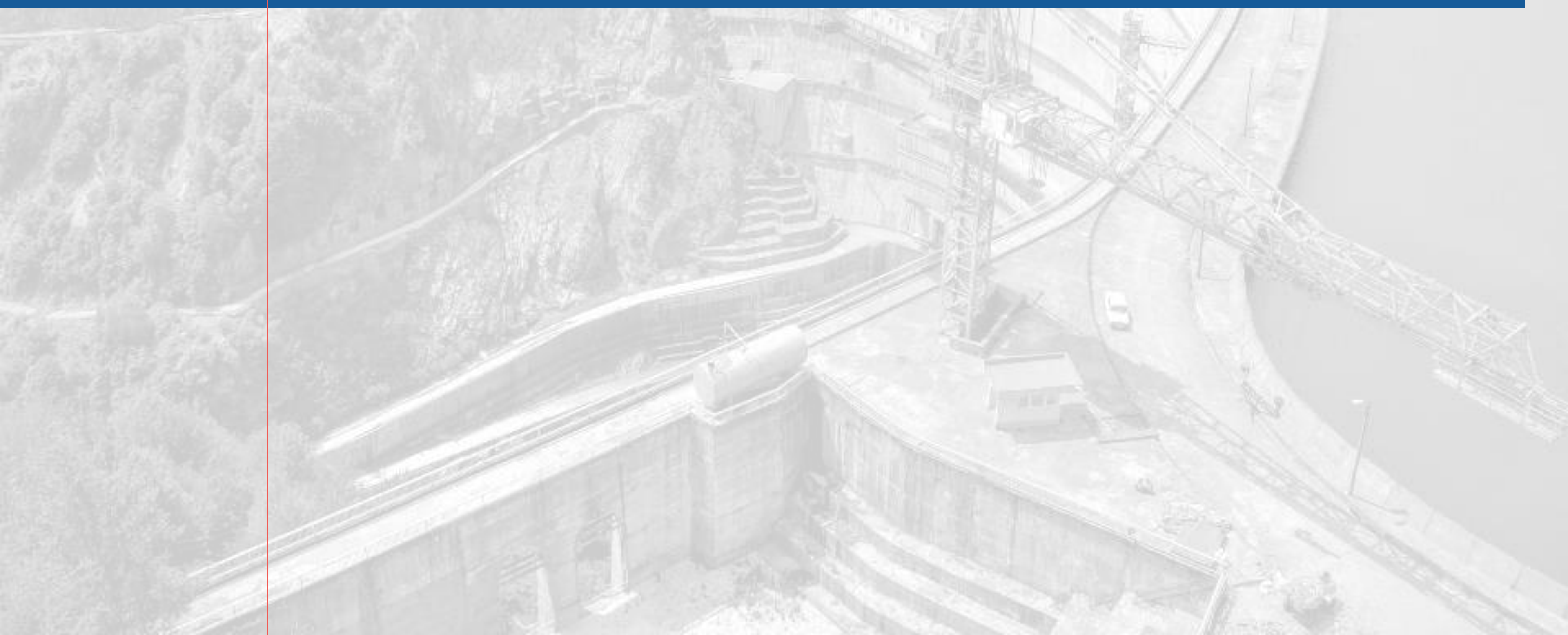
Share in gross electricity generation by fuel 2016



AGEB (2017)

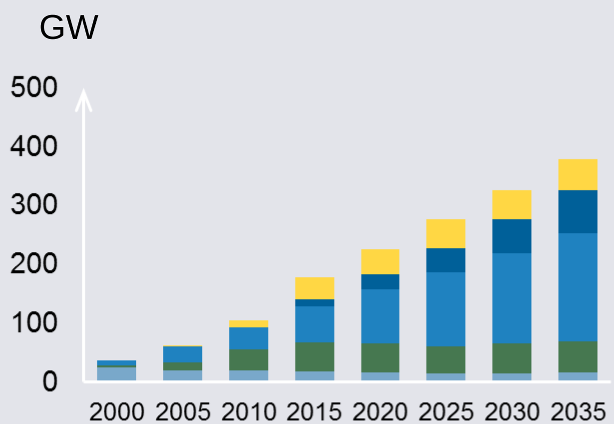


Key Challenges for the Energy Transition



Challenge 1: Wind energy and solar photovoltaic differ in their characteristics from conventional thermal generation – *flexibility becomes key!*

Gross electricity generation of renewable energies 2000 - 2035

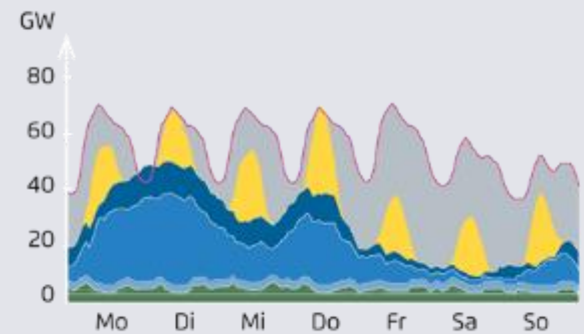


AGEB (2015a), BNetzA (2014), BNetzA (2015b), own calculations

Specific characteristics of Wind and Solar PV

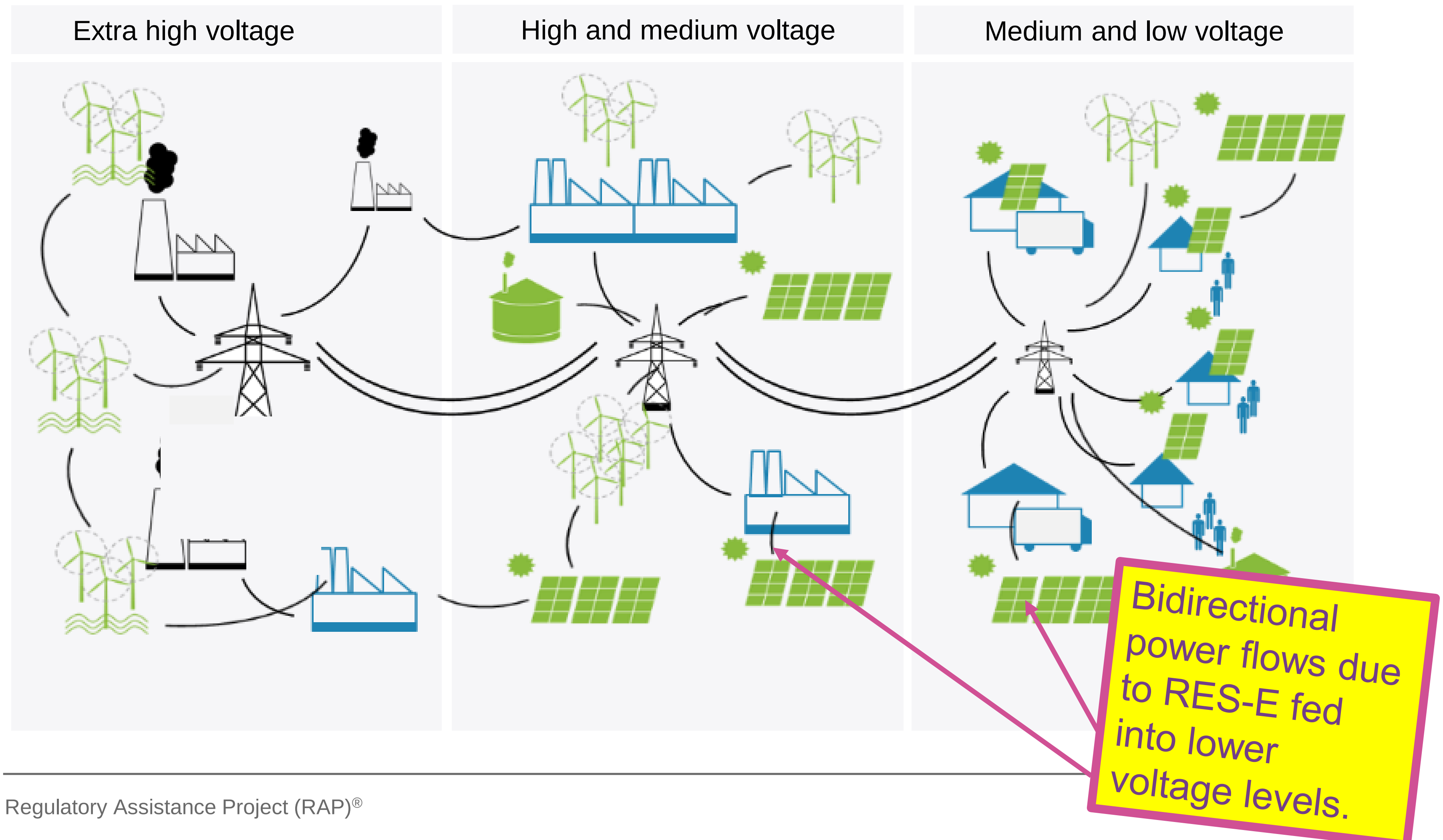
1. Intermittent
2. High capital costs
3. Very low variable cost

Electricity generation and consumption in a sample week 2023



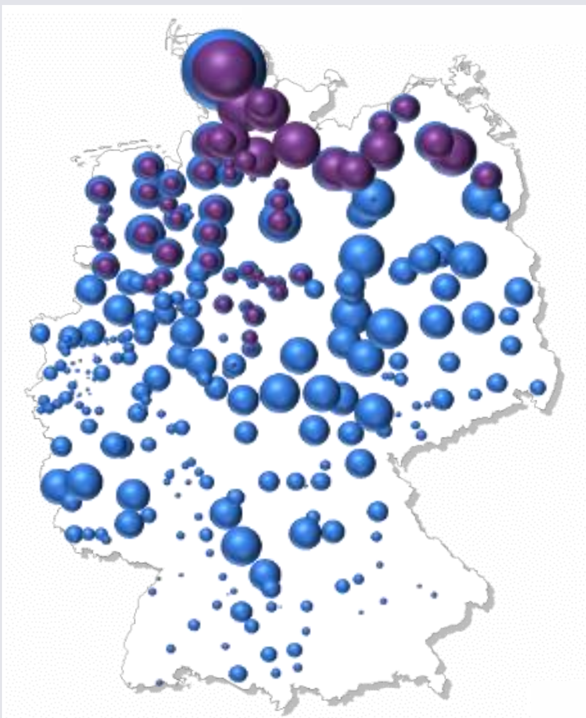
Fraunhofer IWES (2013)

Challenge 2: Electricity is increasingly fed directly into the distribution grid – *transition from a centralized “top-down“ to a more distributed system.*



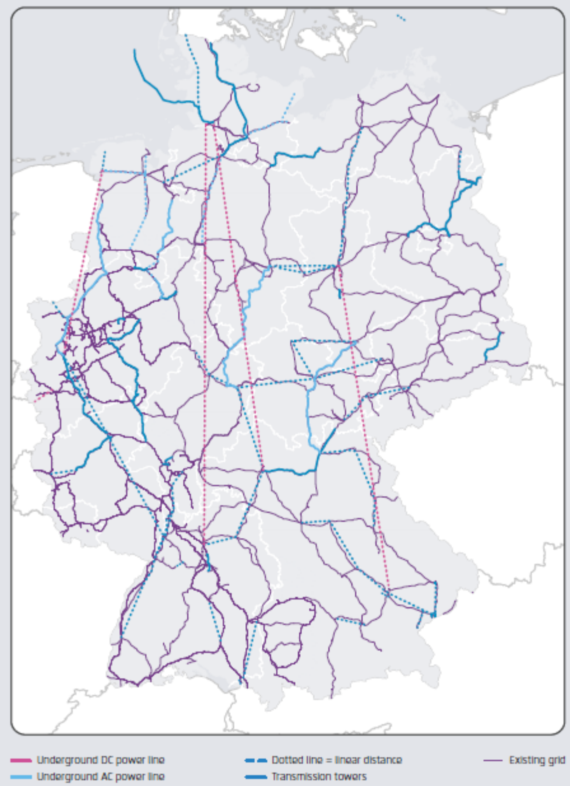
Challenge 3: Grid expansion *– in order to allow for balancing of power supply and demand across regions.*

Siting of new generation



Fraunhofer IWES (2013)

Grid expansion



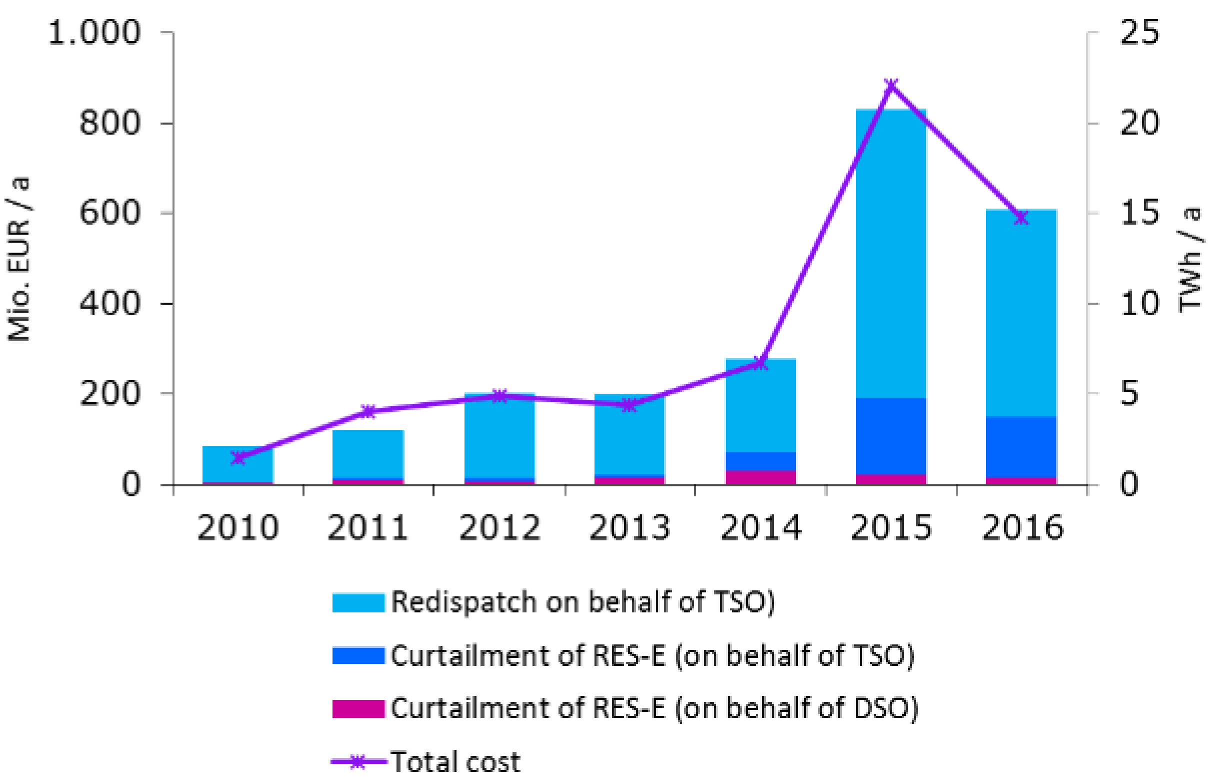
Agora Energiewende based on BNetzA (2016)

Localization of new generation:
- Onshore wind energy particularly in the North of Germany
- Offshore wind energy in the North and Baltic Sea
- Solar PV particularly in the South of Germany

New types of demand:
- Heat pumps, electric vehicles, power-to-heat.

Delays in grid expansion at the transmission level: 850 kilometers are realized by now (7,700 km are needed).

Challenge 4: Grid congestion – *the volume of redispatch and curtailment has been increasing over the years.*



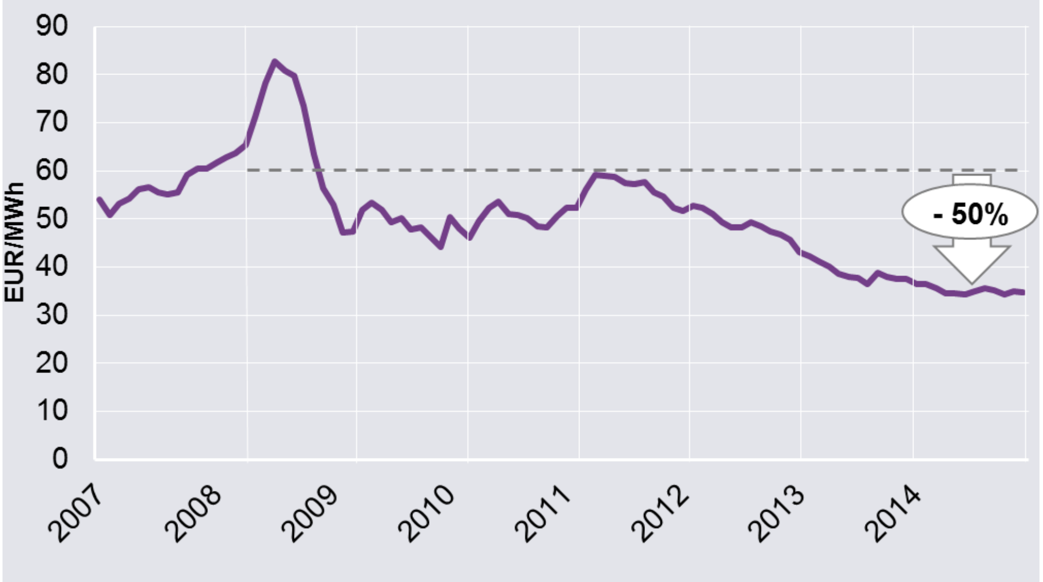
Ecofys (2017) based on data by Bundesnetzagentur and MELUR (Smart-Market-Study on behalf of Agora Energiewende)

Redispatch and curtailment:

- 3%-peak-shaving-approach in grid planning.
- Curtailment is a measure of last resort (RES-E generation and CHP).
- In the first two months of 2017 there has been an increase in redispatch measures taken by the TSOs (as compared to 2016).
- Most of RES-E generation is curtailed in the North of Germany (more than two thirds in the Federal State of Schleswig-Holstein).
- Costs for redispatch and curtailment are socialized amoung electricity consumers via network charges.

Challenge 6: Power market design – *can wholesale power prices provide sufficient incentives for new generation capacity?*

Wholesale electricity prices* 2007 - 2014



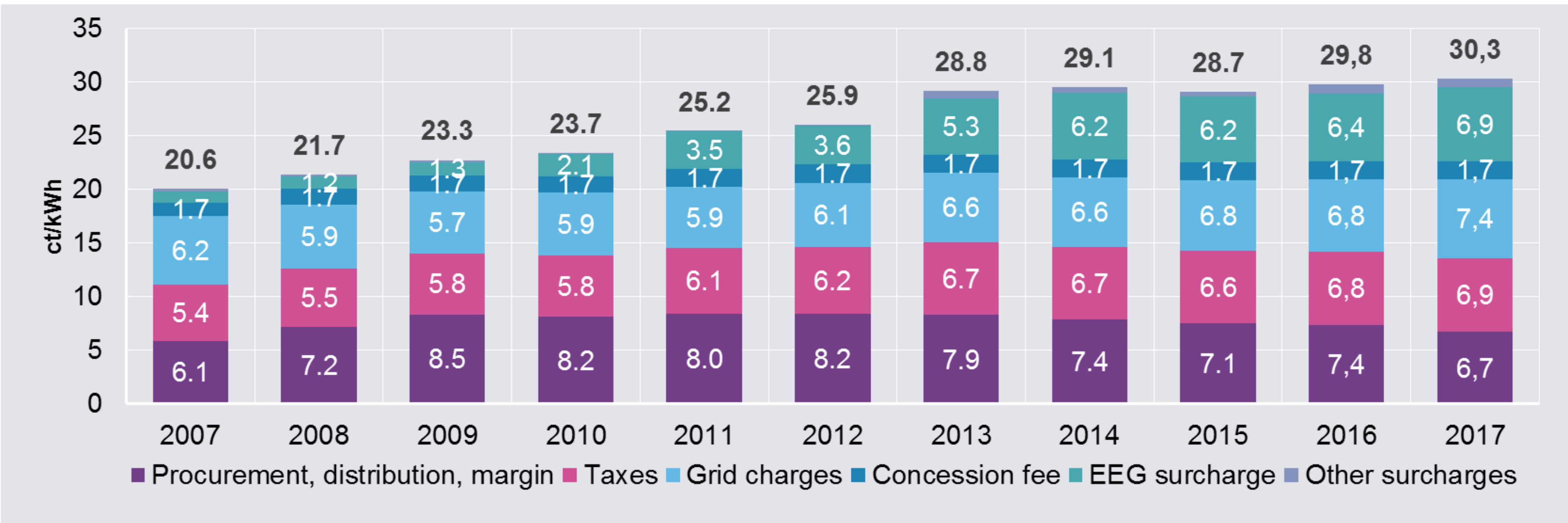
EEX (2015) * rolling annual futures

Reasons for the decline in power prices

- **There is currently excess capacity**
- **CO_2 price dropped:** CO_2 prices in the EU Emissions Trading system dropped since 2008 by around 70% due to high amount of excess certificates
- **Falling resource prices:** Coal prices decreased by a third since 2008
- **Excess capacities:** Large quantities of lignite and coal power plants, low incentives for flexible gas power plants

Challenge 7: Household power prices *– grid fees, EEG-surcharge and levies have been subject of frequent debate.*

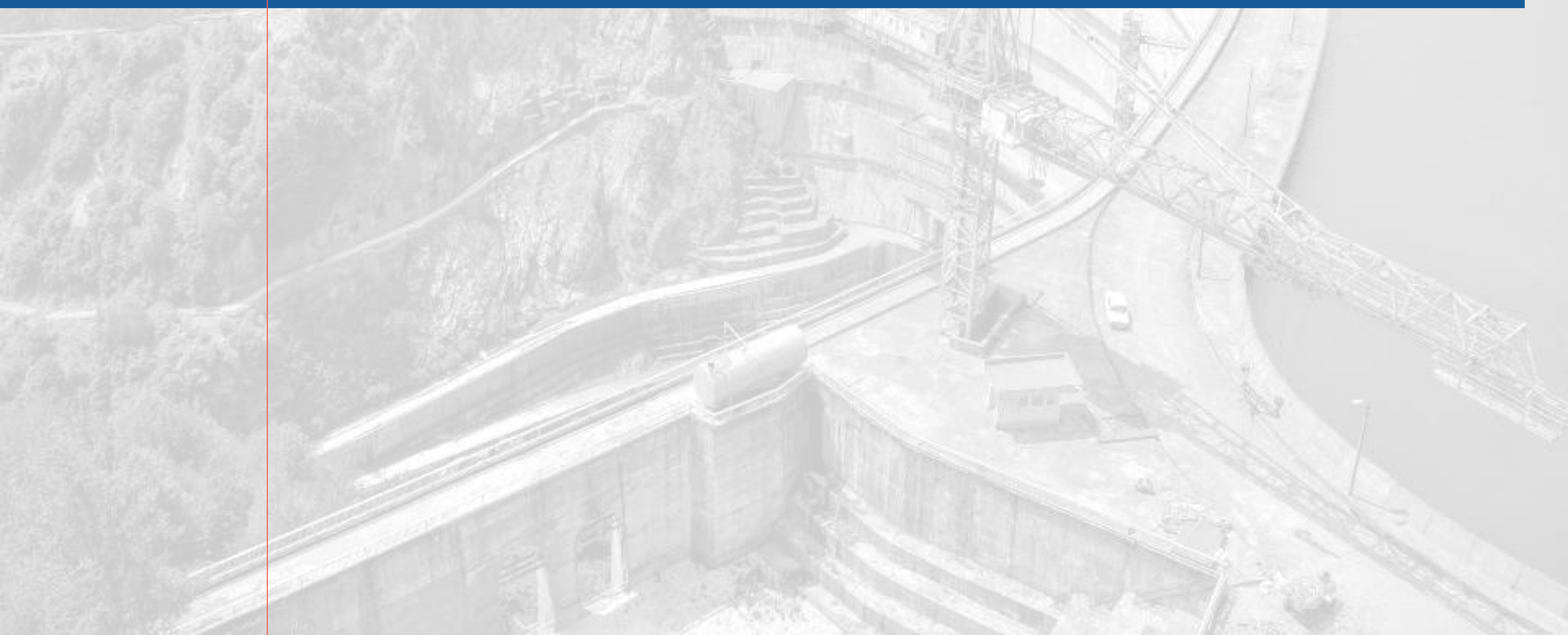
Average household electricity prices in a 3-person household 2007 - 2017



BNetzA (2016), own calculations

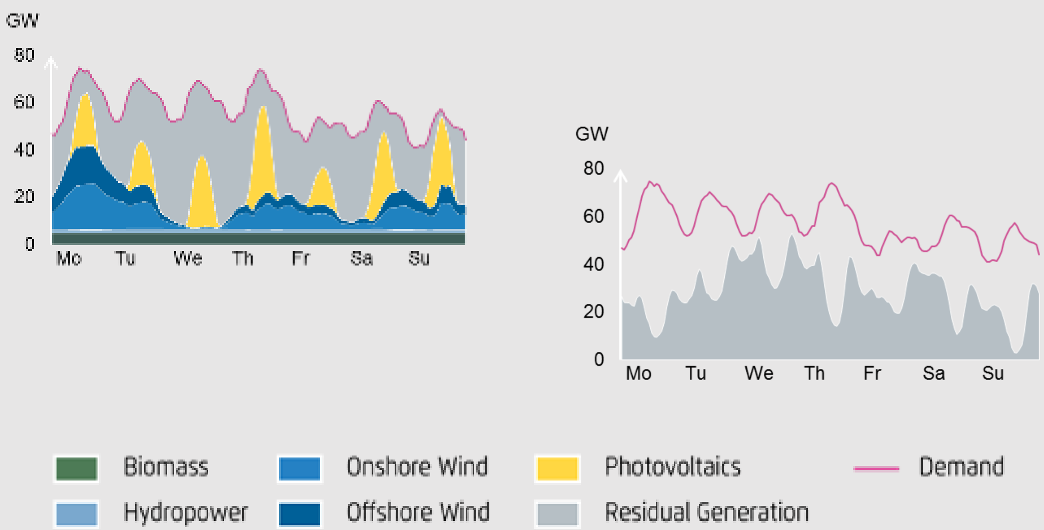
German power market design

- EOM 2.0 “energy-only” market
- German/European set up



Electricity Market 2.0

Electricity generation and consumption in a sample week with 50% RES share



Own calculations on basis of Agora Energiewende (2015b)

Key features of Electricity Market Act

Transition towards system with increasing responsibility for RES-E

Strengthen market mechanisms - “Electricity Market 2.0” - strong electricity price signals without a capacity market

Safeguard **security of supply** - Capacity reserve and cooperation with European neighbors

Enhance **competition** between all electricity producers and **flexibility options**

German electricity market design

Power market design (illustrative)			Grid
Coordinate supply and demand	**Electricity Market 2.0** (complemented by flexible markets for balancing energy)		
Ensure security of supply and deployment of renewables	**Generation Adequacy** Capacity reserve Security standby	**Renewables** Auctions for wind energy, ground-mounted solar PV & biomass; feed-in tariffs for small-scale RES-E	**Grid** Grid reserve
Reaching climate targets	**EU Emissions Trading**		

Own illustration

Security of supply and generation adequacy

Grid Reserve
- Security of supply and grid reliability (accounting for congestions in the grid, voltage stability, redispatch)

Capacity reserve
- Security of supply (2 GW p.a., auction-based mechanism)
- Activated after market closure (only if no clearing prices on day-ahead)

Security standby
- Transition period as of 2016: 2.7 GW lignite plants for four years as security standby. Thereafter, retirement of plants. It contributes to reduction in emissions as well.

In order to rely on free price formation on markets, capacity reserve comes first into play – if necessary – after gate closure of power markets.

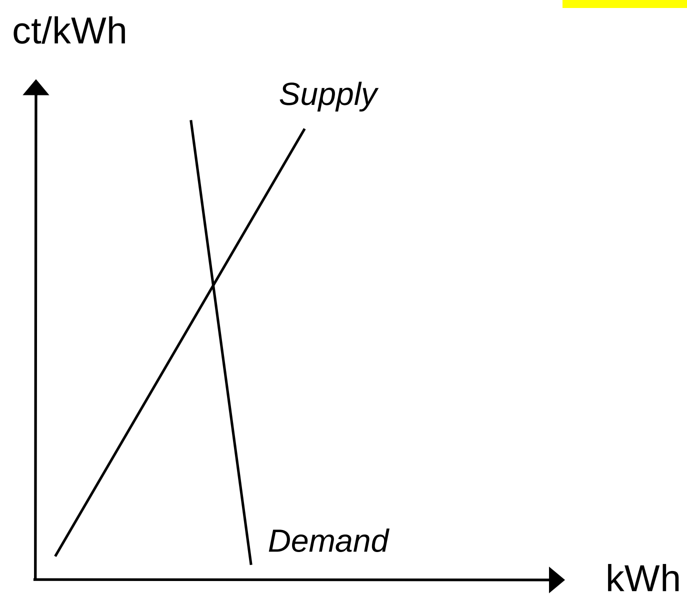
"Mediating" between the power market and the grid

– in order to allow for balancing of power supply and demand across regions.

The power market ("financial") and actual operation of the grid ("physical")

Power market: "copper plate"

≠



Grid operation

- Bottlenecks in distribution and transmission grid: no more "copper plate" in real time. Local congestions may occur.
- Avoid exceeding limit values (current, frequency, voltage).
- Provision of ancillary services in order to ensure grid stability and reliability.

Own illustration

Grid planning

→ If there are delays in grid expansion, more grid bottlenecks occur.

→ 3%-approach: peak shaving included in grid planning.

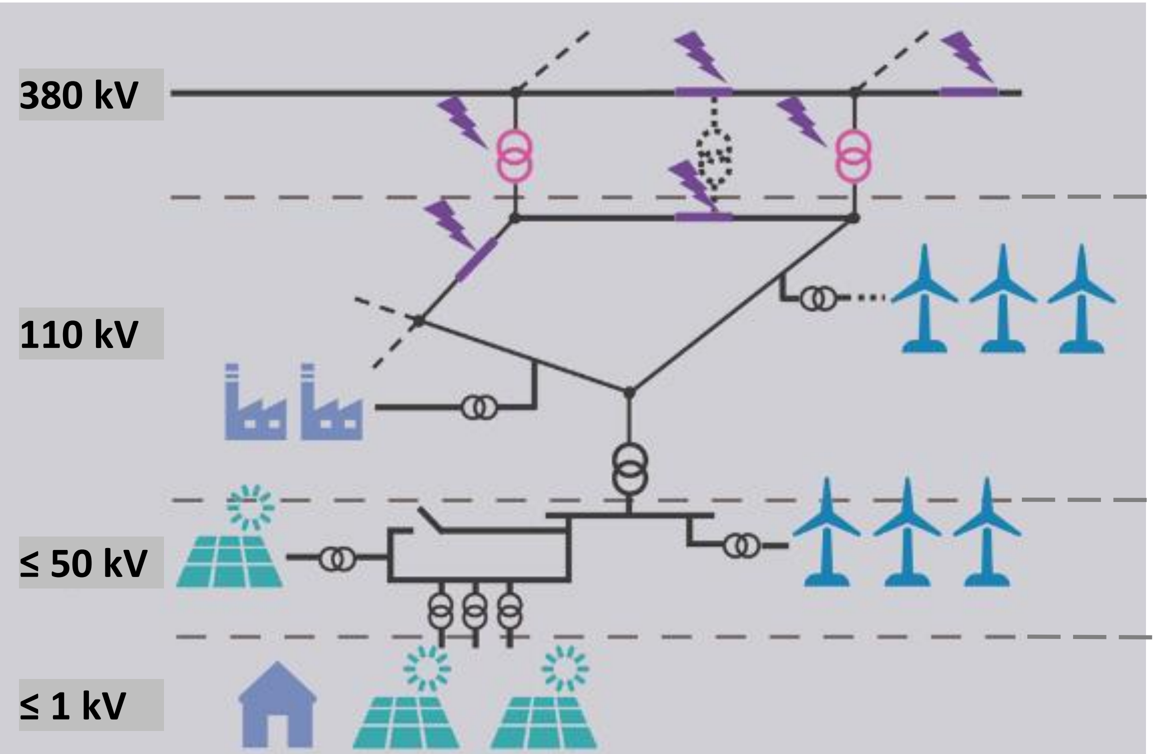
Grid operation

→ In case of congestion grid operators may have to curtail generation to ensure system stability.

- First: redispatch of conventional power plants.
- Curtailment of RES-E as measure of last resort.

Grid congestion – *illustration of interplay of different voltage levels.*

Grid congestion in Northern Germany (illustrative example)



Ecofys und Fraunhofer IWES (2017): *Smart-Market-Study*

Curtailment…

Voltage level	… where bottleneck occurs	…where measures are taken
380 kV	95%	<1%
110 kV	5%	99%
≤ 50 kV		
≤ 1 kV		

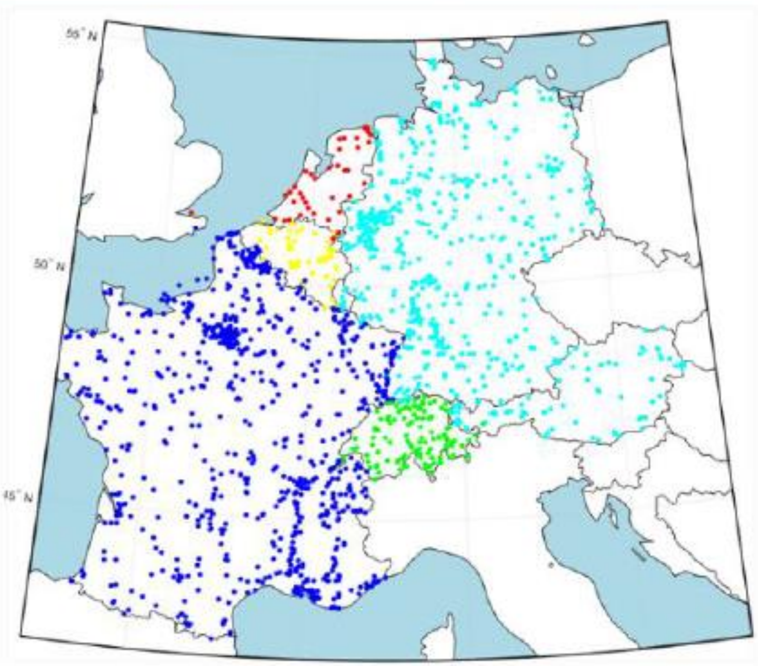
Did we miss anything?

Are there differences between European and US power markets?

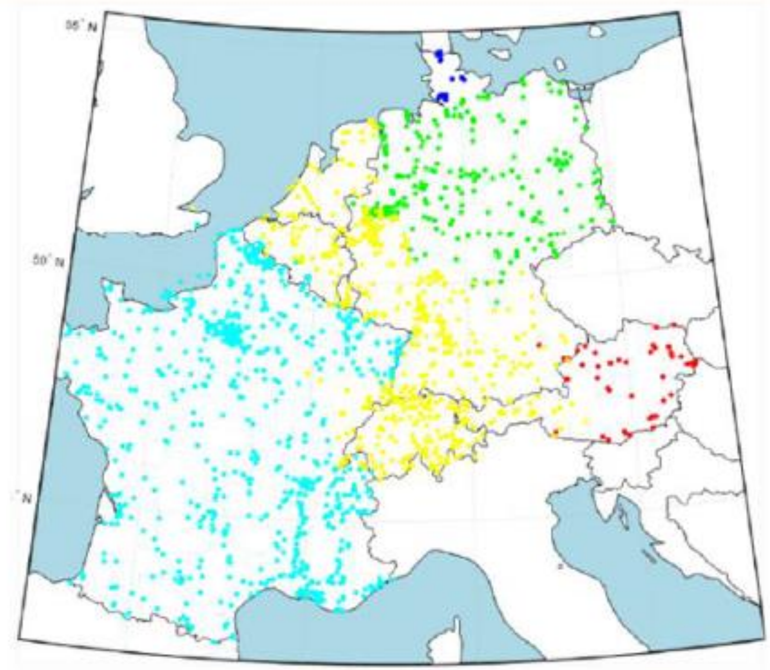
There are differences...

Power market configuration along national borders – without LMP

Current Configuration



Optimized 5-zone Configuration



Source: CEREG (Belgium Regulator 2016)

Transmission: Bundled ownership and operation

25% owned by RWE-utility

100% owned by EnBW-utility

Distribution: Nominally unbundled network ownership from retail (legally, by organization, or just by information)

Competitive retail markets

- bilateral contracts
- retailers are responsible
  - to provide demand side flexibility to the market
  - to offer specific products to customers

Decentralized dispatch

Balancing responsible parties are in charge
TSO balancing by reserves after gate close

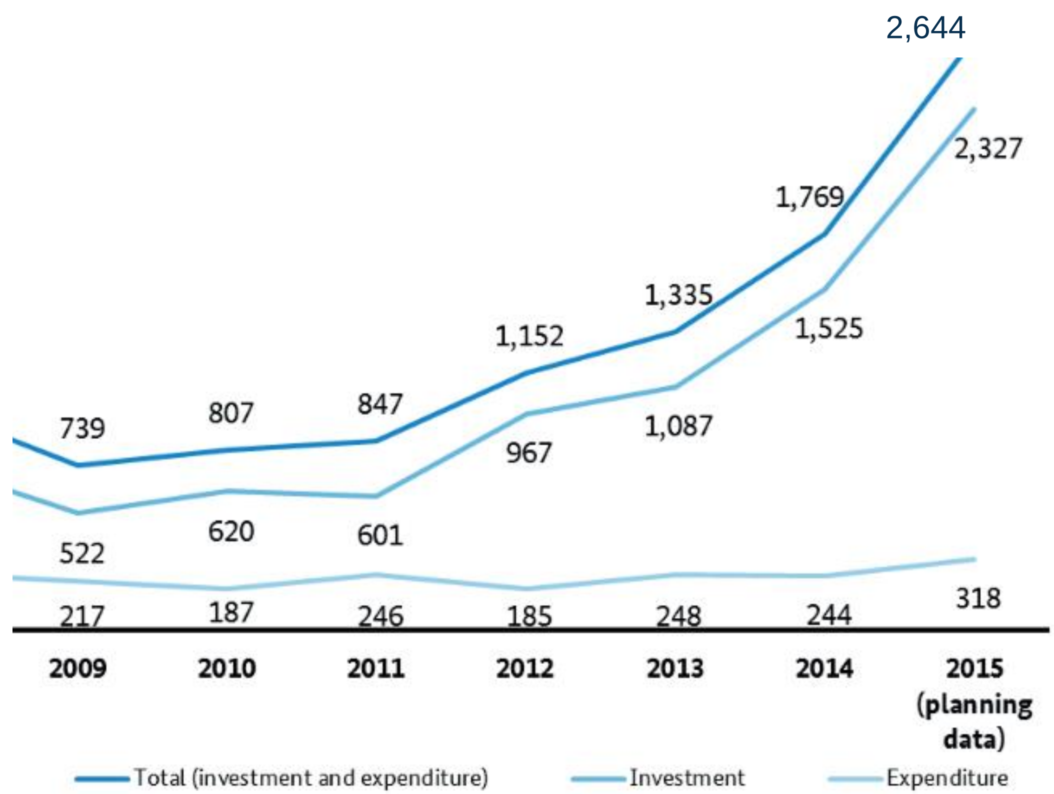
Balance of private portfolios via

- OTC
- private power exchange e.g. EPEXSPOT EUROPEAN POWER EXCHANGE

⇒ Revenues from European market coupling (via EPEX etc.) aren‘t regulated well…

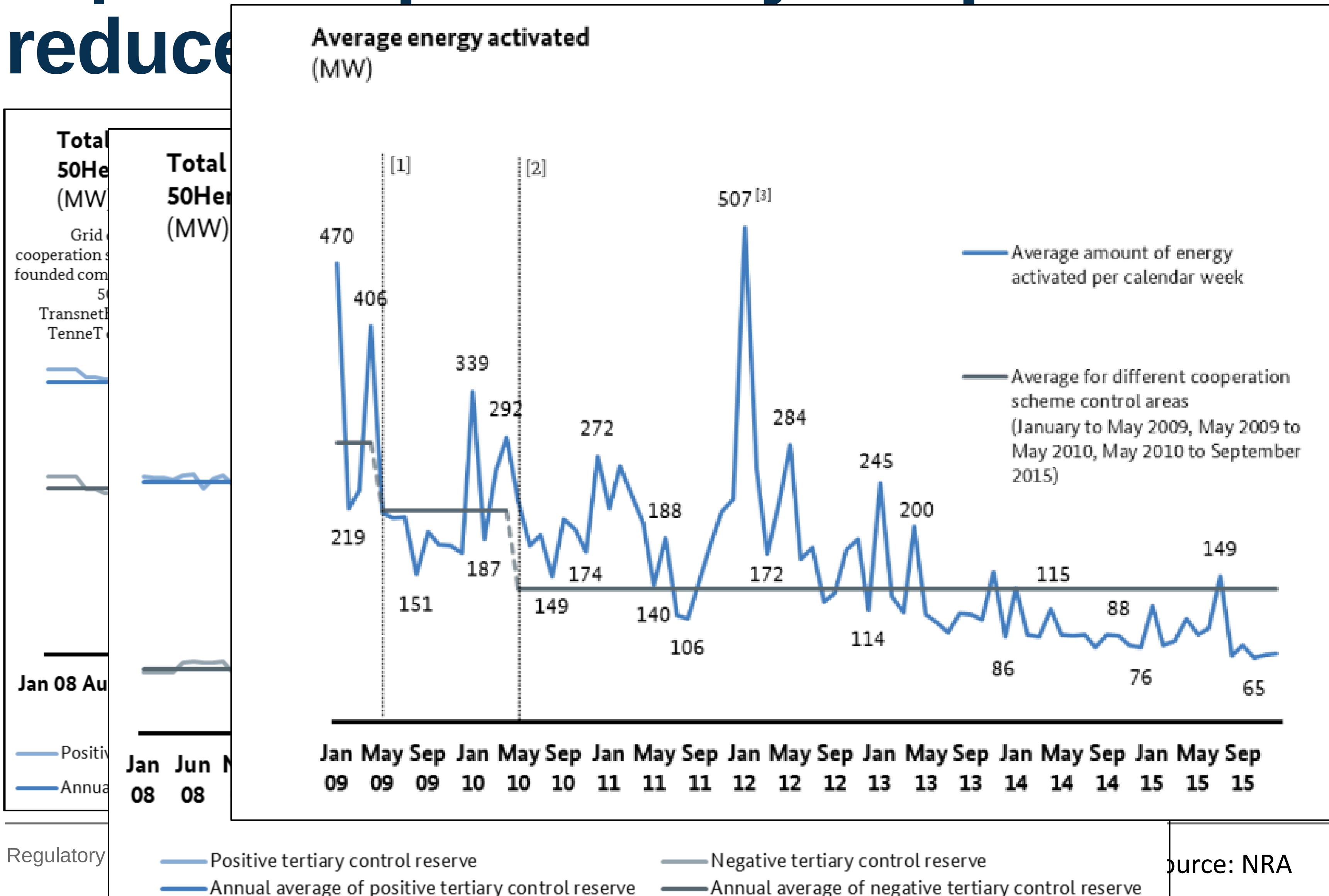
3 Facts and Figures about the German Networks and its Fees

Transmission network constraints and investments by TSO (€ Million)



Source: NRA

Improved operation by cooperation reduce



urce: NRA

Power network costs in Germany

Regulated network revenues in 2017:

- ~ 24 billion Euro paid by consumers only
- Transmission: 6 to 7 billion Euro
- Distribution: 17 to 18 billion Euro

Network costs increased by 25% in 6 years through

- Investments for grid extension
- Dispatch/redispatch - reserves and curtailment increased to 600-900 million Euro/year

Grid costs are allocated locally by

4 transmission networks

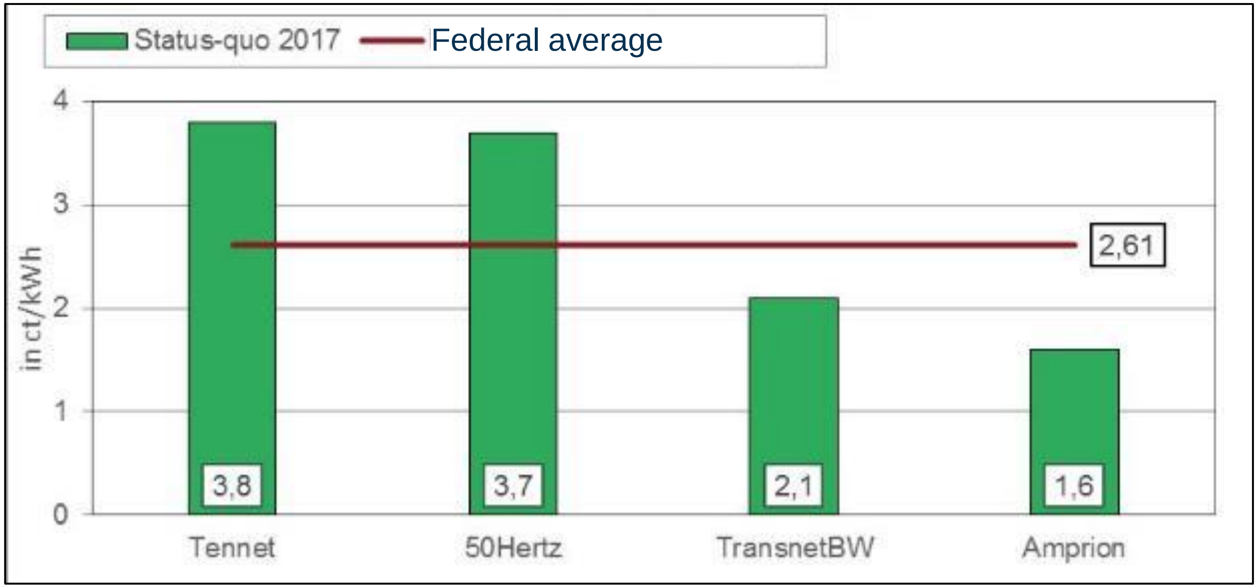
- 220 to 380 kV

860 distribution networks

- 110 kV and below

June 2017: Federal decision to harmonize transmission fees by 2023

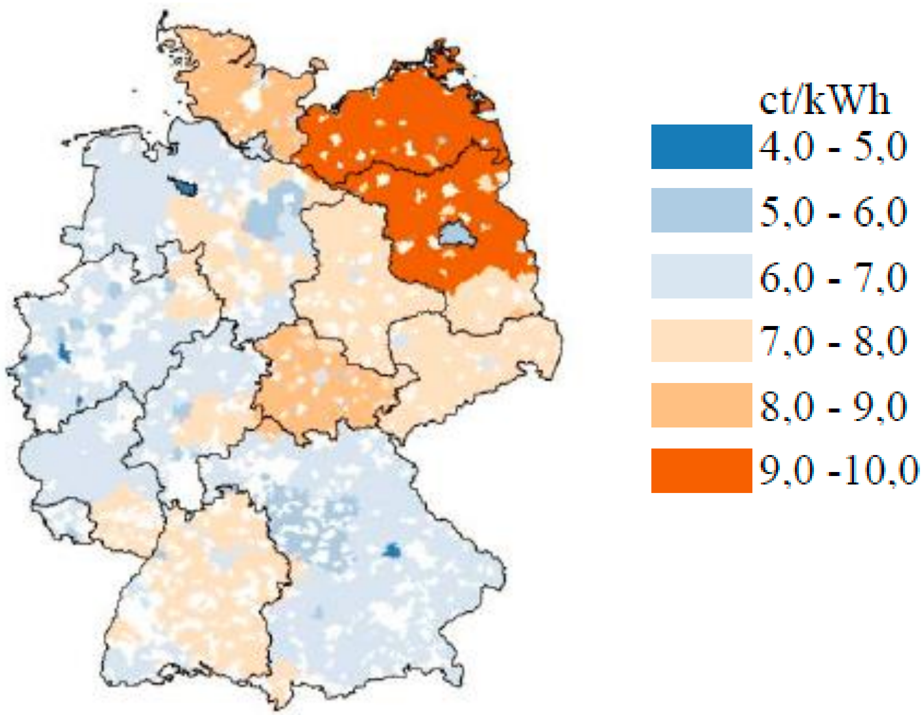
States (Länder): „Differences in transmission fees are an unfair (dis-)advantage to local economy“



Source: 50Hertz, Vereinigung sächsische Wirtschaft

Price differences on distribution level increasing further

Grid fees for household in 2015 (at 3500 kWh)



⇒ Rural networks with high RE-penetration and low demand becoming more and more expensive

⇒ Demand in cites far from supply is affected less and stays cheaper

4 Regional Operation Center

From an national to a European approach?

European Commission propose Regional* Operation Centers

- Establish Regional Operational Centres (ROCs) to enhance coordination in near real time activities at a regional level.
- Cover designated geographic regions to “compliment the role of TSOs by performing functions of regional relevance”
- Have decision-making authority in limited circumstances

* above national/TSO responsibility

European Debate: „Why ROCs are necessary?"

- **To maintain system reliability at the lowest reasonable cost while integrating increasing shares of vRES**
- Response to the increasing regionalisation of electricity markets

⇒ Allow efficient market operation by maximising available grid capacity

- Provide a regional focus to ensure solutions that are in the best interests of a region, rather than of a particular country

Aren't ROCs a win-win option?

Concerns

- ROCs would have a decision-making role rather than simply being service providers. TSOs, and by implication NRAs, would need to give up some authority
- Temporal responsibility split between near real-time and real-time activities, regulatory regime to support ROC responsibility for near-real time activities is not in place
- If successful, ROCs responsibility could be increased by lowering national control further
- If ENTSO-E (European TSOs) accepts something like ROCs, isn't a more ambitious setup necessary, e.g. an ISO?

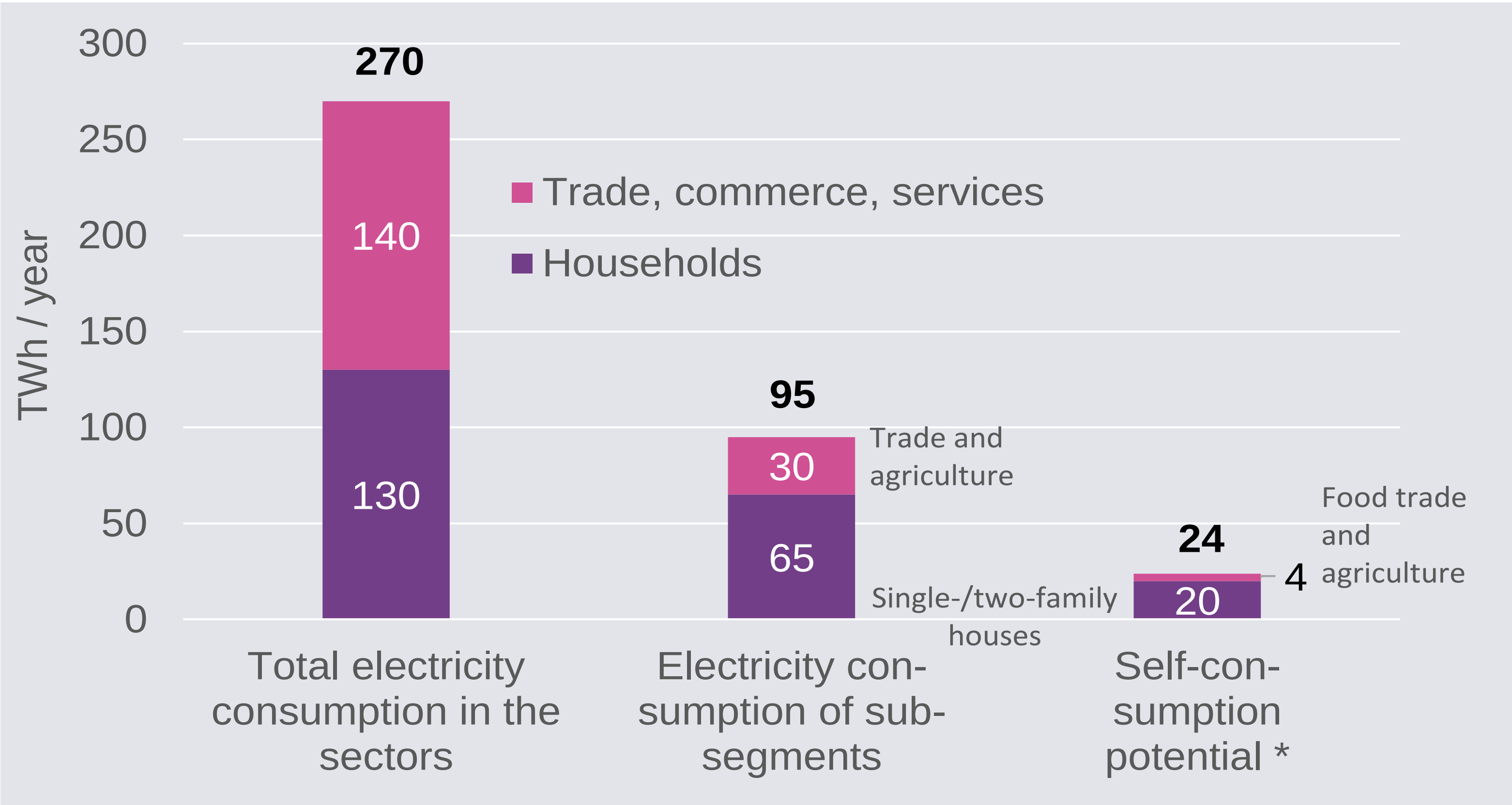
5 German Facts on Rooftop PV and Network Fees

PV self-consumption outlook with low PV and battery costs

Questions

- What are the relevant PV rooftop groups/sectors?
- What amount of rooftop PV can be expected (2035)?
- What will be the decrease in power taken from the grid?
- What are the effects on network revenues and other customers?

Potential for PV self-consumption is limited, even in commercial and residential sector



Prognos (2016) * with reduced energy use from the grid

PV self-consumption potential for Germany in 2035

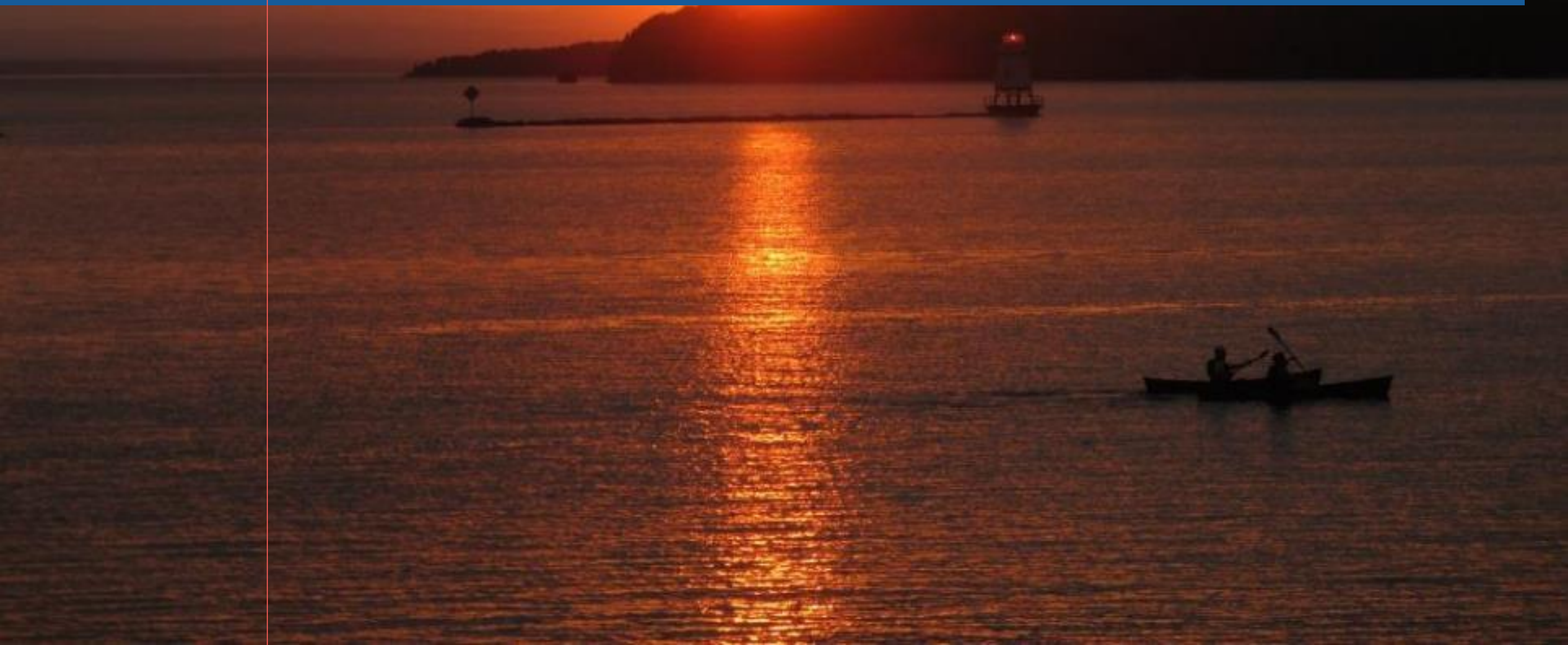
- PV self-consumption can be max. 44 TWh/a
  - Incl. 24 TWh for heat demand
  - 20 TWh less power taken from network (600 TWh total)
- 5% reduction of total demand would increase average volumetric network charge for household by max. 1 €Ct/kWh (approximately 12%)

PV self-consumption isn't a big deal

- German power system is a winter-peaking system (as in most EU states)
- No cost-efficient displacement of winter demand by PV, not even with large roofs or cheap batteries
  - ⇒ Seasonal storage would be required

⇒ Self-consumption won't drive the transition or risk cost allocation / network revenues

6 How could “Energiewende markets” look like?



How could “Energiewende markets” look like?

- Recognize and procure new, important flexibility services in the balancing markets
- Apply reserve shortage opportunity costs and/or co-optimize energy and reserves markets to ensure fully marginal-cost-reflective energy pricing
- Plan and operate networks independent from ownership
- Incentivize flexibility and location requirements by markets, based on grid constraints (LMP instead of national bidding zones)
- Translate emission targets into tradeable caps to minimum costs
- Use strategic capacity reserves as back up, only

About RAP

The Regulatory Assistance Project (RAP)® is an independent, non-partisan, non-governmental organization dedicated to accelerating the transition to a clean, reliable, and efficient energy future.

Learn more about our work at raponline.org

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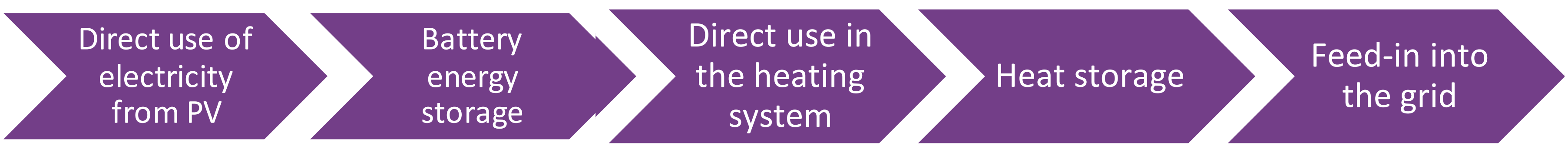
Back Up

Economic evaluation by opportunity cost of electricity and heat

Whenever there is **surplus electricity** that cannot be used at a given level in the chain, the surplus is used at the next level.

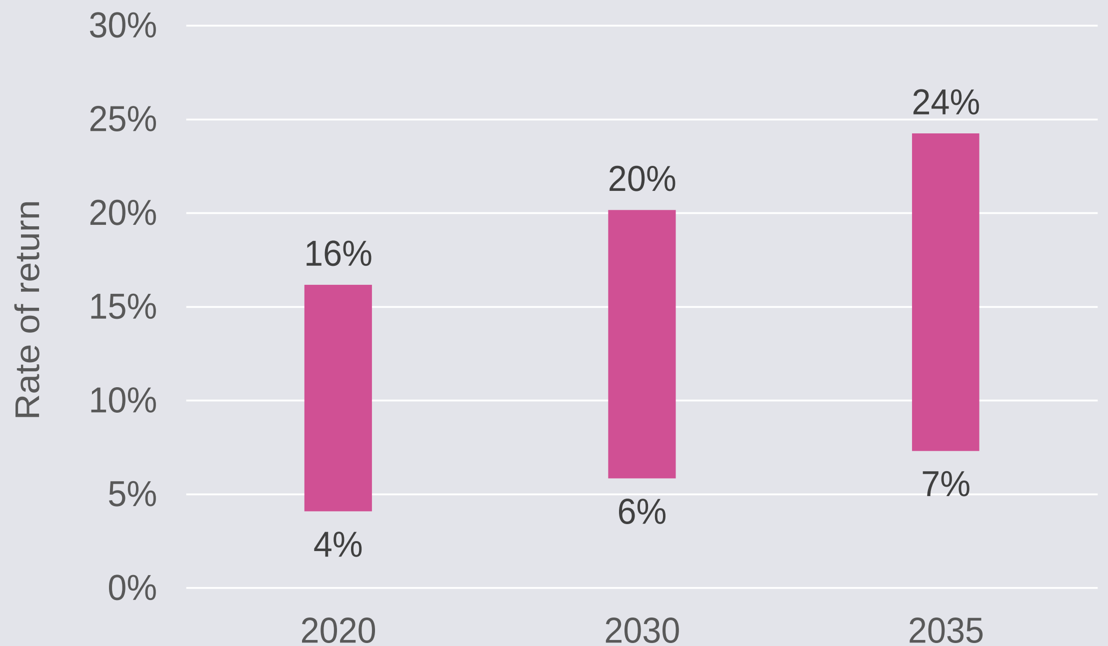
The **economic dimensioning** of a system for self-consumption depends on the technology cost race between PV and battery storage.



Here, we assume considerable cost reductions for both PV and battery storage.

PV self-consumption with storage for single- and two-family homes will become profitable

Rate of return ranges for PV self-consumption



Prognos (2016)

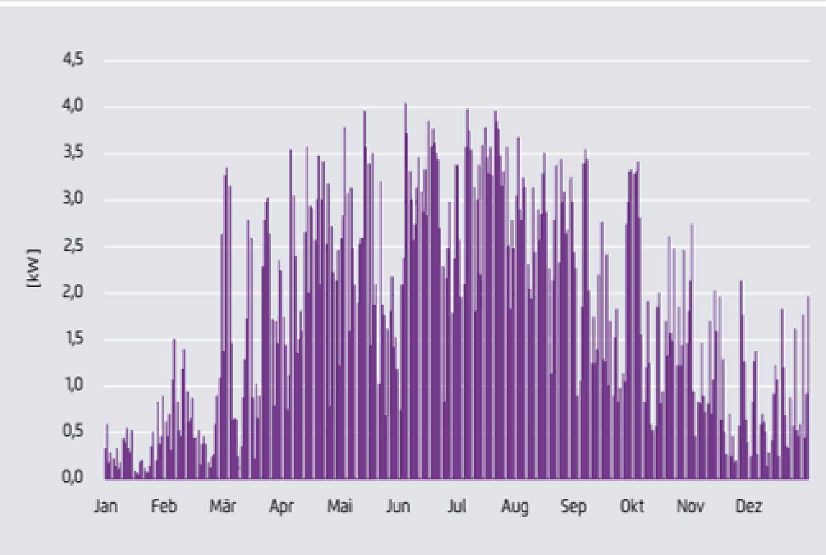
The **highest rates of return** can be expected for PV energy systems *without* storage.

That is, even when factoring in large price drops for batteries, PV energy storage systems, do not make more economic sense.

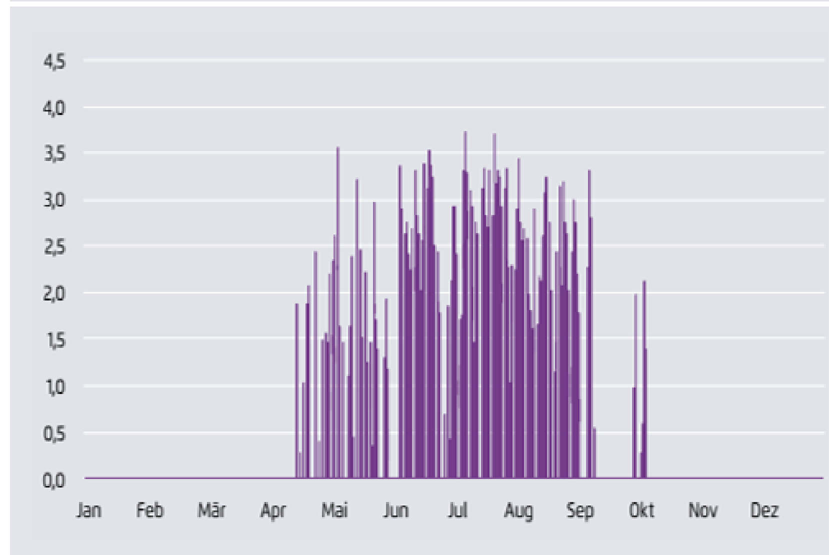
Value of PV feed in from roof tops

Feed-in from PV into the grid *with* self-consumption yields a market value that will remain about 10 percentage points below the one from PV generation *without* self-consumption.*

Feed-in from PV system without storage in kW



Feed-in from PV system with battery storage and heat pump in kW



Prognos (2016)

* Assuming a PV expansion to 60 to 80 GW by 2035.

Performance based regulation in Germany

- Revenues decoupled from throughput
- Easy to achieve cost performance standard of plus 98% by network owners
- Interruption/customer service ranked low

- Lack of transparency:
  - regulated revenues not published until 2017
  - NRA approval still confidential

Resources

- PV Self-Consumption (German)
- Grid Tariffs in 2017 (German)
- Tariff design in Germany (German)
- Designing Tariffs for Distributed Generation Customers
- Smart Rate Design for a Smart Future
- Designing Distributed Generation Tariffs Well
- Time-Varying and Dynamic Rate Design

Increasing fixed charges

Due to lack of regulation, distribution networks increased fix charges over the last couple of years.

Fixed charges for consumers below 100,000 kWh/year (SLP) in Germany

	2013	2014	2016	
Average fixed charge	14.16	16.44	20.71	€/year
Max. fixed charge	33.96	36.50	50.00	€/year
Number of networks without fixed charge	29	24	15	Out of 860 in total

Source: BNetzA Netzentgeltsystematik 2015

Example: Increasing fixed charges = higher bills for low demand

	Charges			Total costs at *X* MWh per year		
Name of Network	Volumetric [€Ct/kWh]	Fixed [€/year]	Metering [€/year]	1,500 [€/year]	3,500 [€/year]	80,000 [€/year]
Netze BW	7.5	0.0	9.8	122	272	6,002
Edis	9.9	58.4	11.6	218	416	7,974
WeserNetz	3.6	58.0	12.0	124	196	2,942
SW Tübingen	3.9	**75.0**	15.2	**148**	226	3,194

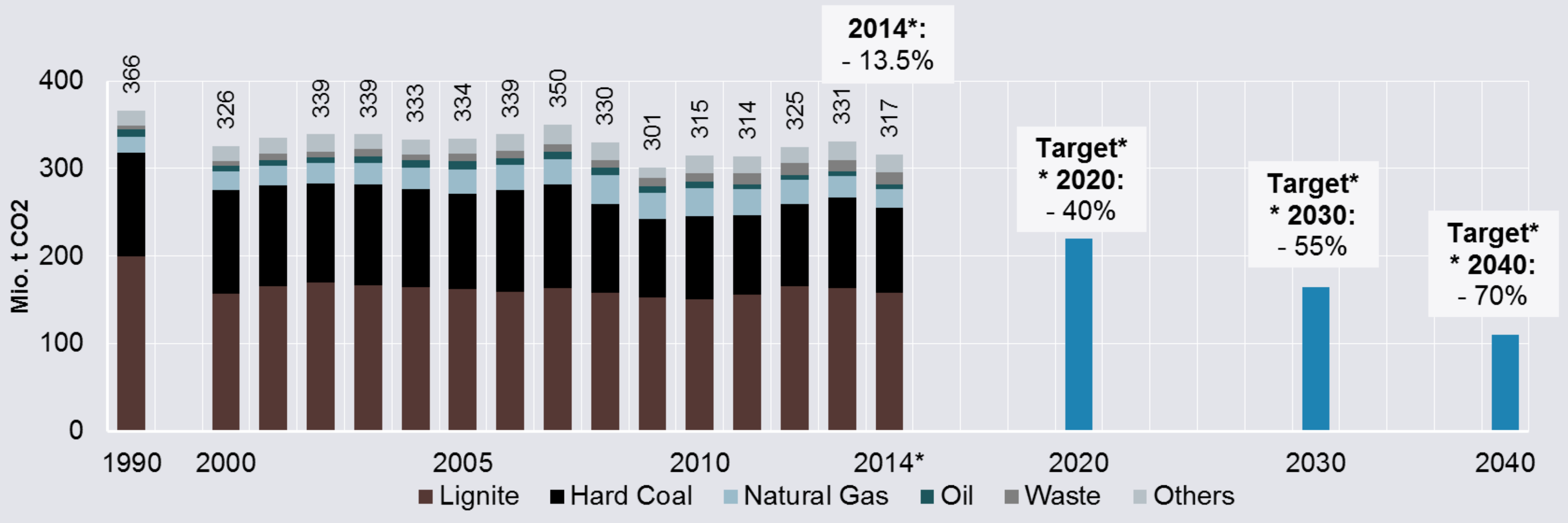
⇒ In some networks, fixed costs for low demand customers (e.g., apartments) already above 50% of network costs

3 principles of rate design

1. A customer should be able to connect to the grid for no more than the cost of connecting to the grid.
2. Customers should pay for grid services in proportion to how much they use the grid and when they use the grid.
3. Customers who supply power to the grid should be fairly compensated for the full value of the power they supply.

Challenge 5: Climate Targets – gradual reduction of lignite and coal use is needed: for 2030/2040 we need a “coal consensus”.

CO_2 emissions from electricity generation 1990 - 2014 and climate targets** 2020 - 2040



UBA (2015), own calculations

*preliminary, **application of a sectoral 40%-target