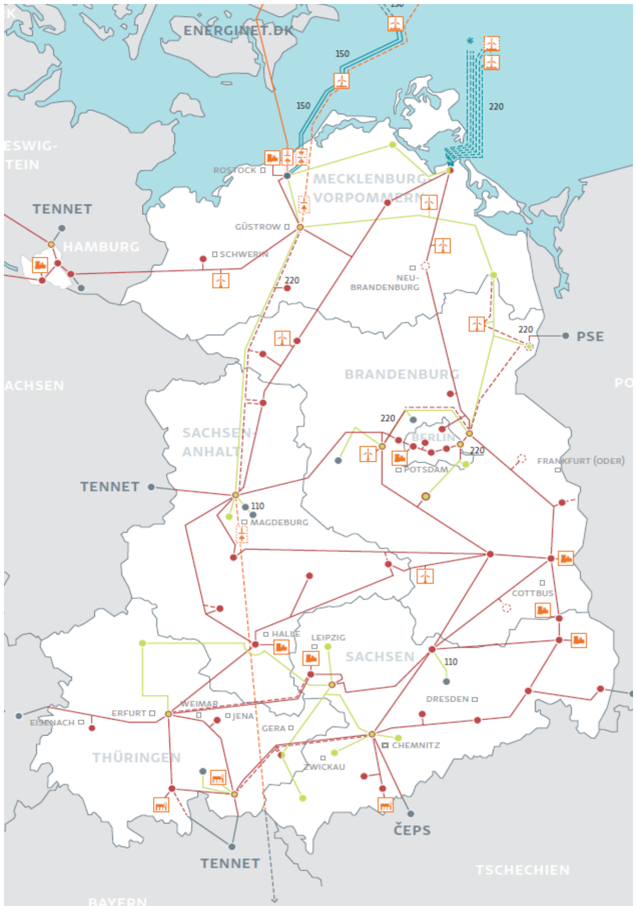
Sector Coupling

An energy economic perspective

Enerday 2018
Dresden, 27.04.2018
Dr. Johannes Henkel

Agenda

50Hertz at a glance

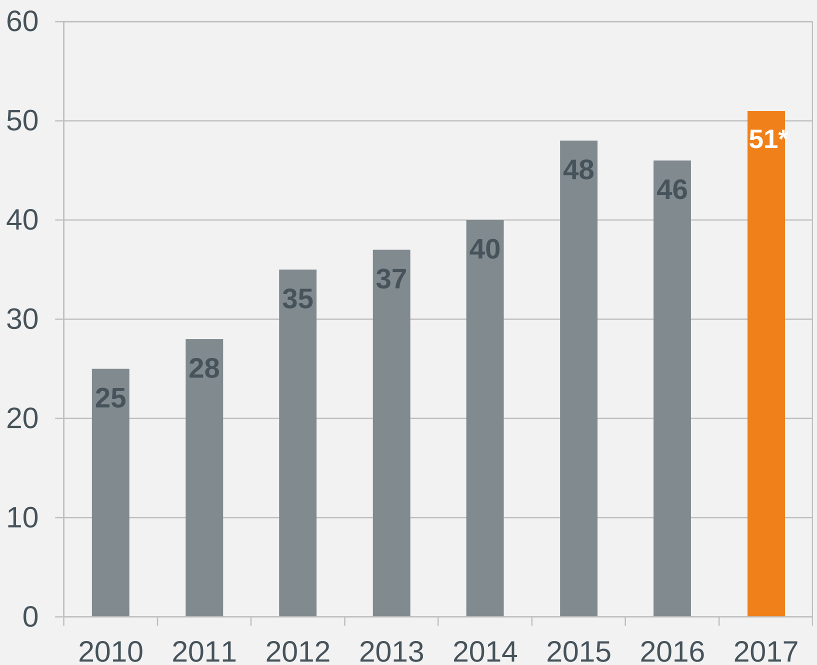


	2017 (share Germany)
Grid area	109,589 km² (~31%)
Length of lines	10,200 km (~30 %)
Max. load	~ 16 GW (~20 %)
Power consumption (based on electricity supplied to end-consumers in acc. with Renewables Energy Law „EEG“)	~96 TWh (~20 %)
Installed capacities - of which Renewables - of which Wind	54,069 MW (~26%)* 31,177 MW (~30%)* 18,556 MW (~34%)*
RES share in power consumption	53.4 %
Turnover - of which Grid	9.9 bn. € 1.3 bn. €
Employees	1,043

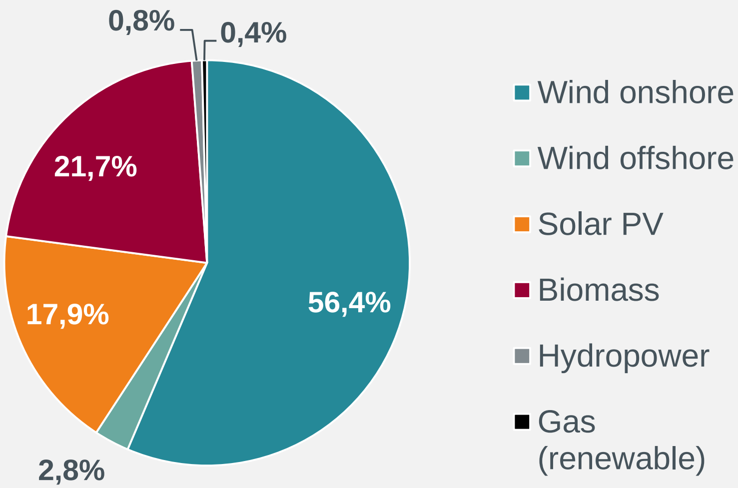
Source: 50Hertz; *preliminary data; as of 06/03/2018

Feed-in of renewable energies within the 50Hertz grid area

50Hertz grid area: development of RES feed-in (TWh)



50Hertz grid area: composition of RES feed-in (2017, in %)



Source: 50Hertz; *preliminary data, as of 03/01/2018

The power system in the 50Hertz grid area

TSO (400 kV, 220 kV)

5 TSOs

- TenneT
- CEPS
- PSE
- Energinet.dk
- Svenska kraftnät

9 Windfarms

- 7 onshore
- 2 offshore

3 Steel Plants

50hertz

12 conv. power plants /storages

- Schwarze Pumpe
- Boxberg
- Jänschwalde
- Lippendorf
- Reuter West
- Goldisthal
- Markersbach
- Hohenwarte II
- Brunsbüttel (GKW)
- Moorburg
- Rostock
- Schkopau

DSO – 1st level (≤ 110 kV)

Approx. 1.200 Windfarms
PV, biomass and other RES

10 Distribution System Operators

- AVACON
- E.DIS
- ENSO Netz
- SW Magdeburg
- MITNETZ Strom
- Stromnetz Berlin
- Stromnetz Hamburg
- TEN
- WEMAG Netz
- SW Staßfurt

CHP and IPP

DSO – 2nd to m. level (< 110 kV)

200 Windfarms
PV-, biomass and other RES

159 Distribution System Operators

CHP and IPP

DSO – low level (< 110 kV)

PV-, biomass and other RES

Other DSOs

CHP and IPP

Source: 50Hertz; as of 31/12/2017

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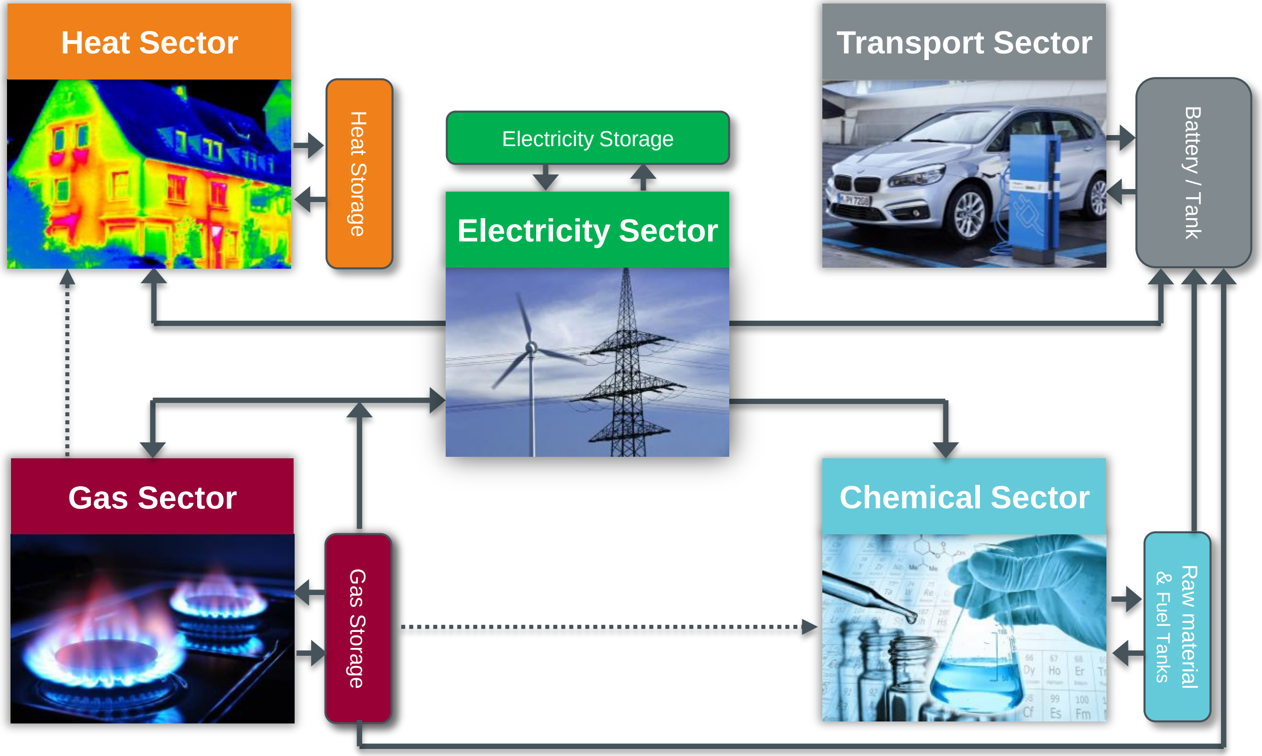
Definition Sector Coupling

Sector coupling characterizes an optimized application of energy converters and storages with the objective of an efficient **system integration of RES-E** and **decarbonisation** of other sectors.[1]



Power to Heat
Heat Pumps

Electric Mobility
Quick Charge

Power to Gas
Electrolysis
Methanation
Reconversion in Fuel Cell

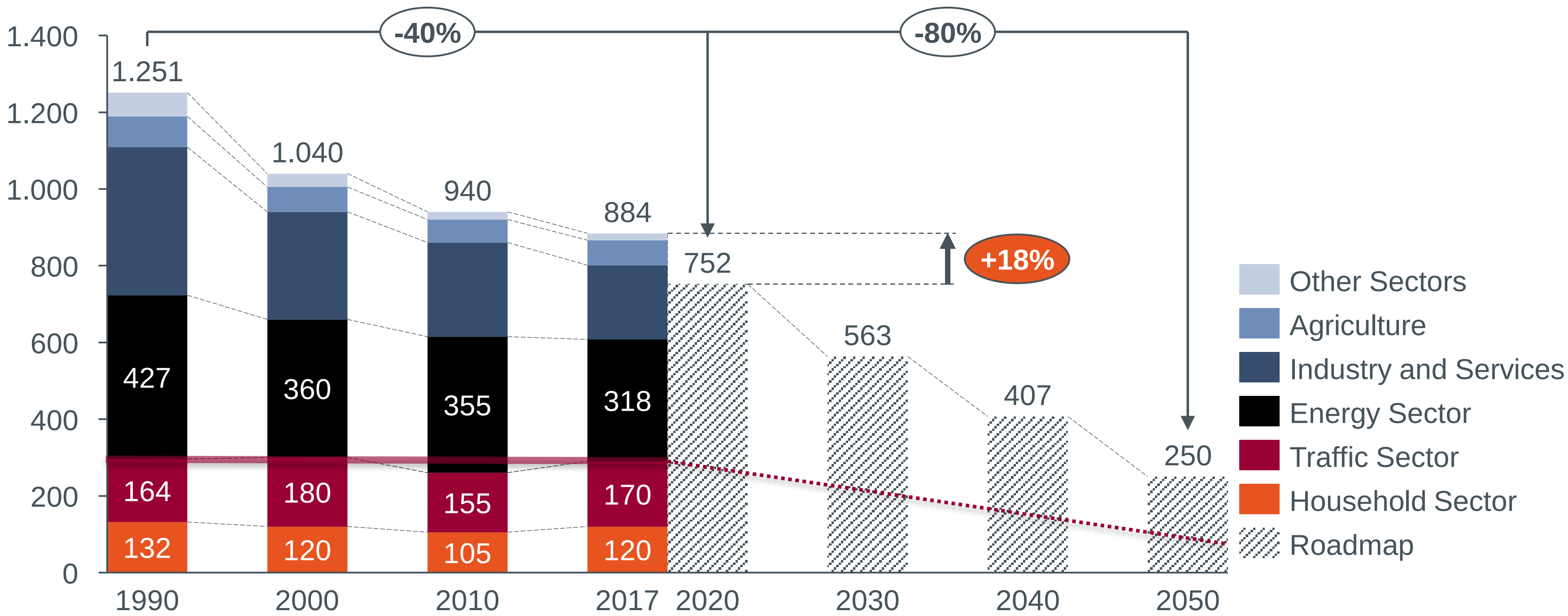
Power to Chemicals
Fischer-Tropsch-Synthesis,
CO_2-Capture

Chart inspired by Fraunhofer IWES

[1] Definition according to Sterner und Stadler (2017)

Sector coupling is an option to reduce GHG in traffic and household sector

Greenhouse gas emissions (CO_2 and others) in Mil. t. CO_2-equivalents



In recent years GHG reduction in household and transport sector were unsuccessful. Sector Coupling may provide a solution.

Source: Umweltbundesamt (2018); Klimaschutzplan der Bundesregierung (2016)

Rising share of RES leads to new requirements and challenges

< 10% RES – **RES as a niche**

10-40% RES – **RES as major player**

> 40% RES – **RES as dominant player**

- RES as “**fuel-saving technology**”
- Development of **grid infrastructure** necessary in order to meet new transport demands (due to new areas of generation) and as source of flexibility
- **Sector Coupling** as option for temporary excess electricity

RES have evolved from a niche to a dominant source of energy in the 50Hertz grid area leading to new challenges and requirements for the grid.

Energy and climate protection are corner stones of the German Coalition Agreement 2018

CO_2 reduction targets:	min 55 % until 2030; min 80 % until 2050, Measures to reach the 40 % target until 2020 Commission for coal phase out (*Strukturwandel*)
Renewable energies:	65 % until 2030 80 % until 2050 Synchronisation with grid expansion
Special tender:	4 GW Wind-Onshore 4 GW PV additional Offshore contribution
Grids:	Create acceptance and accelerate grid expansion
Sector Coupling:	National battery production R&D on synthetic fuels and hydrogen synthesis Promote Power-to-Heat

Source: Coalition Agreement 2018

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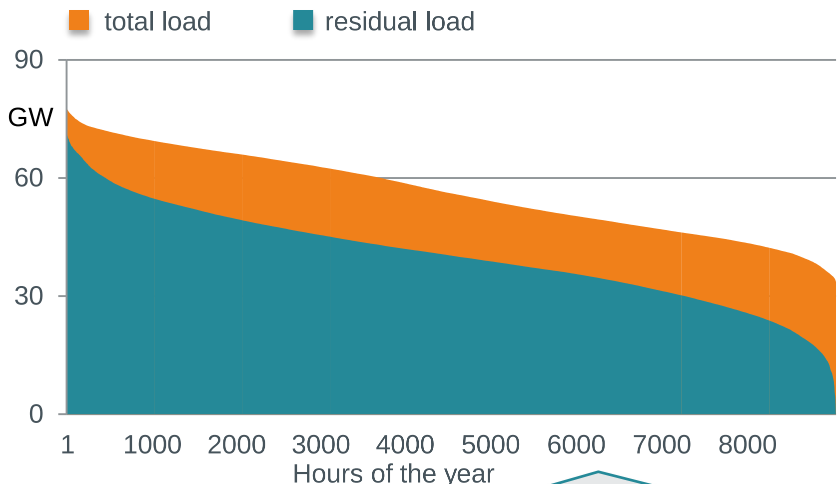
Residual load declines from 2017 to 2030 but peak load increases

German annual load duration curve 2017

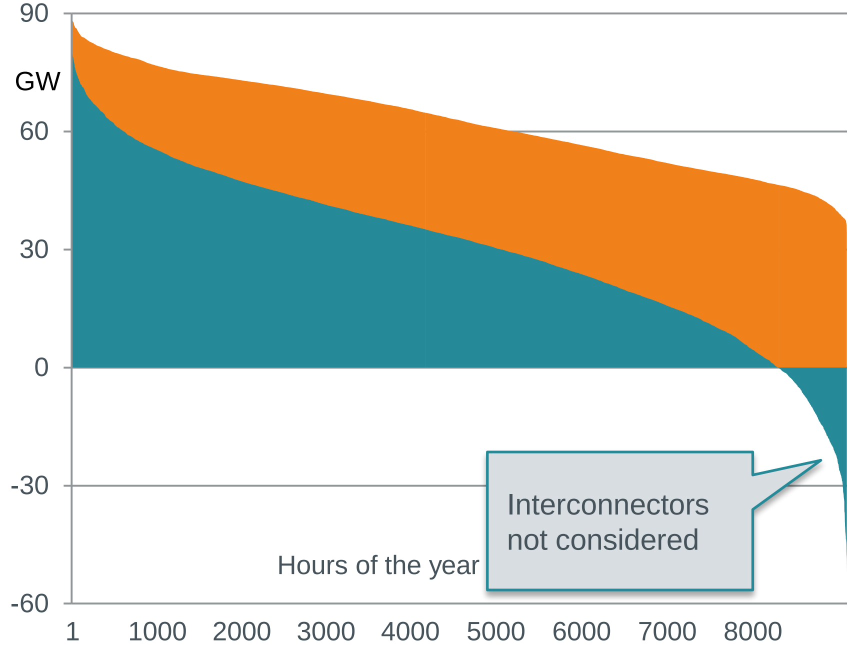


15 minute values:*

Load:	min 29453 MW	max 79481 MW
Residual Load:	min 155 MW	max 73250 MW

* Load data my contain errors

… and projection for 2030

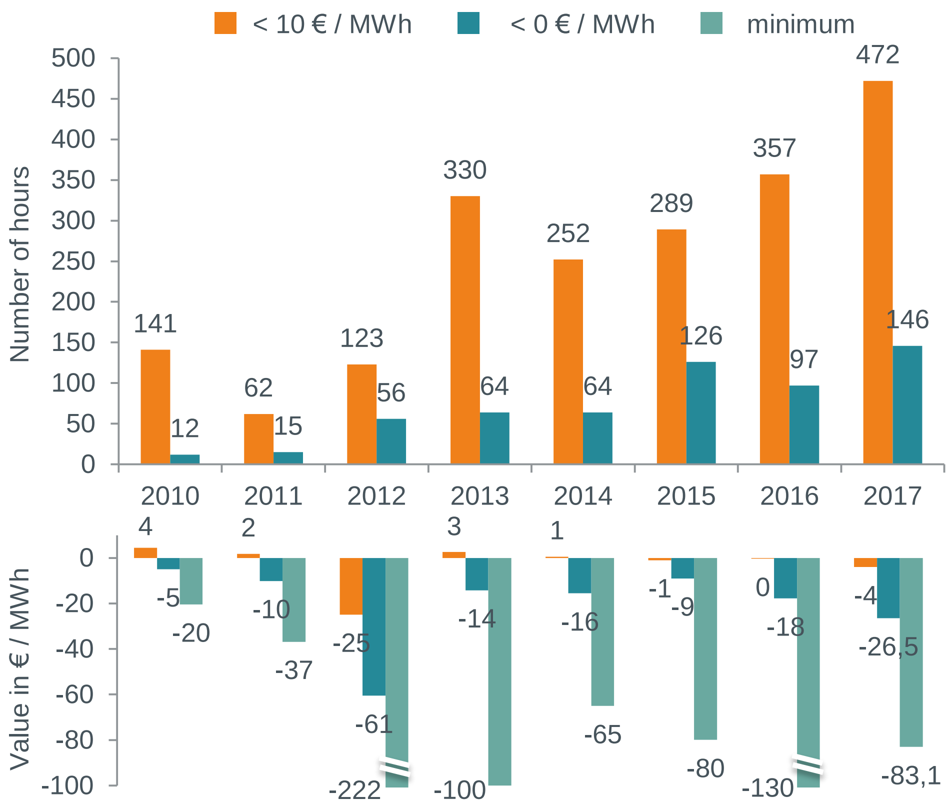


The share of hours per year with a RES-E oversupply increases till 2030 and could provide a potential for sector coupling.

Source: Extrapolation by German TSOs (2018); Agora Energiewende (2018)

An increasing number of low spot market prices may incentivize sector coupling

Number and value of Day Ahead spot market prices in Germany 2017



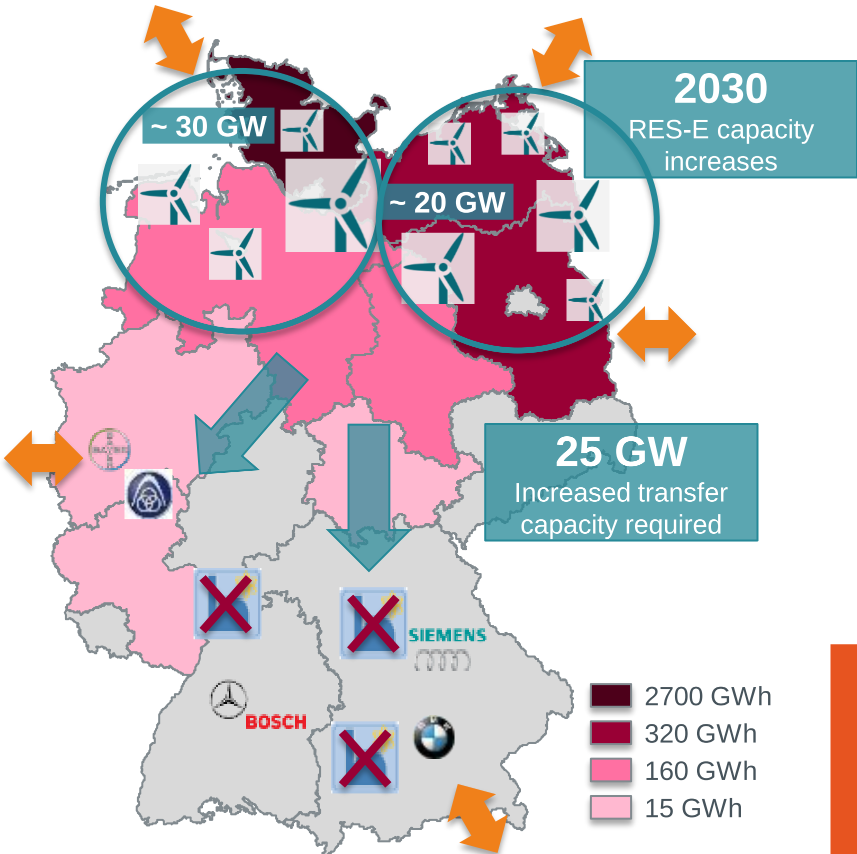
yearly average	44	51	43	38	33	32	29	34

- 472 hours with Day Ahead spot price < 10 € / MWh in 2017
- 146 of which were negative
- buyers would have earned in these 472 hours 4 € on average
- average Day Ahead spot market price was **34 €/MWh** in 2017, end costumers payed **250 €/MWh**
- Gas price for end costumers 62 €/MWh

3,7 TWh of RES-E Curtailment were conducted in Germany in 2016

Regional Distribution of RES-E curtailment* 2016

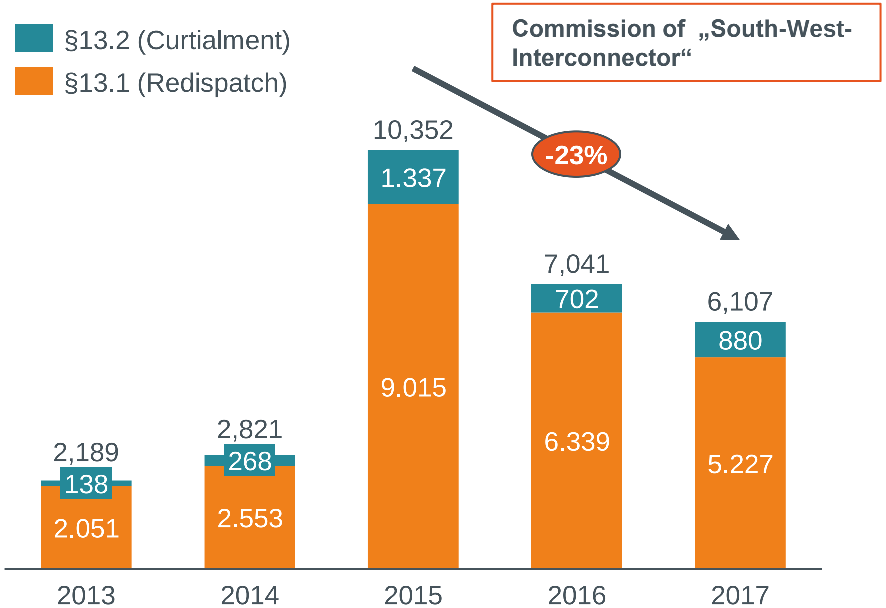
** TSO and DSO Volume combined*



Monitoring BNetzA 2017

Volume* of Redispatch and RES-E curtailment in GWh

** 50Hertz control area*

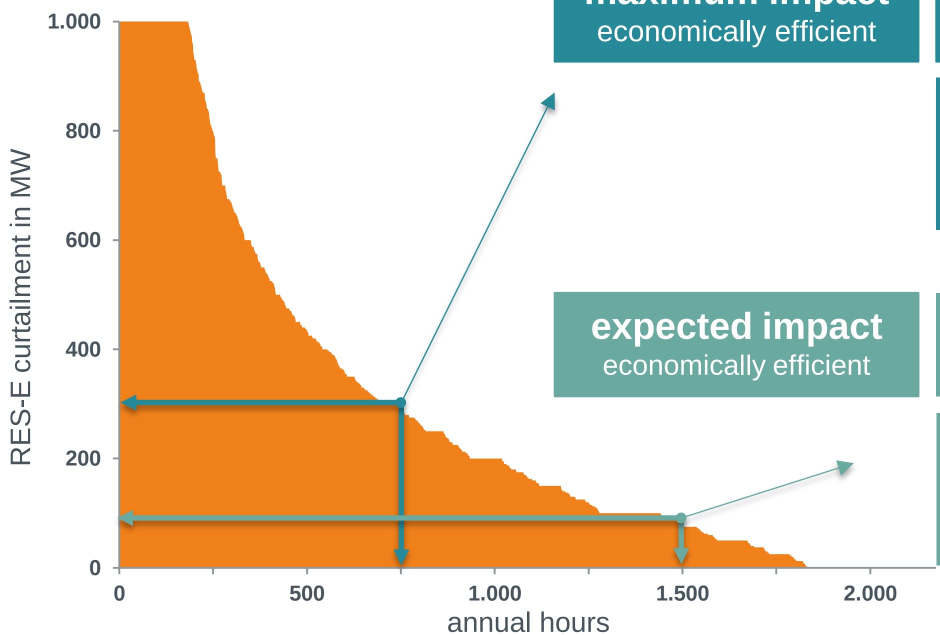


Despite ongoing grid extension RES-E curtailment will be conducted by TSO and DSO in the foreseeable future.

„Use not loose“ of RES-E production could replace 100 MW capacity in 2016 in 50Hertz grid area

Annual load duration curve for RES-E curtailment* 2016 in MW

** conducted by 50Hertz, cut at 1000 MW*



maximum impact
economically efficient

100% compensation of CHP and PtH
practically impossible

Implication: displacement of 1 MWh CHP result in reduction of RES-E curtailment of 2 MWh.
At least 750 h/a full load at 200 €/kW for refinancing needed. Leads to a potential of 300 MW in 2016.

expected impact
economically efficient

50% compensation of CHP and PtH
practically possible

Implication: displacement of 1 MWh CHP result in reduction of RES-E curtailment of 1 MWh.
At least 1.500 h/a full load at 200 €/kW for refinancing needed. Leads to a potential of 100 MW in 2016.

High uncertainties for both intertemporal and regional distribution of RES-E over capacities may reduce the economic potential.

Source: 50Hertz

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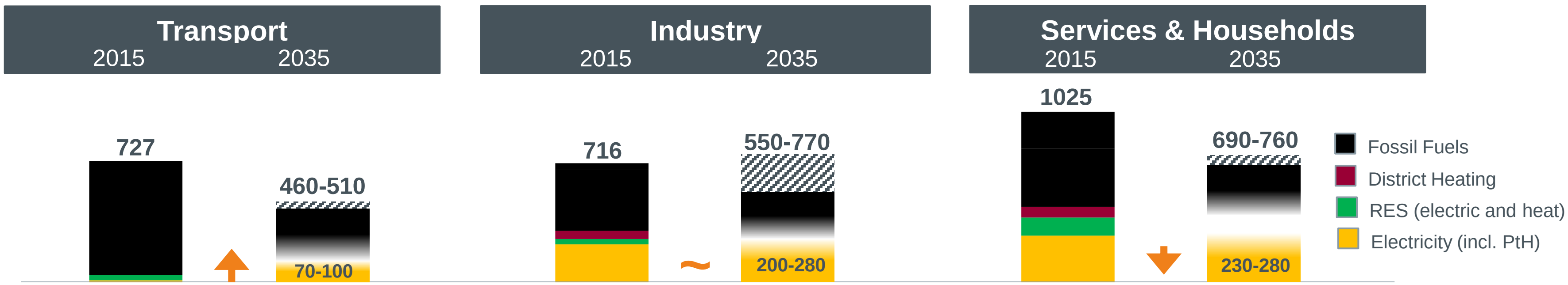
Sector coupling provides short term potential for electrification in transport and residential sector

Final energy consumption by sectors, sources and technologies in Germany in TWh



Transport

Short term:

- EV and hybrids

Long term:

- Overhead line for trucks
- Hydrogen electrolysis (PtH_2)
- Power-to-Gas and Liquids (PtX)

Industry

Long term:

- Power-to-Heat (PtH)
- High capacity heat pumps
- Electric arc furnace
- Power-to-Liquids (PtL)

Services & Households

Short term:

- Power-to-heat (PtH)
  - Heat pumps (HP)

Long term:

- Electrolysis and Methanation (PtG)

Up to 10 Mil. EV by 2035 will increase power consumption in Germany

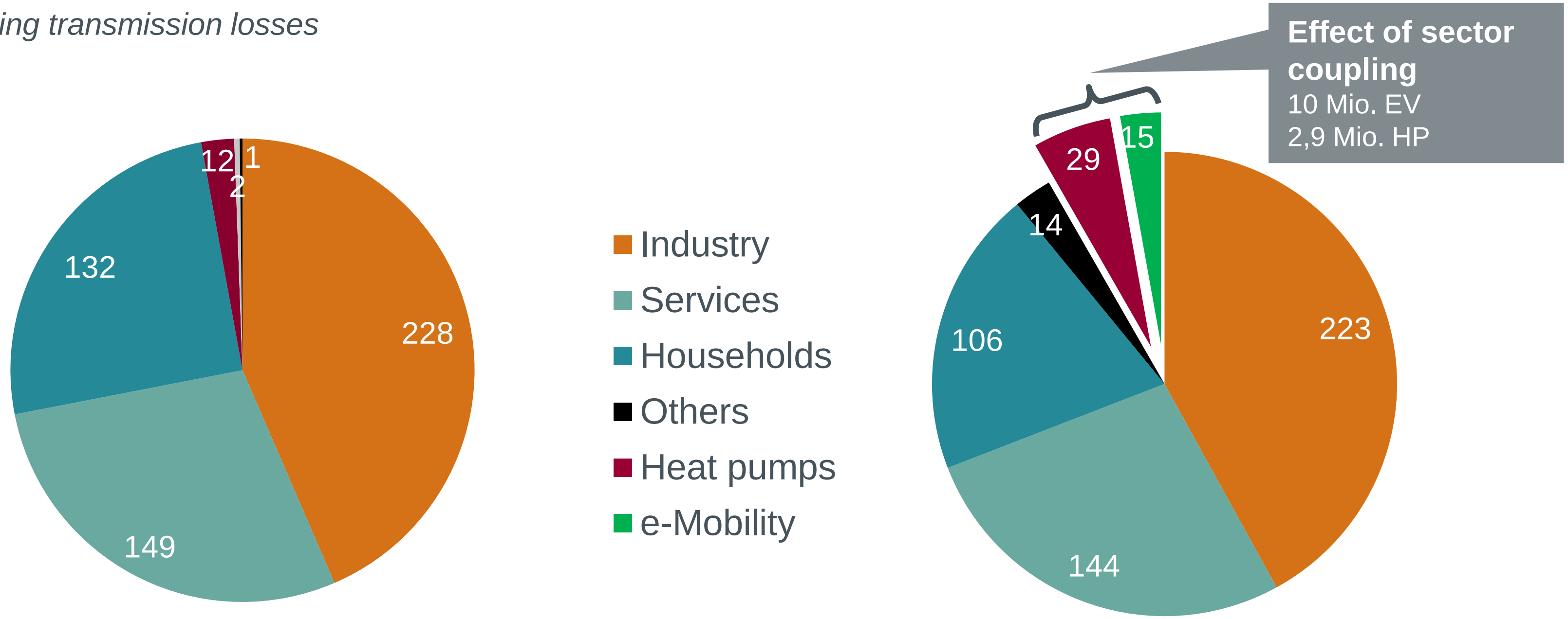
Electrification for selected Applications is compensated by efficiency gains

Efficiency gains and demographics dominate power consumption by heat pumps

HP and EV increase power consumption only marginal until 2035

Power consumption* in Germany in TWh

** excluding transmission losses*



Source: Umweltbundesamt (2017)

Source: Netzentwicklungsplan 2035B (2017)

2015 ∑ 524 TWh

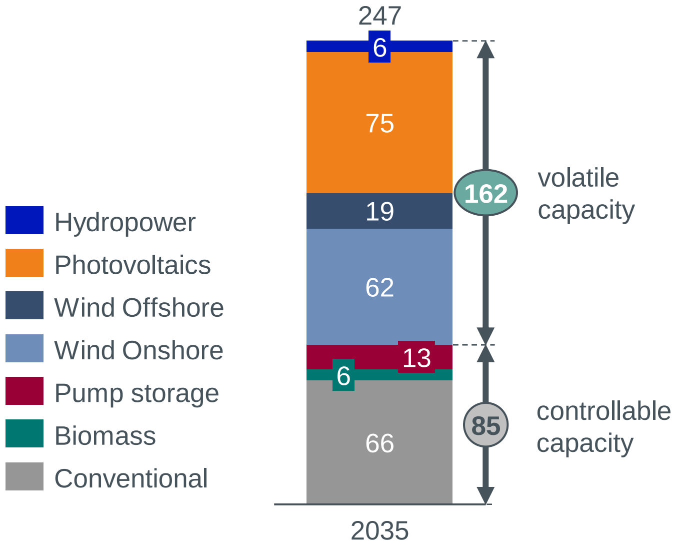
2035 ∑ 531 TWh

The expected impact on total power consumption by sector couplings remains low, even with high assumptions for EV and HP.

HP and EV increase Peak Demand – Is there enough Peak Power / Flexibility in 2035?

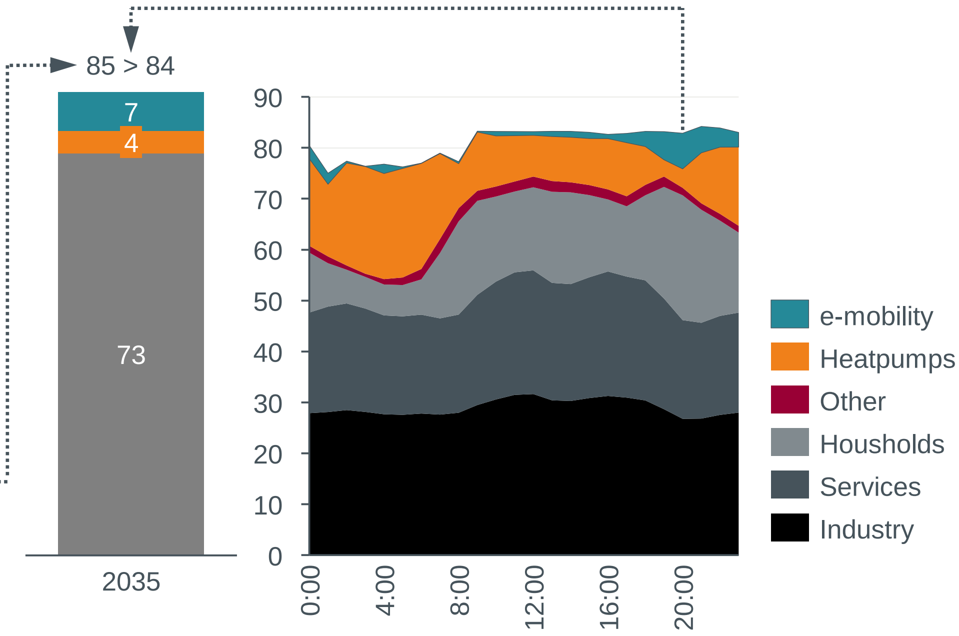
Total* installed capacity in GW

** without interconnectors*



Peak load („dark doldrums “) in GW

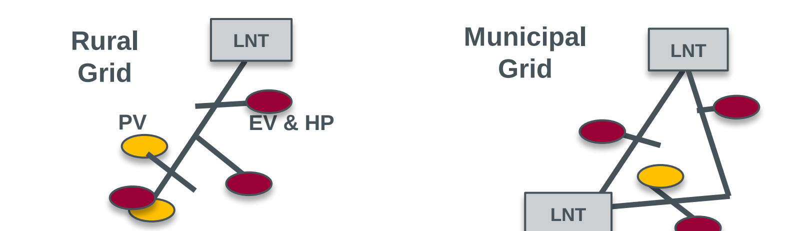
Example for 07.02.2035



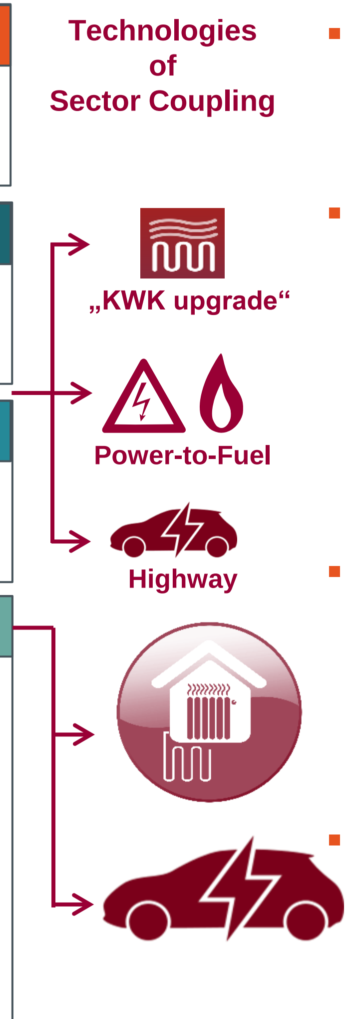
Under the condition of smart HP and charging solutions for EV peak load may be met by the installed controllable capacity.

Predominant challenge for increased load arises in the distribution grid

Grid	Voltage		Length	Operator
Transmission Grid	380 kV	220 kV	35,000 km	TSO
High Voltage Grid	110 kV	60 kV	95,000 km	DSO
Medium Voltage Grid	30 kV – 1 kV		510,000 km	DSO
Low Voltage Grid	400 V – 230 V		1,150,000 km	DSO



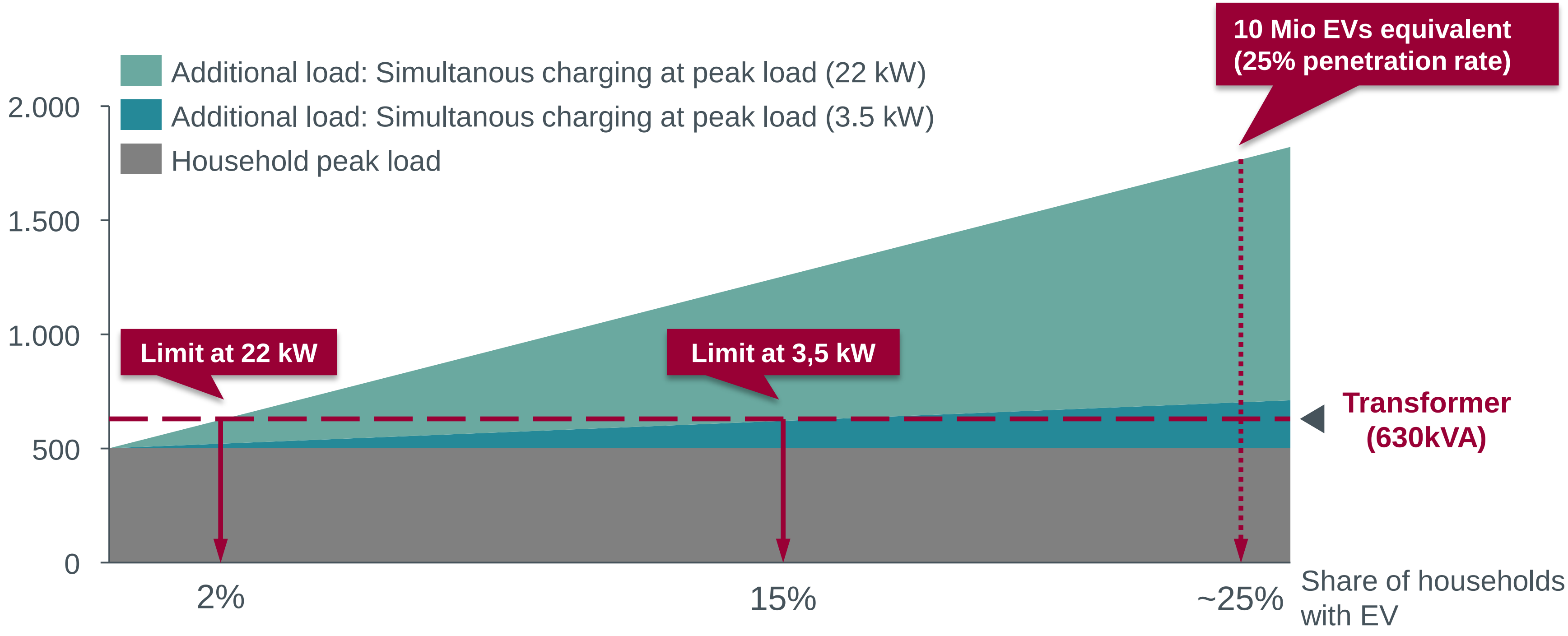
LNT: local network transformer



- Congestions primarily caused in 110 kV to 380 kV grids by wind power feed in
- Planned grid extension targets congestions
- Technologies of sector coupling are expected to be connected to the medium and low voltage grid and may cause additional congestions
- Rural grids are further developed due to recent PV installations but less meshed than municipal grids

Estimation of grid infrastructure limits with no optimised charging patterns (worst case)

Maximum load for 228 households in kW with different penetration rates for EV

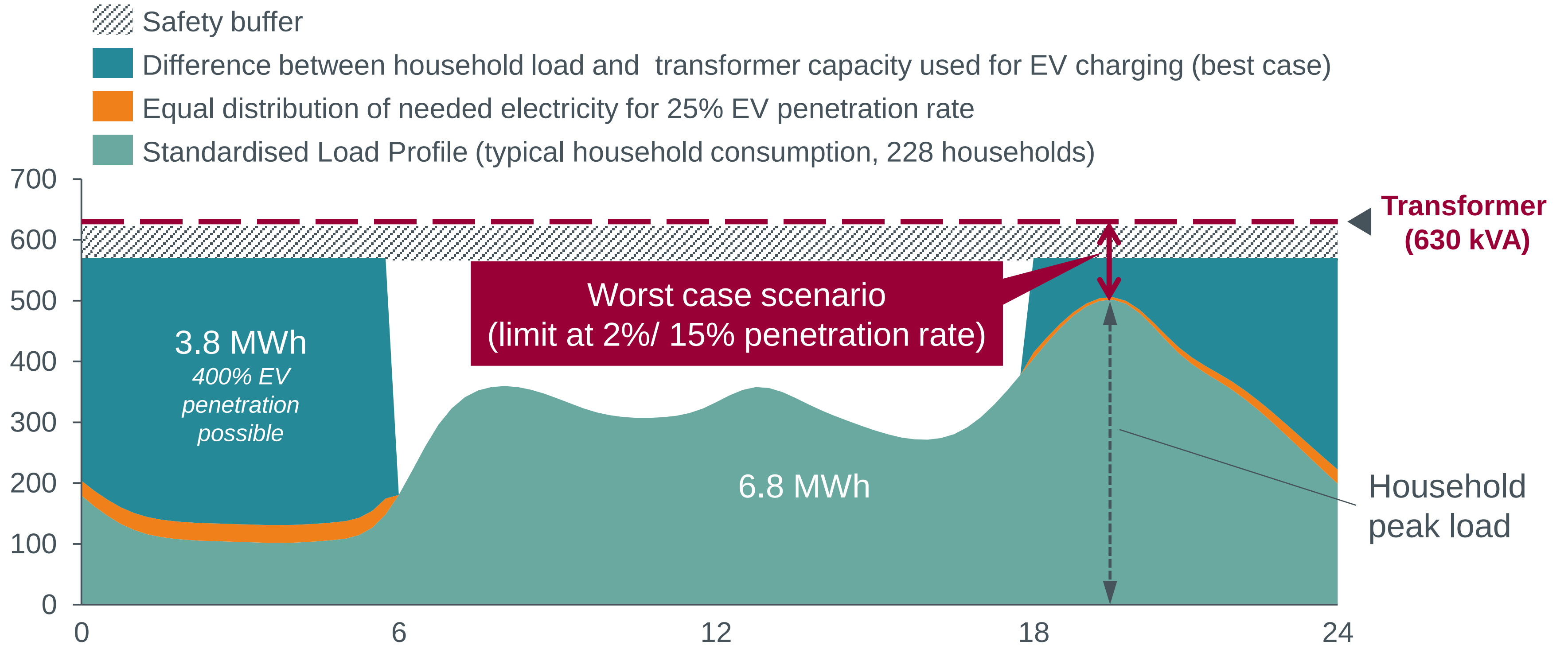


With simultaneous charging at 22kW the local transformer is limited to 5 EVs (2% penetration) with no optimised charging algorithm in place.

Challenge III

Estimation of grid infrastructure limits with idealised charging optimisation (best case)

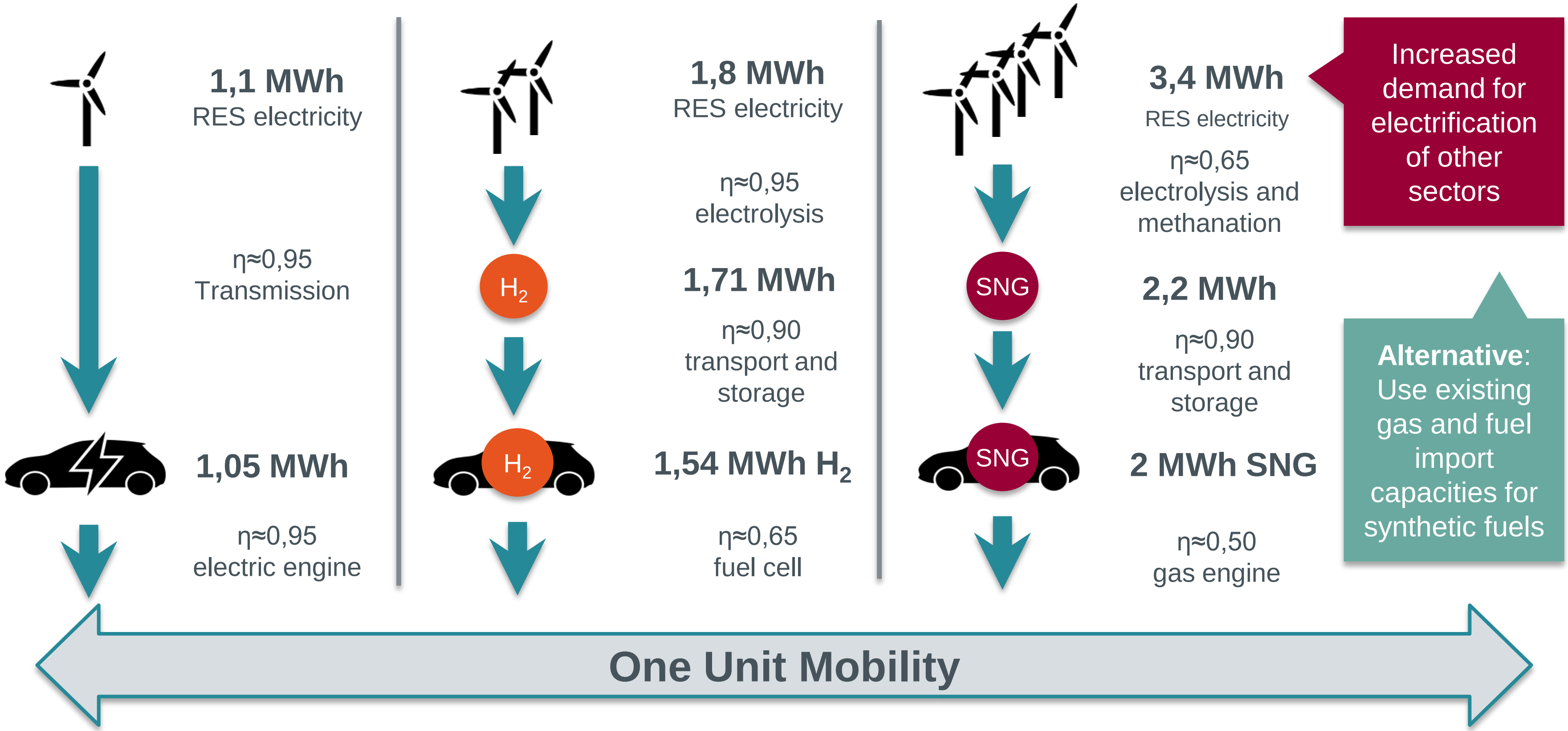
Daily load profile for 228 households in kW with different penetration rates for EV



A 100% idealised charging optimisation allows each household to use 4 EVs. However, this will be strongly limited by typical charging patterns.

Challenge IV

Direct electrification of the transport sector uses RES electricity most efficiently

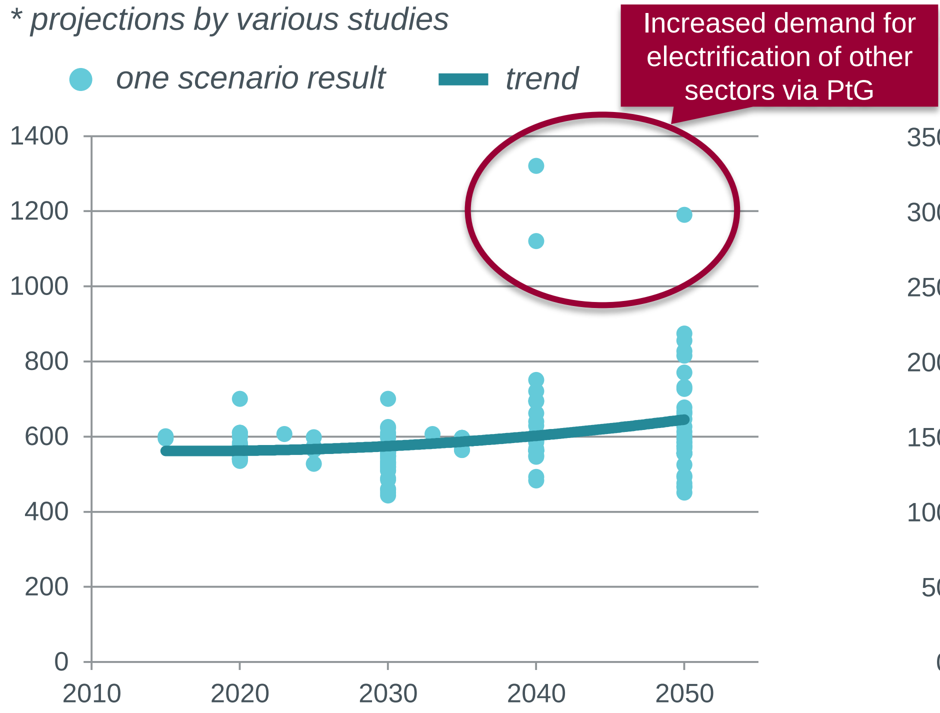


Direct electrification of the transport sector allows domestic use of RES-E capacities. PtG production may be more economically efficient overseas.

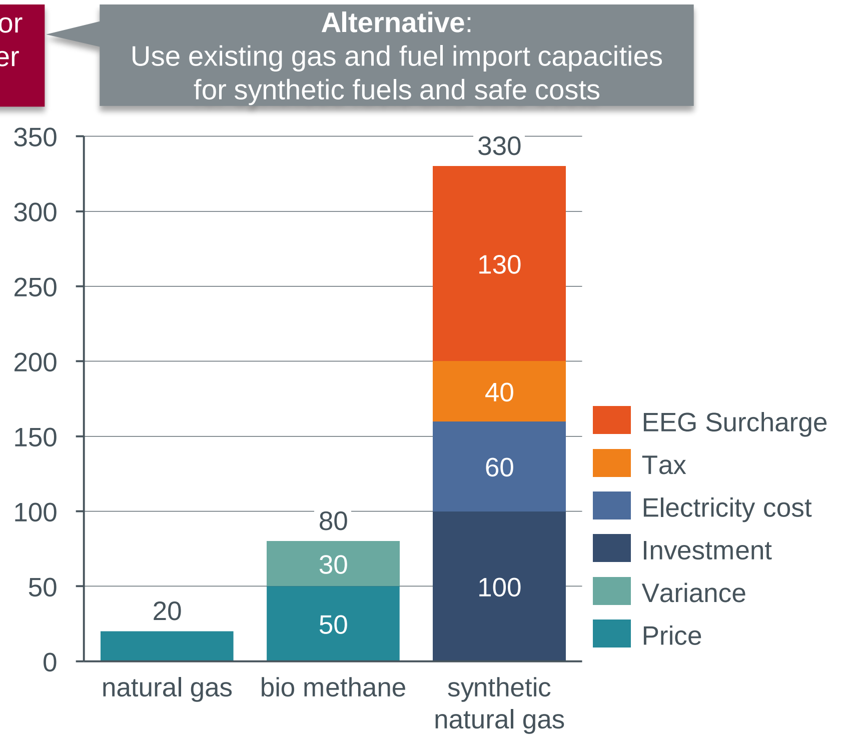
An increased total power consumption is expected for Germany in 2050

Total power consumption* in Germany in TWh

* *projections by various studies*



Gas prices and syn-gas cost in €/MWh in 2017



High estimates for national PtG production capacities increase the electricity demand significantly. Syn-fuel imports could reduce that and safe costs.

Source: ISI (2018); Dena (2017)

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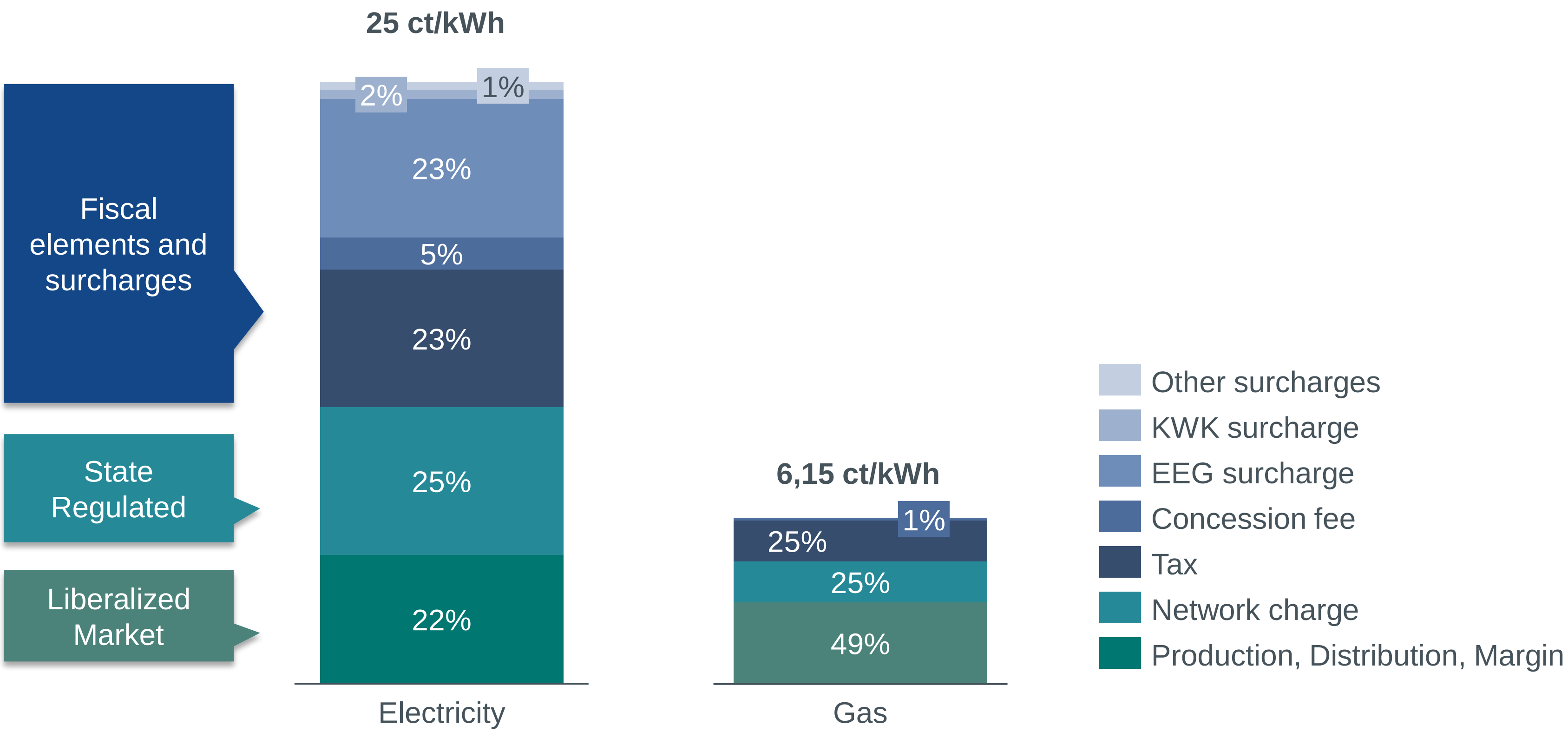
The financial burden for electricity reduces the potential for sector coupling on domestic level

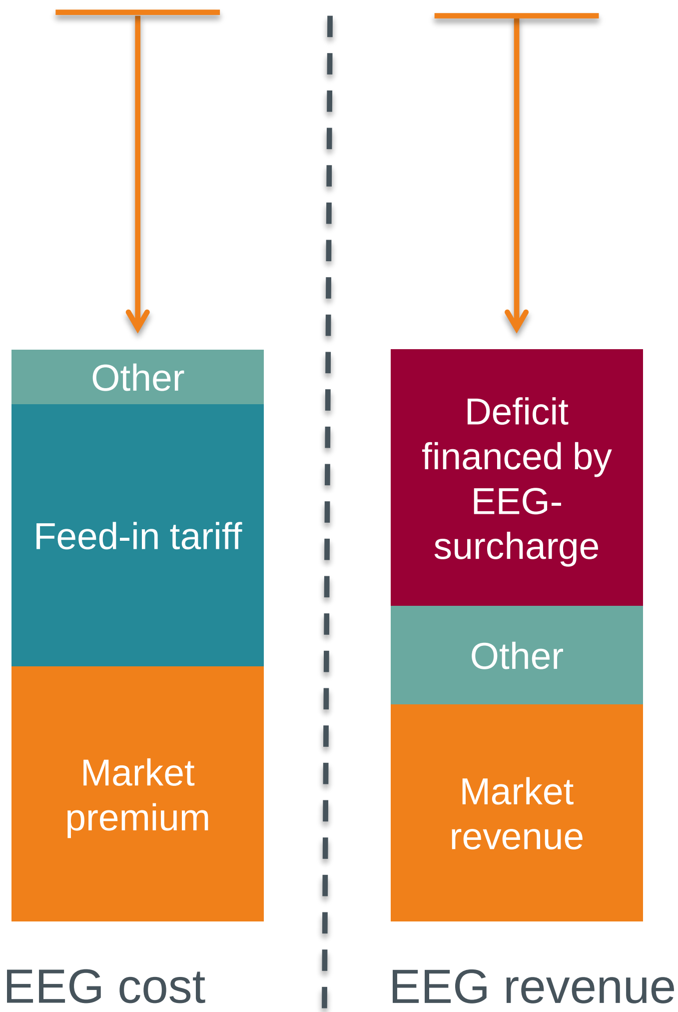
Elements of the energy bill for households* in 2017

** Consumption of 2500 - 5000 kWh (Electricity) und 5500 - 55.500 kWh (Gas)*



Option 1

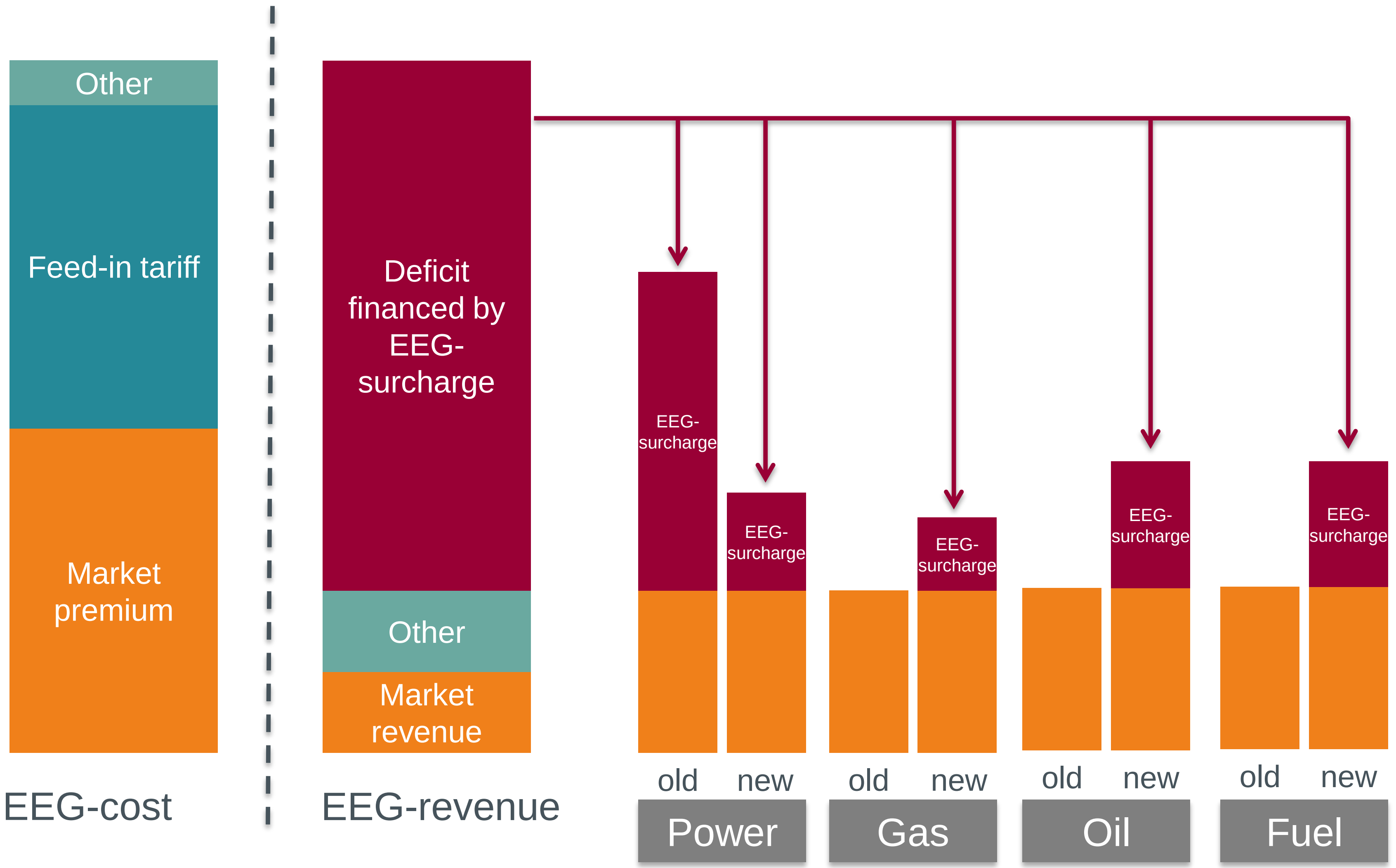
Introduction price floor or carbon tax for CO_2



- Introduction of a CO_2-price floor or a CO_2-tax of significant scale (> 75 €/t CO_2) would increase market prices
- In consequence:
  market **premium payments decrease**
  revenues from direct marketing **increase**
- EEG-surcharge decreases significantly
- Price distortions caused by EEG-surcharge would decrease

Option 2

Collection of EEG surcharge on other sources



Comparison of the two options

	Criteria	Option 1: CO_2-tax/ CO_2-price floor	Option 2: Distribution on other energy sources
Energy Economics	Reduction of inefficient incentives for self consumption	in part	depends on implementation
	Reduction of barriers for sector coupling	tax: yes floor: no	
	Introduction of new disincentives	if implemented only nationally	
Politics	Overall feasibility	internationally: difficult	challenging
	Fair cost distribution	depends on implementation	
Adminis-tration	Implementation		challenging

Ranking: positive; depends on implementation; negative

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Sector Coupling as an Enabler of Full Decarbonisation

- **For reaching 2050 climate goals, the different sectors of the energy system have to be integrated much further than today**
  This will have to be prepared in the years to come
- **Sector coupling could also address grid congestion issues; however, grid extension is still necessary**
  "Use not loose" with Power-to-Heat could reduce RES-E curtailment. However, economics are challenging (even if focusing on the macroeconomic view). Grid extension remains the cheapest option, as long as there is acceptance
- **Charging of electric vehicles does not necessarily lead to congestion in low voltage grids**
  But there will for sure be severe congestion if EV are charged in an uncoordinated manner or are controlled by wholesale prices only
- **Revision of EEG surcharge and other regulated cost necessary**
  Introduction of fiscal elements and expansion of EEG-surcharge on other energy sources can alleviate current distortions

Thank you for your attention!

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Dresden, 27.04.2018