The e-mobility revolution: impacts on the German power market and new business models

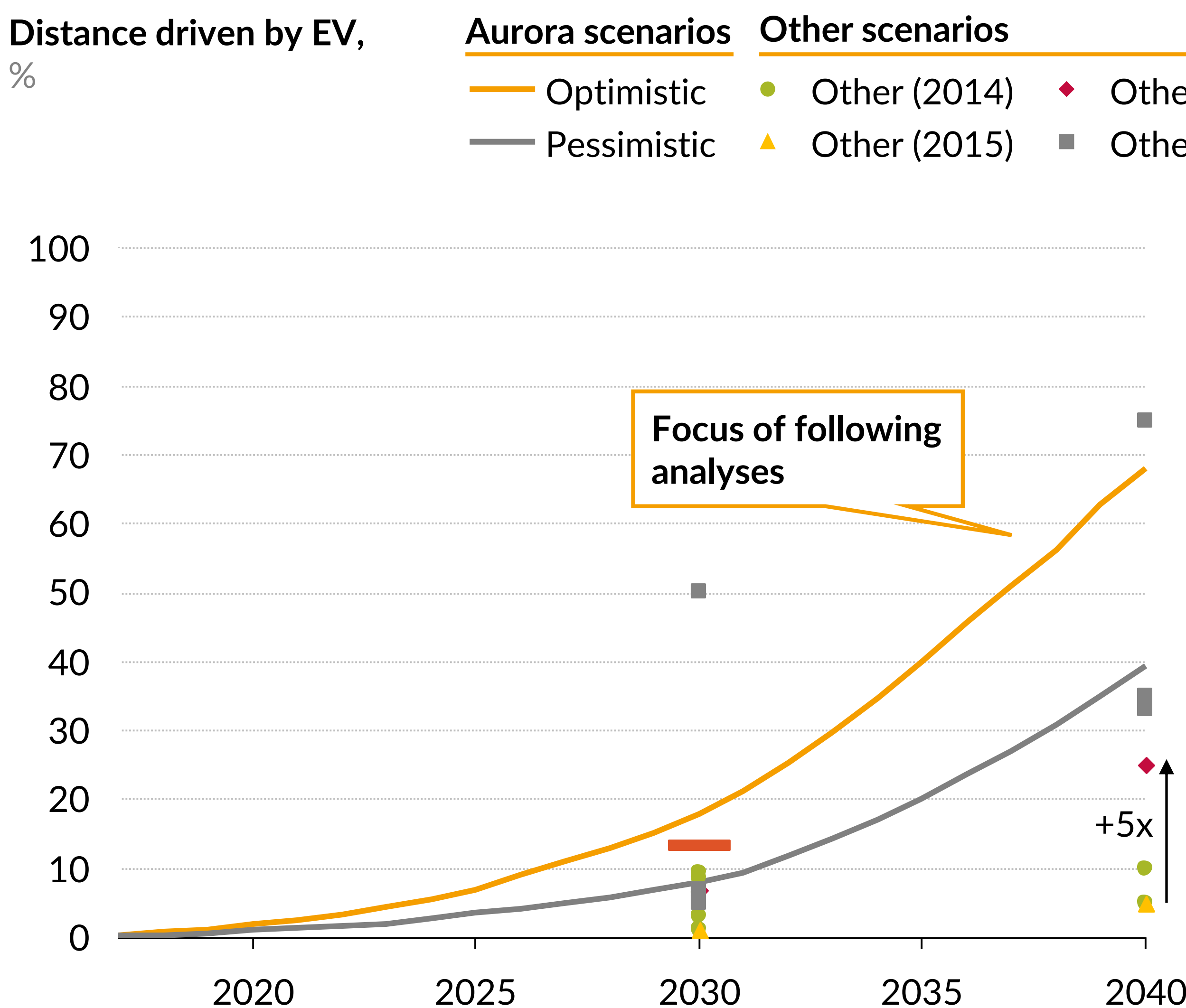
January 2018

Executive Summary

- **Context:** Electric vehicles (EVs) are likely to become the dominant individual transportation technology in the long run, driven by shifting consumer preferences, technological progress and government support
- **EV uptake in Germany:** EV penetration is likely to reach 20–40% of kilometres driven in 2035
- **Impact on power market**
  - EV uptake with smart charging has a limited impact on overall price, yet increases renewables capture prices by 5 EUR/MWh and raises baseload load factors by 13%
  - Unconstrained charging requires 5 GW of additional dispatchable capacity and high grid investment
  - If no further measures to phase out coal plants are taken, most of the power used to charge EVs is supplied by coal plants. The impact on emissions in Germany is nonetheless negative
- **Business models: New business models for utilities open up**
  - Time-of-use tariffs and partnerships with park site owners with cross-selling opportunities seem most promising and offer a good capability fit with utilities
  - The overall EBIT contribution of EV-related business models for utilities could be 500-700 m EUR per year

Source: Aurora Energy Research

For Germany, we expect a 40% EV penetration rate in 2035 in the Technology Optimistic case



- Over the past 3 years, EV forecast have continuously been revised upwards, primarily due to advancements in battery costs
- Based on our economic consumer switching model, we forecast almost 70% penetration in 2040 in the Optimistic case
- The Pessimistic penetration is based on slow battery cost trajectories and low petrol prices

Source: Aurora Energy Research, Shell, Öko-Institut, BMWi, BMVI, OPEC, BNEF

The optimistic case results in 31 TWh of additional power demand in 2035 in Germany

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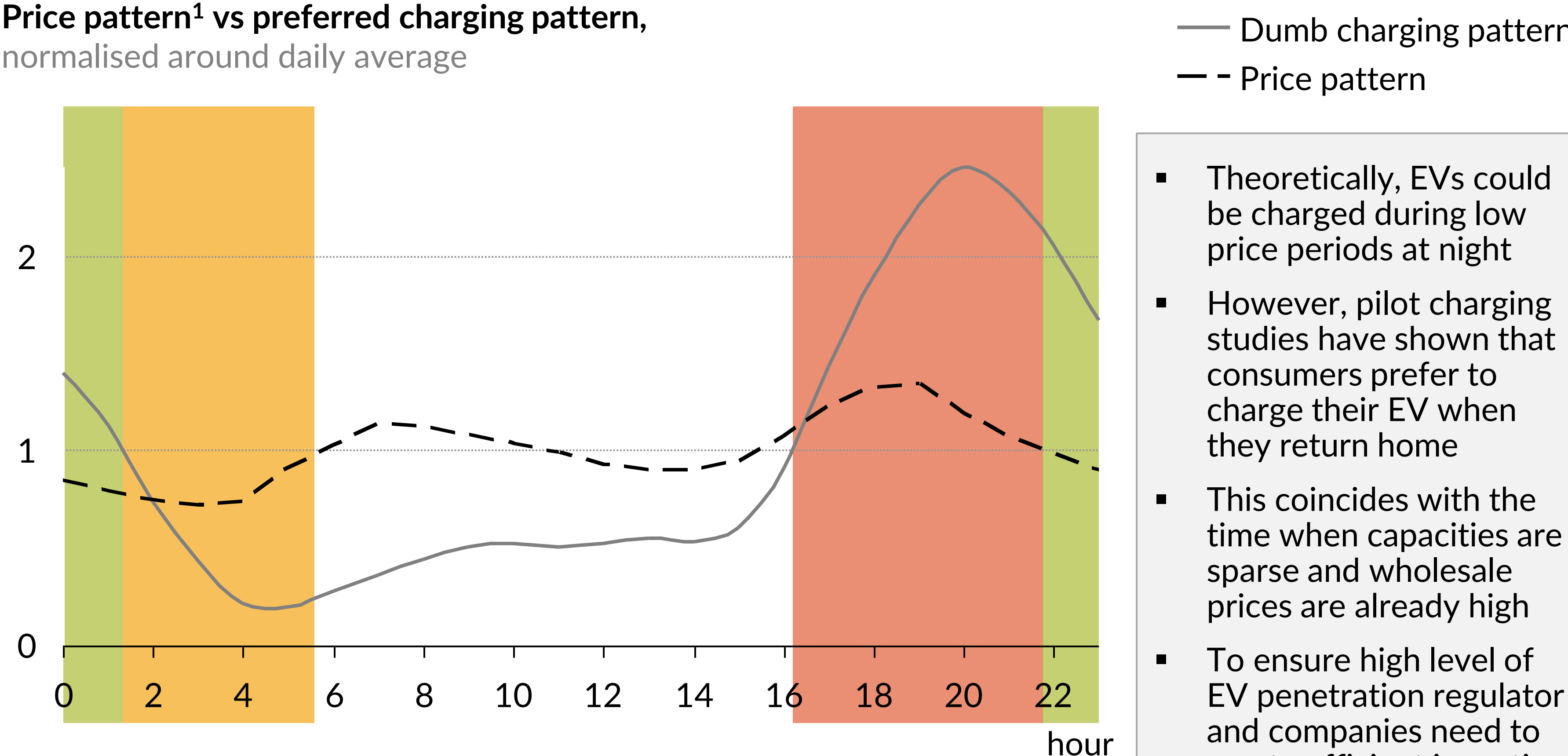
	2017	2020	2025	2030	2035	2040	Delta	Comment
# cars (Mio)	46	47	46	45	44	43	-7%	▪ Car sharing and autonomous vehicles result in higher utilisation with less cars
km/car/year (k)	14	14	14	15	15	16	+16%	
EV % of fleet	0%	2%	7%	18%	40%	70%	x875	▪ Economic consumer choice
kWh/ 100km	17	15	13	12	12	11	-34%	▪ Higher car efficiency
Demand (TWh)	0.1	2	6	15	31	52	x520	▪ 5% of total demand in 2035

Source: Aurora Energy Research, KBA, Shell, BMVI

EV integration could be easy as they could charge at night when prices are low, yet preference studies show a different picture

Price pattern[1] vs preferred charging pattern, normalised around daily average



✘ Inefficient: Consumer preference for charging but prices high

✓ Efficient: Charging preference coincides with low price period

✘ Inefficient: Little charging preference but low prices

- Theoretically, EVs could be charged during low price periods at night
- However, pilot charging studies have shown that consumers prefer to charge their EV when they return home
- This coincides with the time when capacities are sparse and wholesale prices are already high
- To ensure high level of EV penetration regulator and companies need to create efficient incentive systems for system optimal charging

1. Price pattern based on 2025 without impact of EV.

Source: Aurora Energy Research, National Grid

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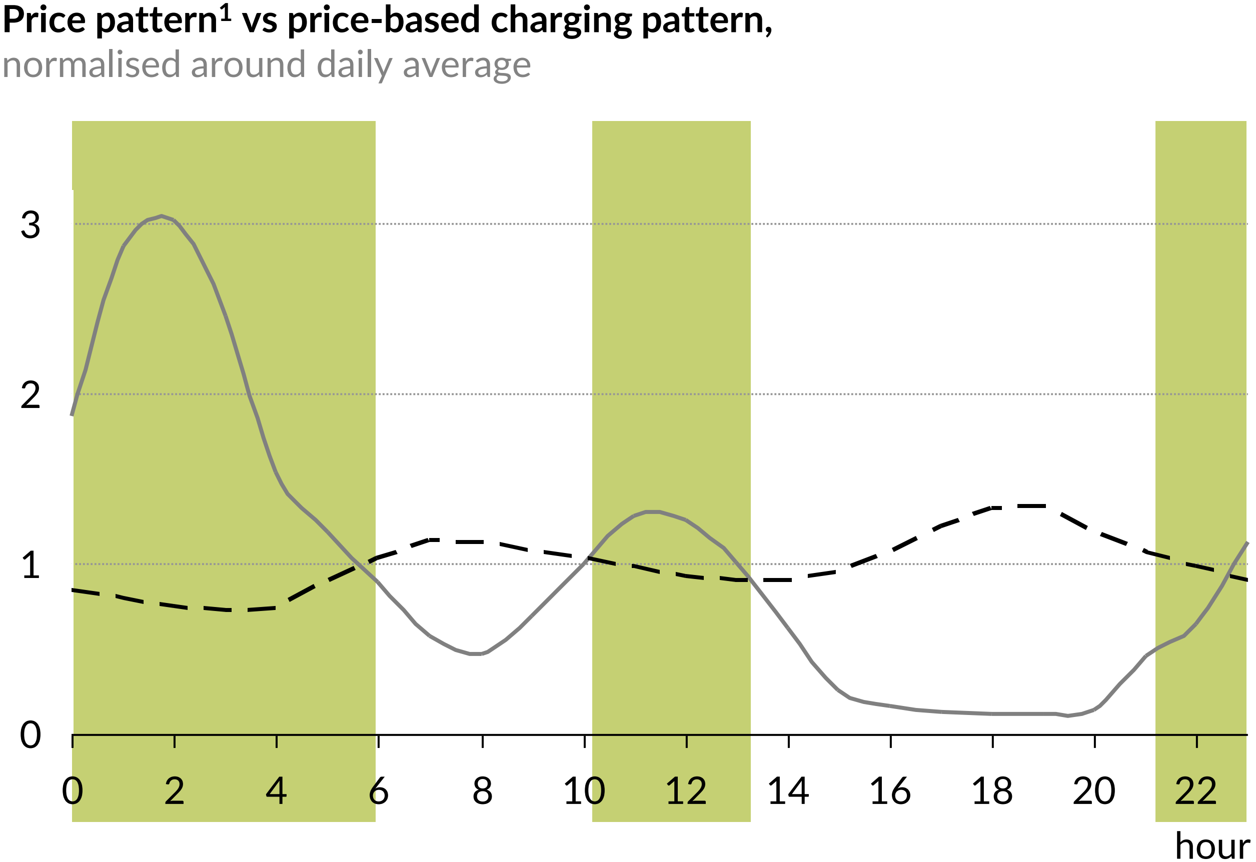
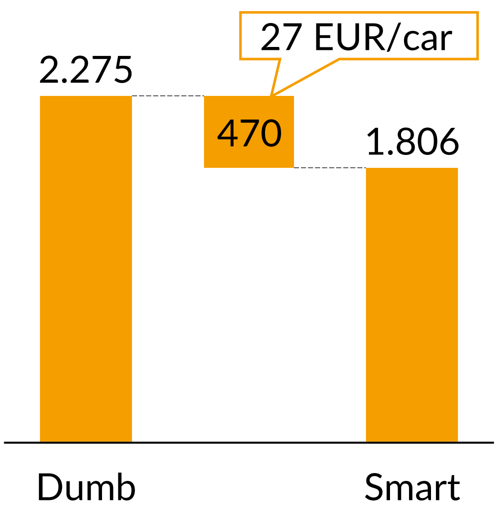
The problem can be addressed by time of use tariffs or real time pricing, incentivising EV to charge when price is low

Price pattern[1] vs price-based charging pattern,
normalised around daily average



Wholesale cost EV charging,
EUR m, 2035



✓ Efficient: Charging preference coincides with low price period

1. Price pattern based on 2025 without impact of EV.

Source: Aurora Energy Research, National Grid

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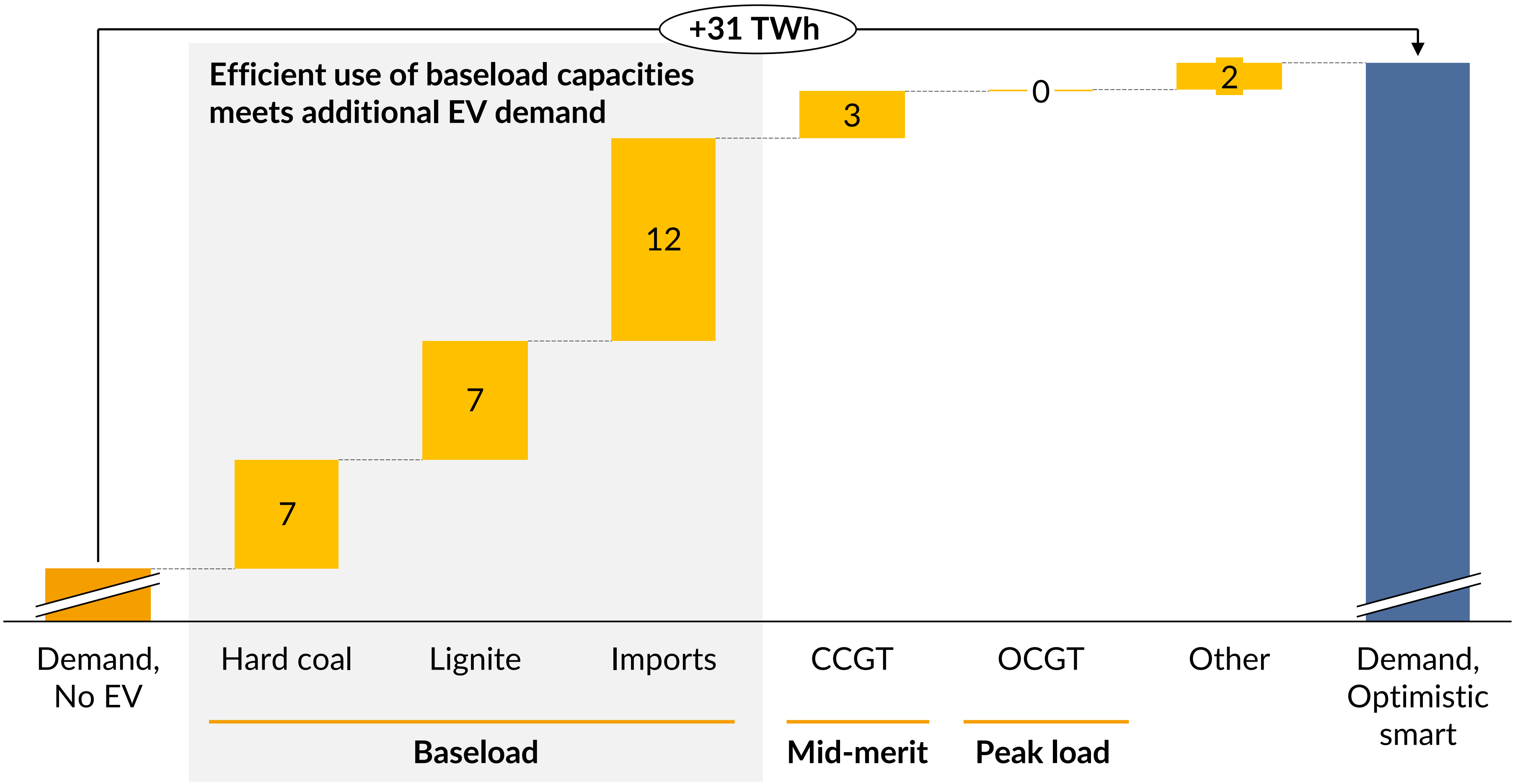
EV penetration of 40% adds more than 30 TWh to demand, which will be met by higher utilisation of coal plant and imports

Yearly generation 2035,
TWh

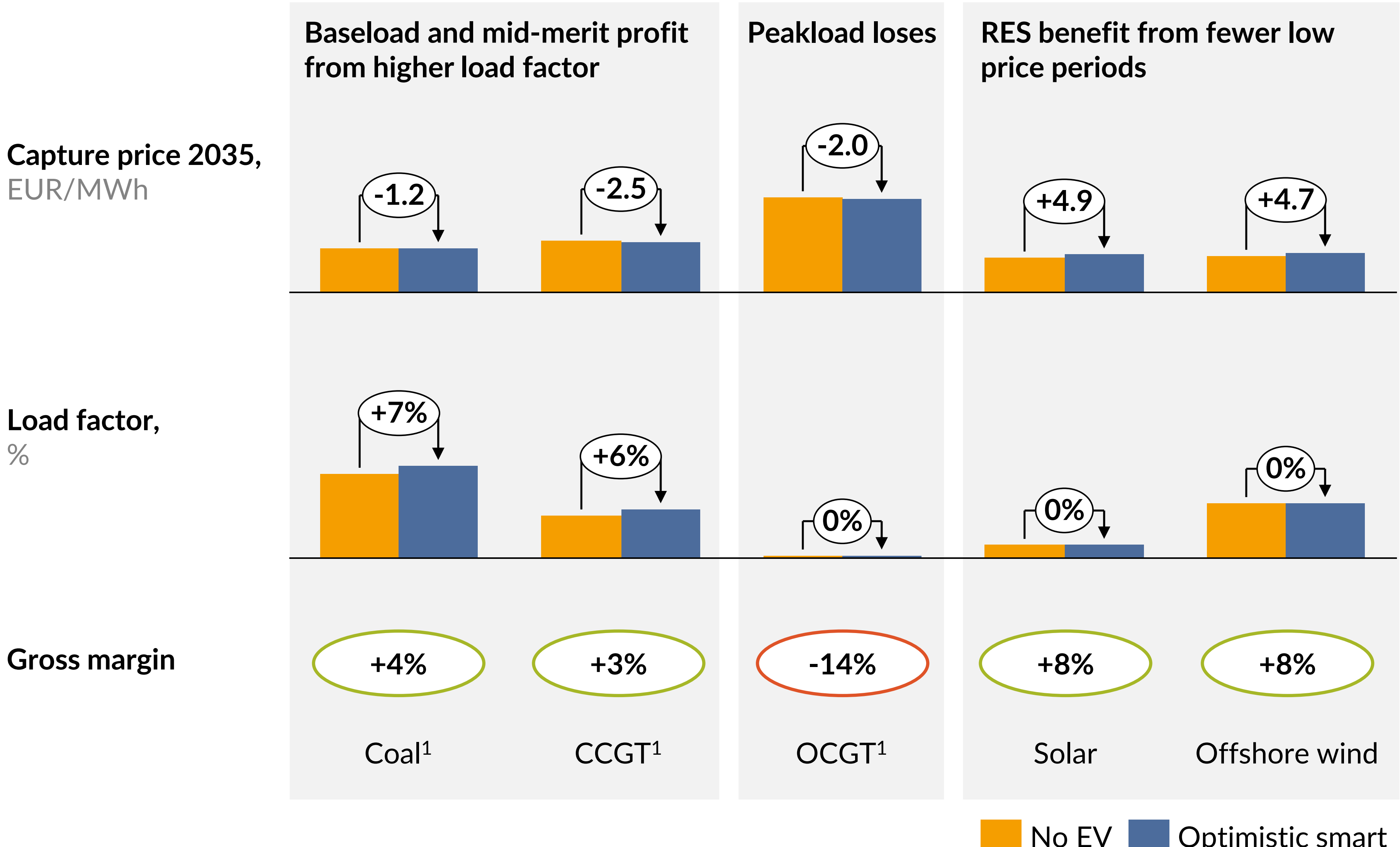


This analysis does not assume policy-driven coal exit and endogenous RES buildout. Imports are from all neighbouring countries but primarily coal. EV case assumes similar buildout in neighbouring countries, 50% slower in Poland and Czechia.

Source: Aurora Energy Research

Optimistic smart

This increases gross margins for renewables and baseload thermal while flexible capacities lose out



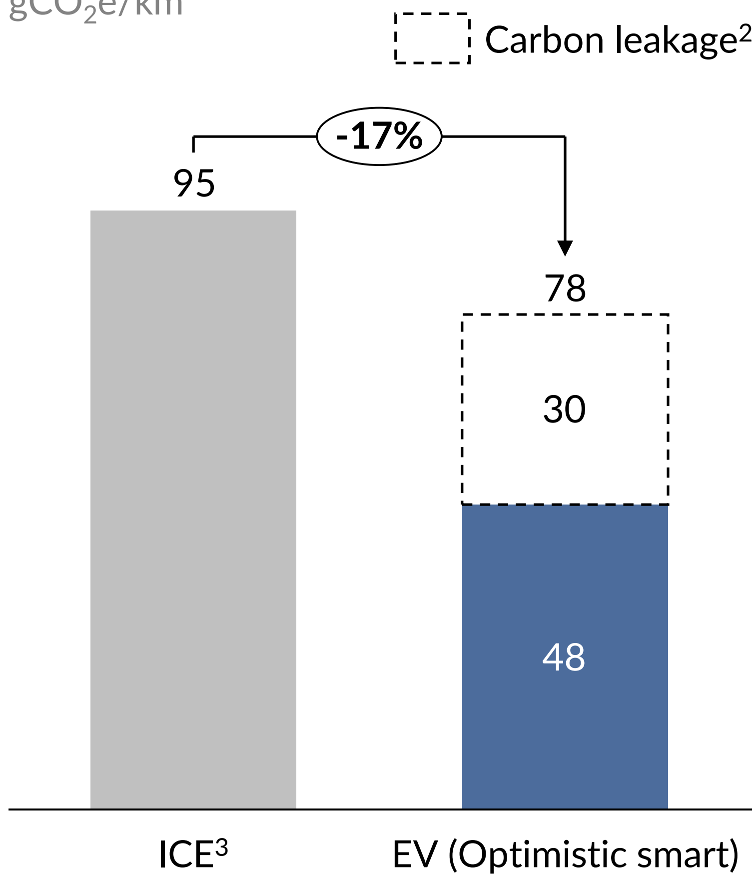
1. Coal with 36% HHV efficiency, CCGT with 53% and OCGT with 35%.

Source: Aurora Energy Research

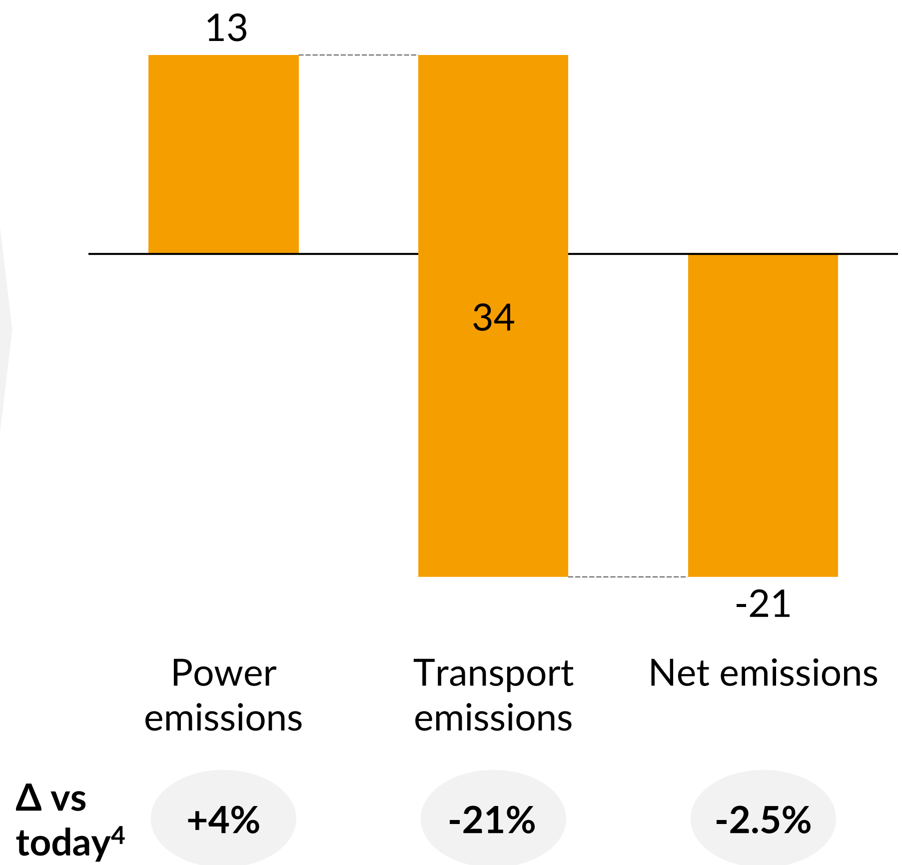
Optimistic smart

Despite coal providing share of power for EVs, emissions are reduced by 21 MtCO2 in 2035

Average emissions per km driven 2035[1],
gCO_2e/km



Change in German emissions 2035,
$MtCO_2e$



1. Does not include CO2 emissions during vehicle production. 2. In power sector. 3. 2020 Targets, actual emissions might well be higher than reported levels. 4. In 2015.

Source: Aurora Energy Research, UMB, DEKRA, KBA

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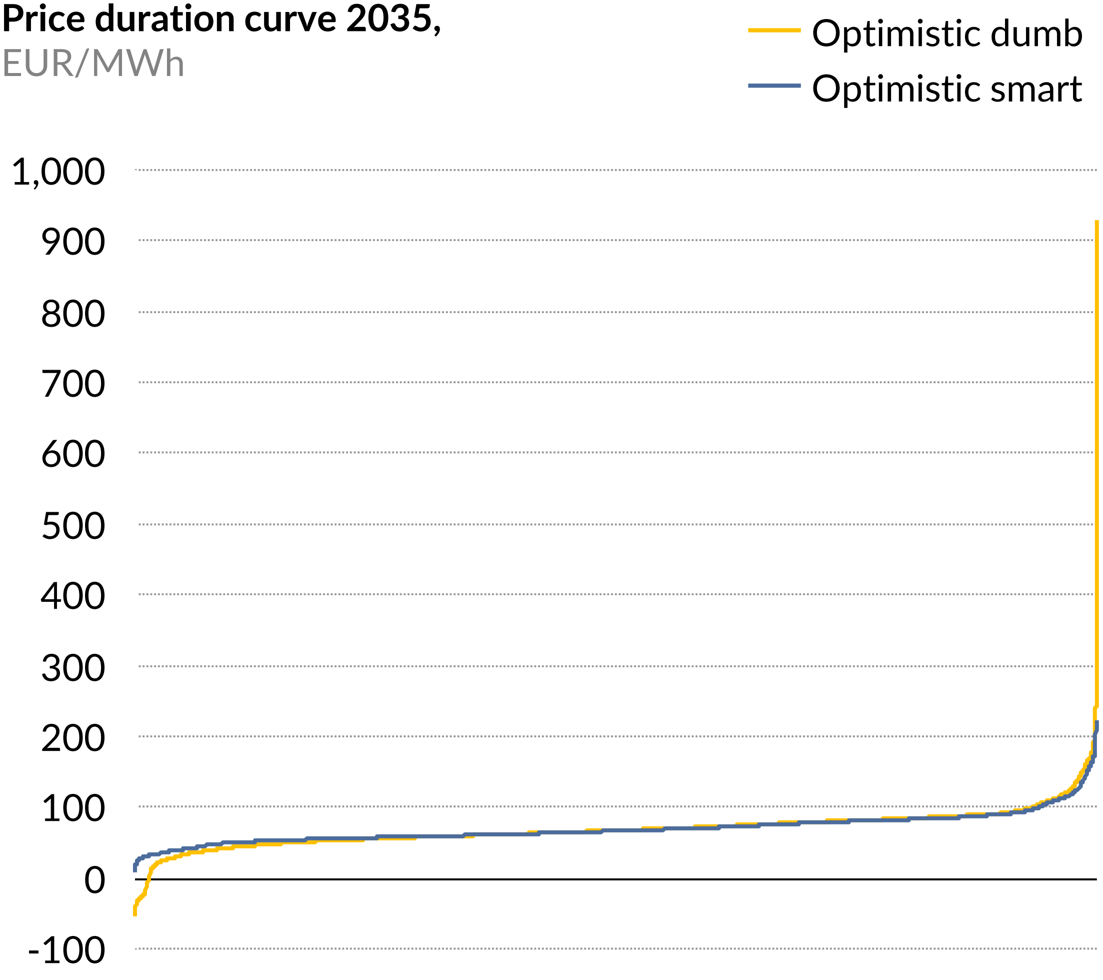
If integrated in a dumb way, peak residual demand increases, requiring 5 GW more capacity and causing higher prices

Price duration curve 2035, EUR/MWh



If EVs are integrated in a dumb way …

1. Peak residual demand increases by 8.5 GW
2. 4 GW of hard coal and 1 GW of CCGT stay longer on the system
3. Peaking and flexible generation gross margins increase by 157%
4. Renewables gross margins decrease by 6%
5. 2030 emissions are increased by 5% compared to smart

Source: Aurora Energy Research

Flexible RES buildout, smart EV integration and supporting EV penetration are main implications for policy-makers

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Main findings	Policy implications
1 Smart integration of EV has range of benefits ▪ Lower demand volatility decreases network costs ▪ Lower capacity requirements decreases system costs	▪ Set political framework to enable time of use or optimised charging, e.g. smart meter rollout, hourly settlement, smart enabled chargers ▪ Potentially enable fast grid expansion
2 EV emits less than combustion engine ▪ Higher efficiency decreases emissions, even if coal produces additional power ▪ Benefit especially large with additional renewable build-out	▪ Support EV penetration to reach climate targets and decarbonise transport sector
3 EV supports market driven renewables build-out ▪ Smart integration would lead to charging during hours with lowest prices ▪ This primarily reduces price cannibalisation in higher RES scenario	▪ Set framework for market driven renewables buildout to avoid inefficient capital allocation

Source: Aurora Energy Research

New business models for utilities are emerging to capture this opportunity, only some of them seem lucrative

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Value chain steps

Generation → Transmission → Retail → Charging → After sales

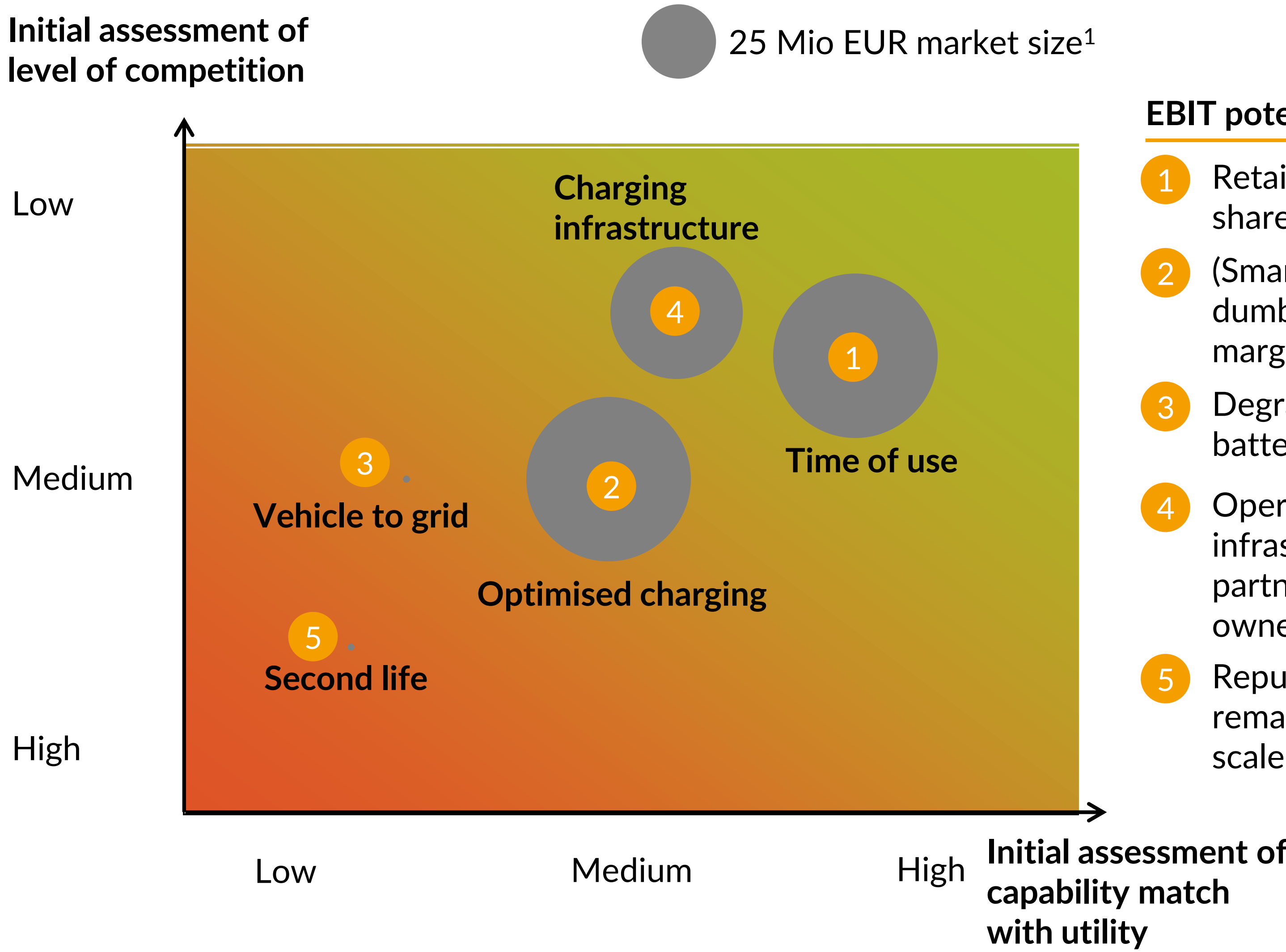
Generation: Analysed above

Transmission / Retail: 4 · Retail: 1 · Charging: 2, 3 · After sales: 5

Business model		Description	Example
1	Time of use tariffs (TOUT)	▪ Offers power tariffs to EV owner ▪ Customer benefit from lower power price during off-peak hours (TOUT)	polarstern
1 + 2	Optimised charging (DSR)	▪ Optimises EV charging remotely, comparable to DSR ▪ Customer benefit from discount on power price	PlanB
1 + 2 + 3	Vehicle to grid	▪ Optimises charging & discharging to grid, comparable to battery ▪ Customer benefits from additional discount on power price	parker
4	Charging infrastructure	▪ Owns and/or operates on-street and motorway charging points capturing payments for use of infrastructure & power sale ▪ Cross-selling or petrol station model	Tesla, allego, IONITY
5	Second life batteries	▪ Purchases second life battery to use for grid or power market applications at a cost advantage to new batteries	Digital Energy Solutions

Source: Aurora Energy Research

Time of use tariffs and optimised charging are most attractive for utilities due to market potential and capability match



EBIT potential

1. Retail margin x household share of EV consumption
2. (Smart wholesale revenue – dumb wholesale revenue) x margin
3. Degradation costs EV battery likely > grid battery
4. Operating charging infrastructure in partnership with car park owner (cross-selling model)
5. Repurposing costs + remaining value likely < grid scale battery

1. EBIT in 2035.

Source: Aurora Energy Research

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