TECHNISCHE UNIVERSITÄT DRESDEN

Chair of Energy Economics, Prof. Dr. Möst

The role of grids and storage for renewable integration

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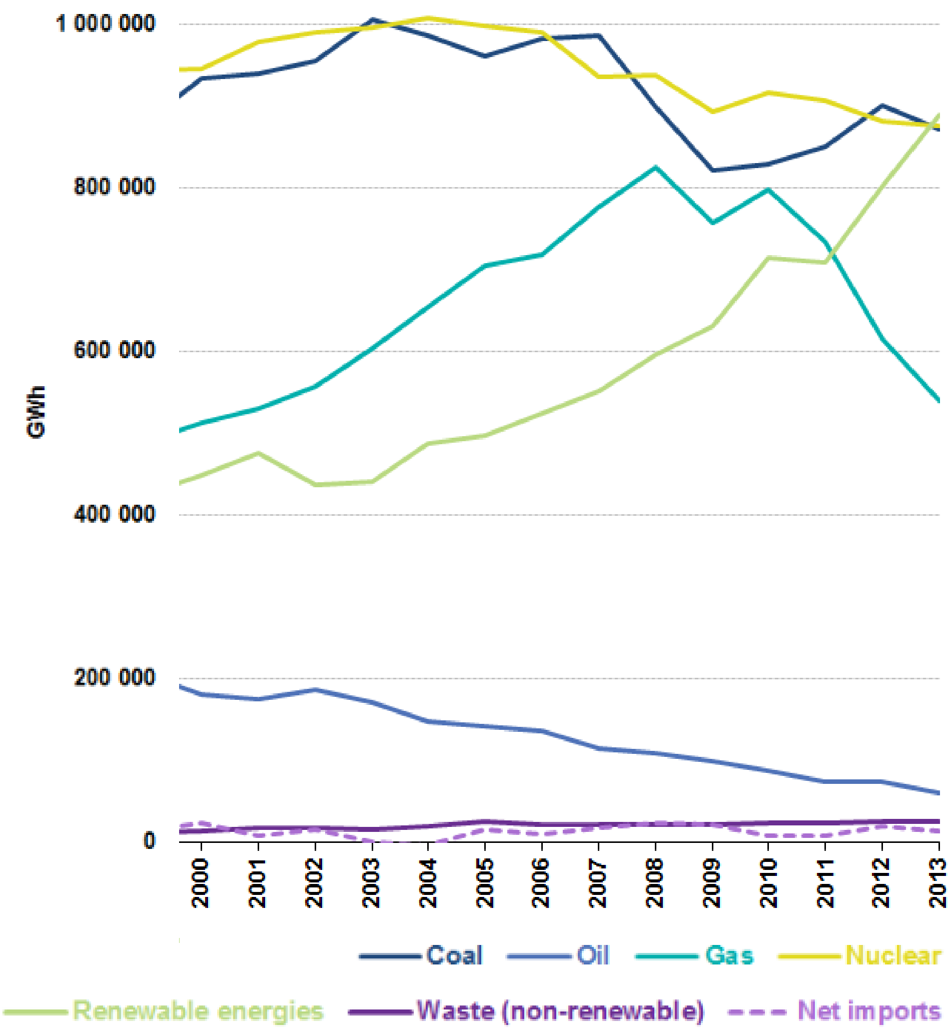
Dual Plenary II: New designs in electricity markets

IAEE Wien - „HEADING TOWARDS SUSTAINABLE ENERGY SYSTEMS: EVOLUTION OR REVOLUTION?”
04.09.2017

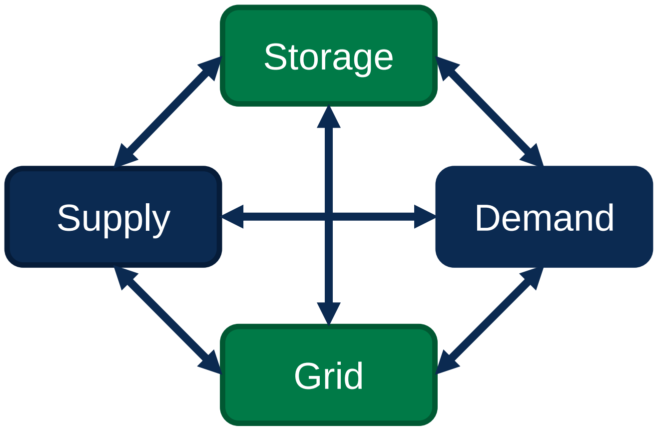
Prof. Dr. Dominik Möst, TU Dresden

Increasing amount of intermittent renewables

Electricity production in Europe



- Installed capacity of renewable energy sources (RES) will increase in Europe (and worldwide)
- Flexibility need will grow
- Several options can provide flexibility:



Source: Eurostat

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1	**Graphical analysis: optimal capacity and long-term merit order effect**
2	Model based analysis: trade-off between grid and storage capacities
3	Market zones, grid extension and the impact on congestion management
4	Some final thoughts

Hours with surplus renewable feed-in will increase

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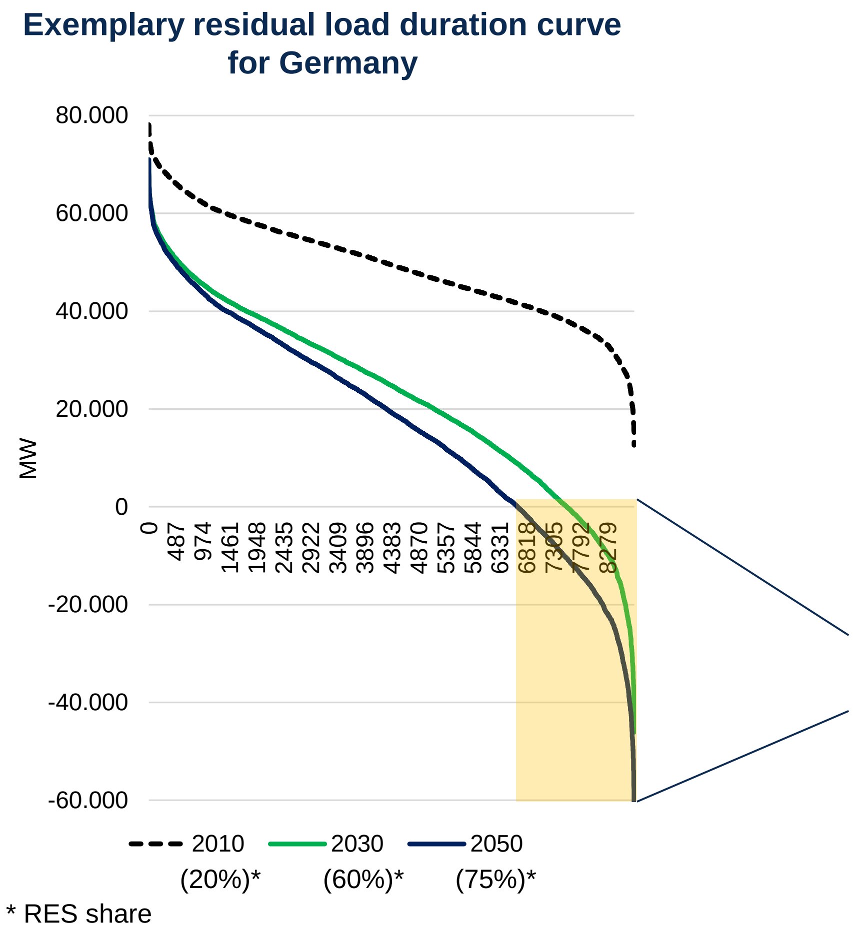


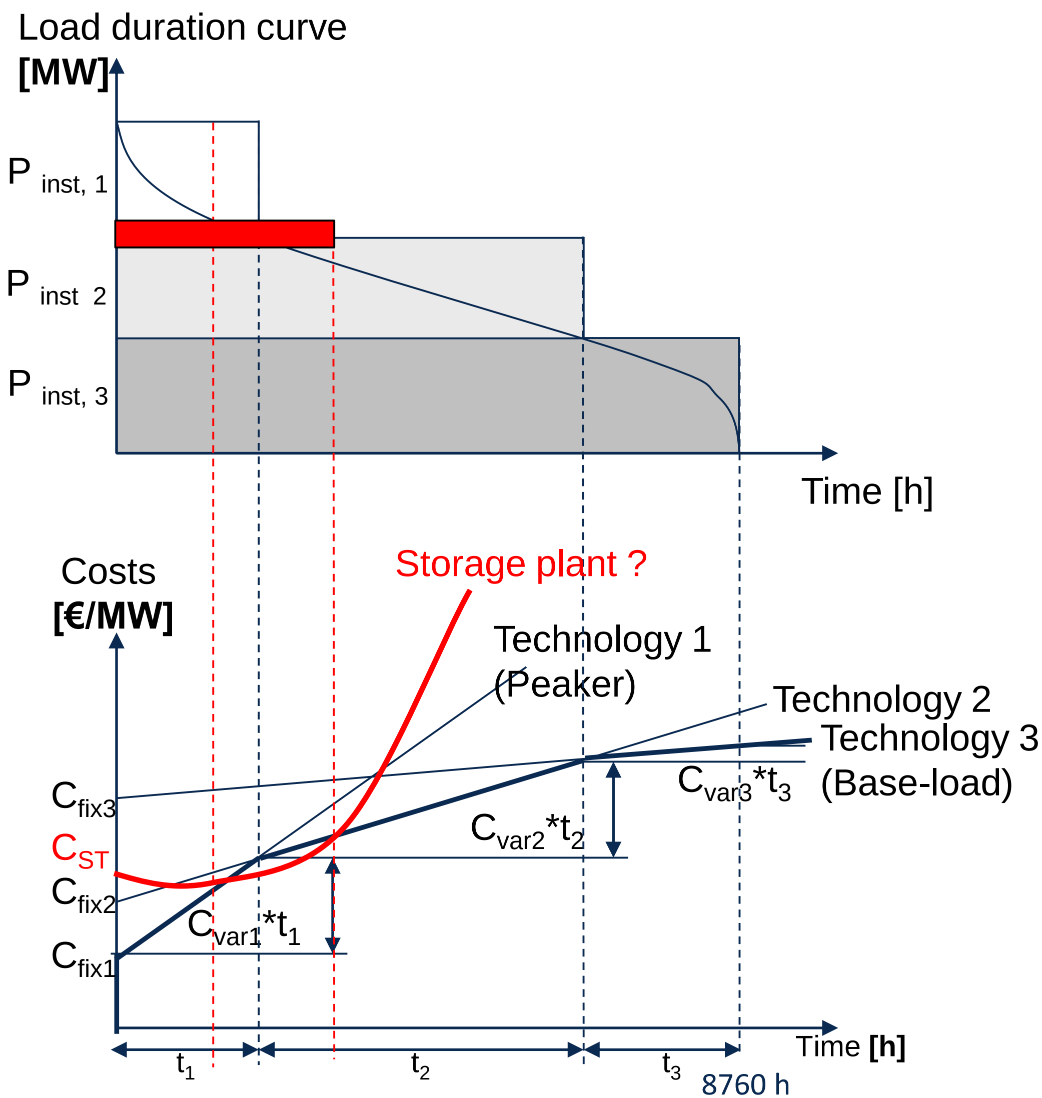
The integration of renewable energy sources (RES) significantly influences the residual load:

- Number of hours with negative residual load rises
- Surplus of RES feed-in increase
- Level of maximal negative residual load grows

What to do with the surplus?

➢ **Store, export or curtail?**

Simple (graphical) capacity model



Illustrative model

- Simplified visualisation of necessary capacities in steady-state

Optimal capacity in long-term equilibrium

- Assumption:
  - Immediate adaption to optimal power capacities
  - No congestions in the considered system
  - ….

System perspective
Adaptation of „optimal“ capacity?

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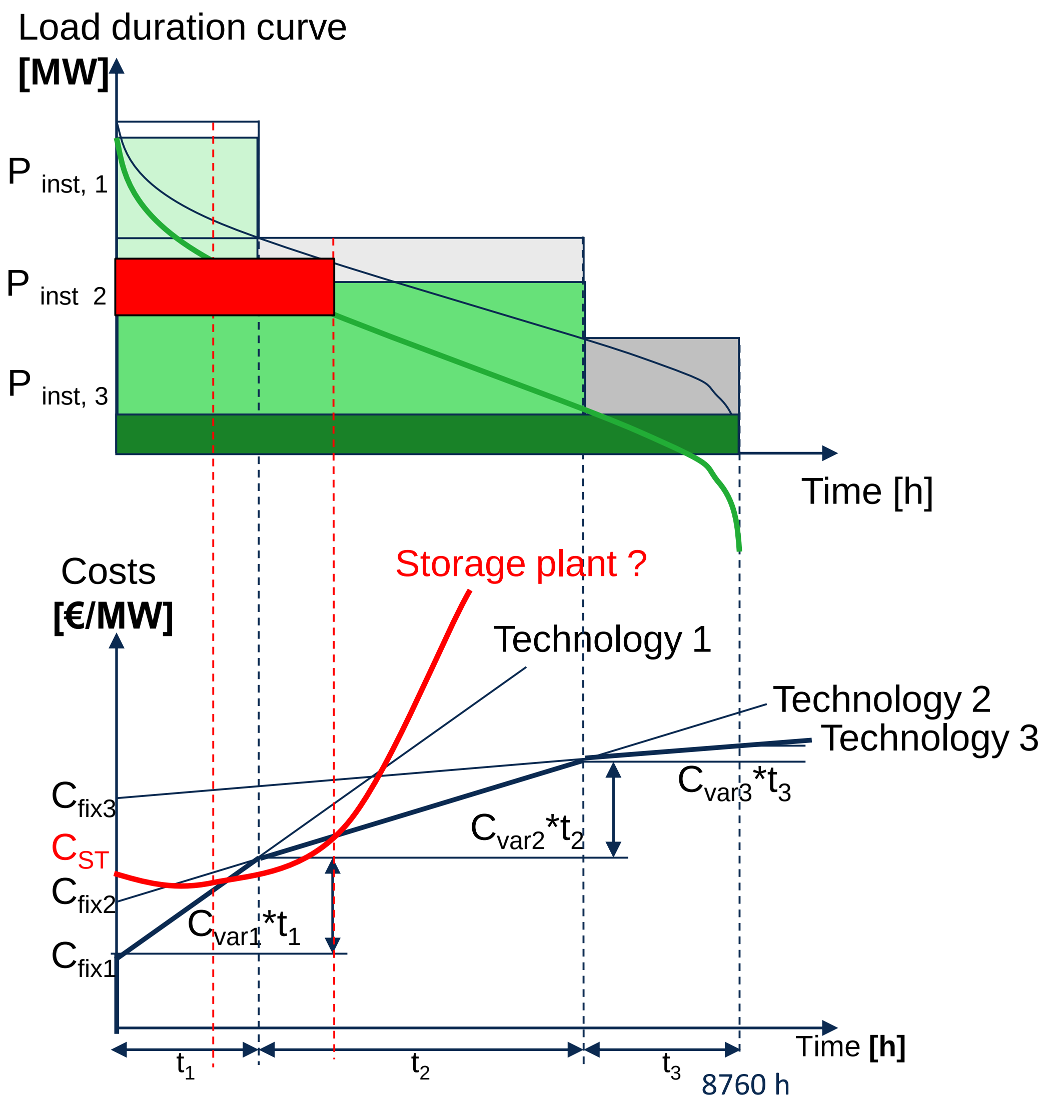


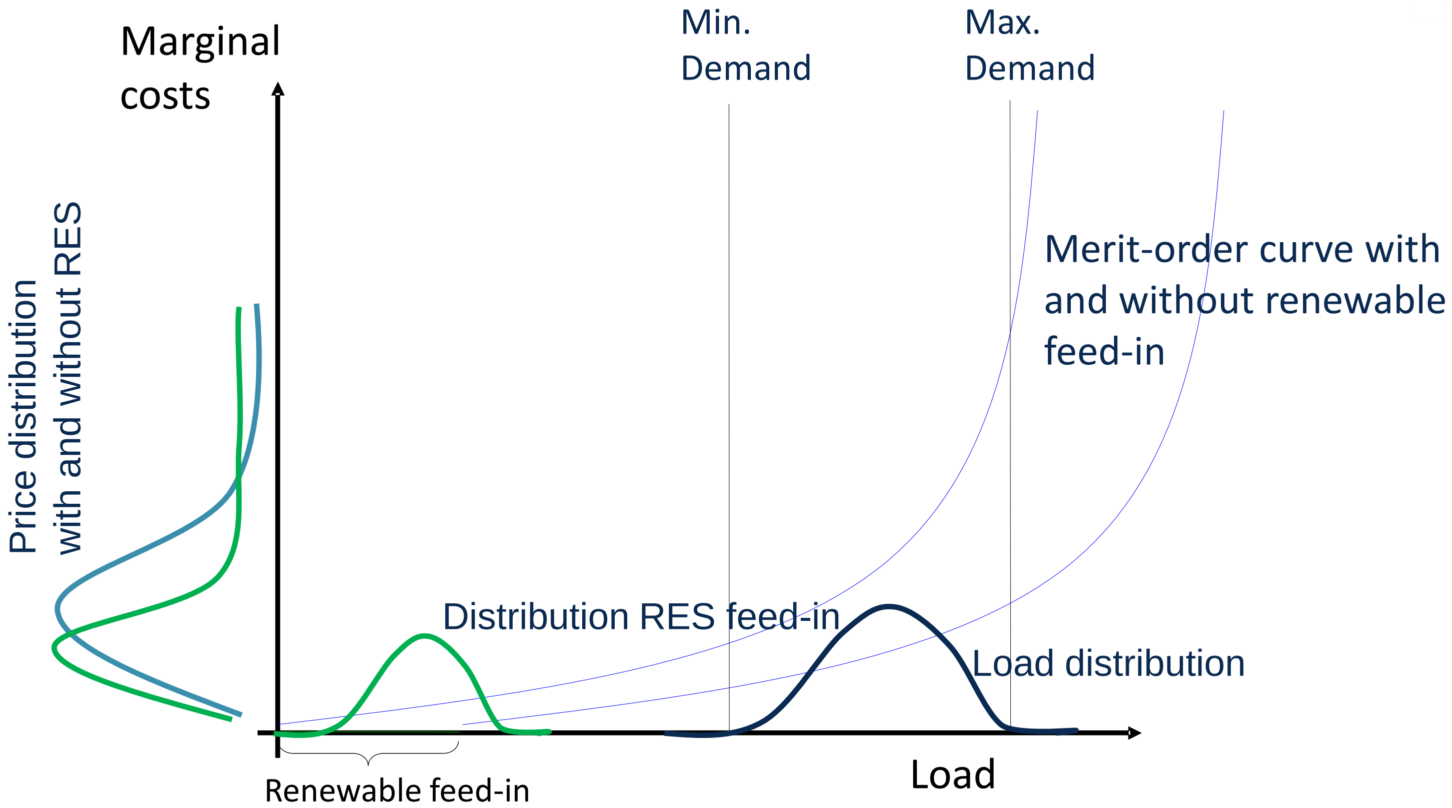
Necessary generation portfolio – what will change?

- Reduction of base-load and mid-load
- Increase of peak-load
- Increase of storage power plants

What to do with the surplus?

- Store
  - Decreases variable production costs (as surplus will probably be „cheap“)
- Export
- Demand Side Management *(Smart Market)*
- Curtail surplus

Schematic merit-order effect and impact on price distribution

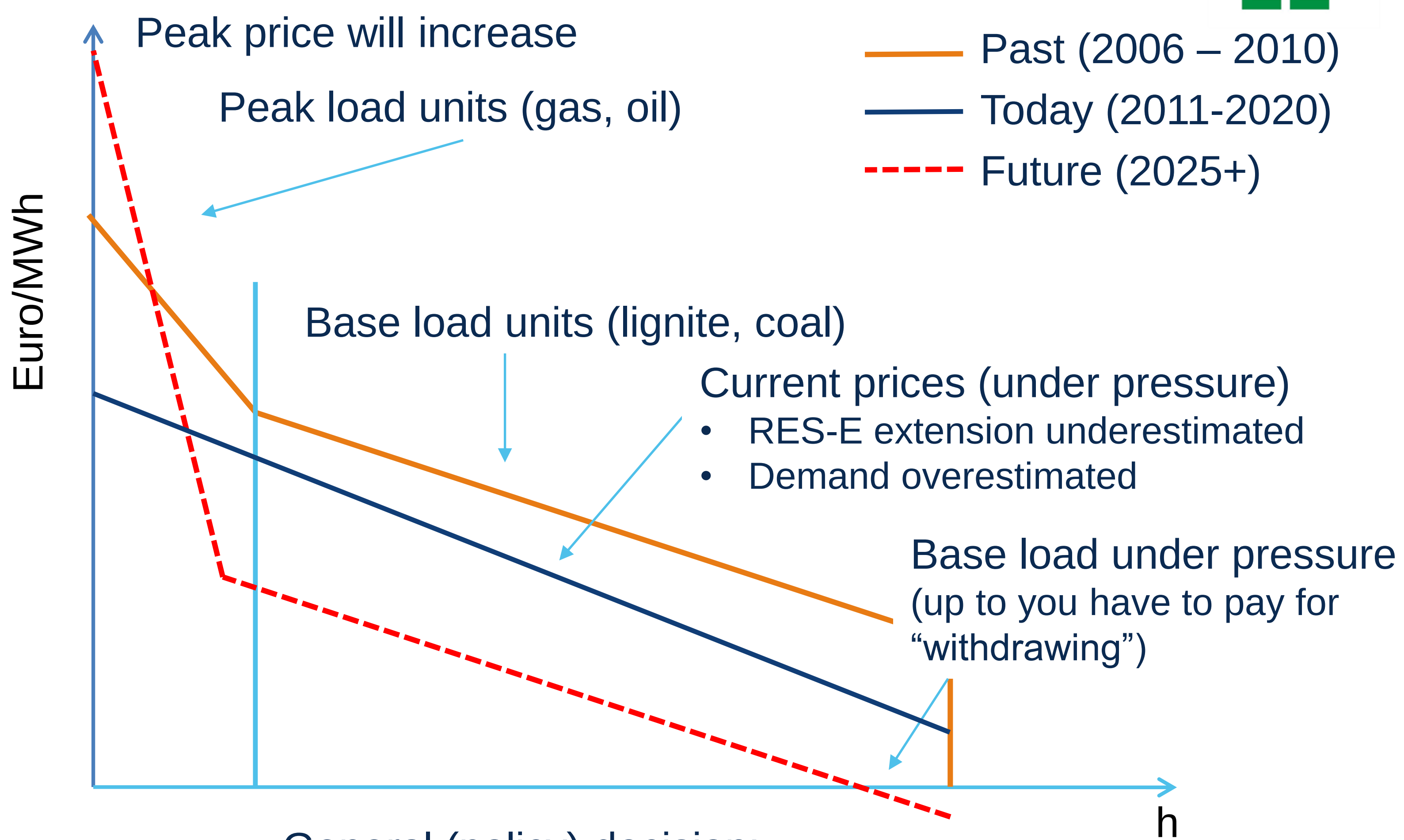


- Self-marginalisation with high shares of renewables (e.g. 100 GW PV)
- Speed of change/RES extension and expectations for subsidies prevent a market equilibrium!

=> Further incentive schemes for renewables are necessary!

Impact on the price duration curve

The merit-order effect of renewables (long-term effect)



General (policy) decision:
Correct scarcity pricing signals
versus
a regulated capacity "market" (resulting in a cut-off of extreme price peaks)?

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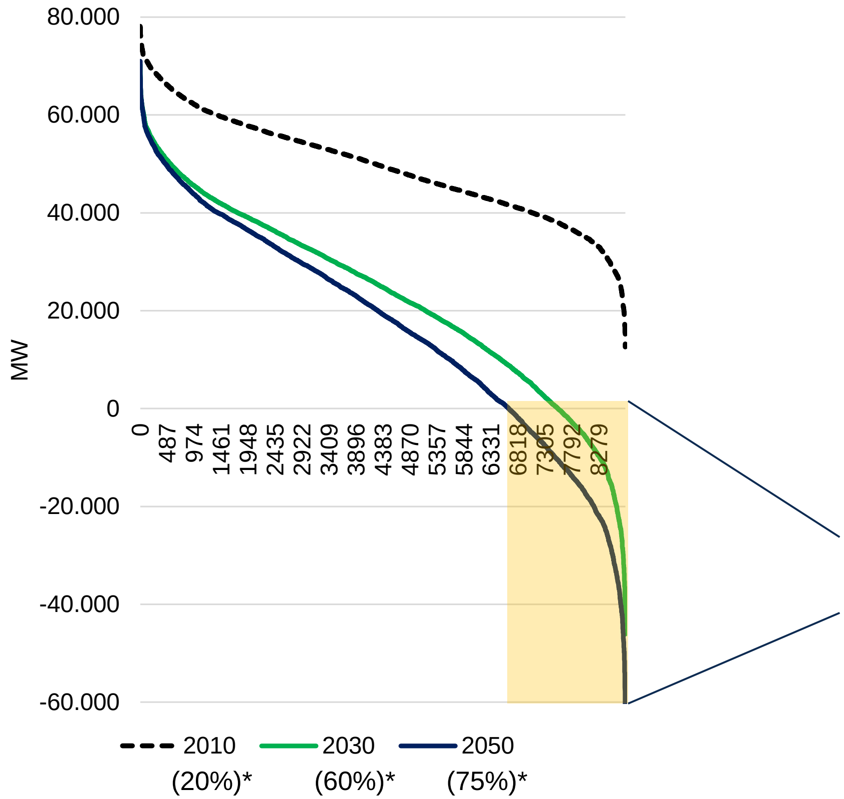
2 **Model based analysis: trade-off between grid and storage capacities**

3 Market zones, grid extension and the impact on congestion management

4 Some final thoughts

Hours with surplus renewable feed-in will increase

Exemplary residual load duration curve for Germany



* RES share

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- Surplus of RES feed-in increase
- Level of maximal negative residual load grows

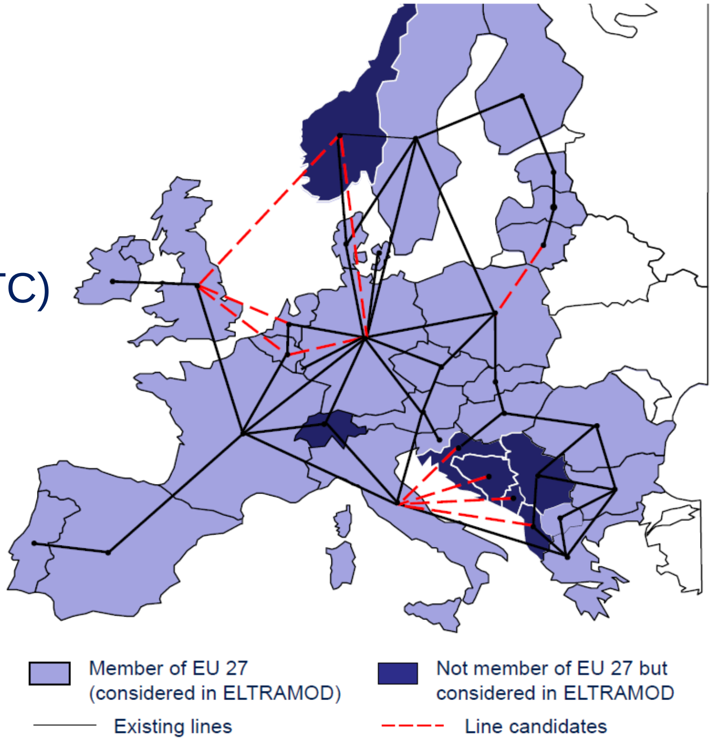
What to do with the surplus?

➢ **Store, export or curtail?**

Electricity system model **ELTRAMOD** to analyse the interdependence between storage need, grid extension and renewable curtailment

Model purpose

- Fundamental system model / bottom-up model
- Integration of renewable energy sources (RES) in the European energy system
- Flow calculation based on Net Transfer Capacity (NTC)
- Trade-off between grid and storage extensions
- Combined investment and production planning



Main characteristics

- Temporal resolution of 8760 hours
- Calculation of the cost-minimal generation dispatch and investments in additional transmission lines and storage facilities
- Country specific times series of wind and PV feed- in

Grid and Storage Extensions in Europe till 2050

An application of ELTRAMOD for the
Energy System Analysis Agency (www.esa2.eu)

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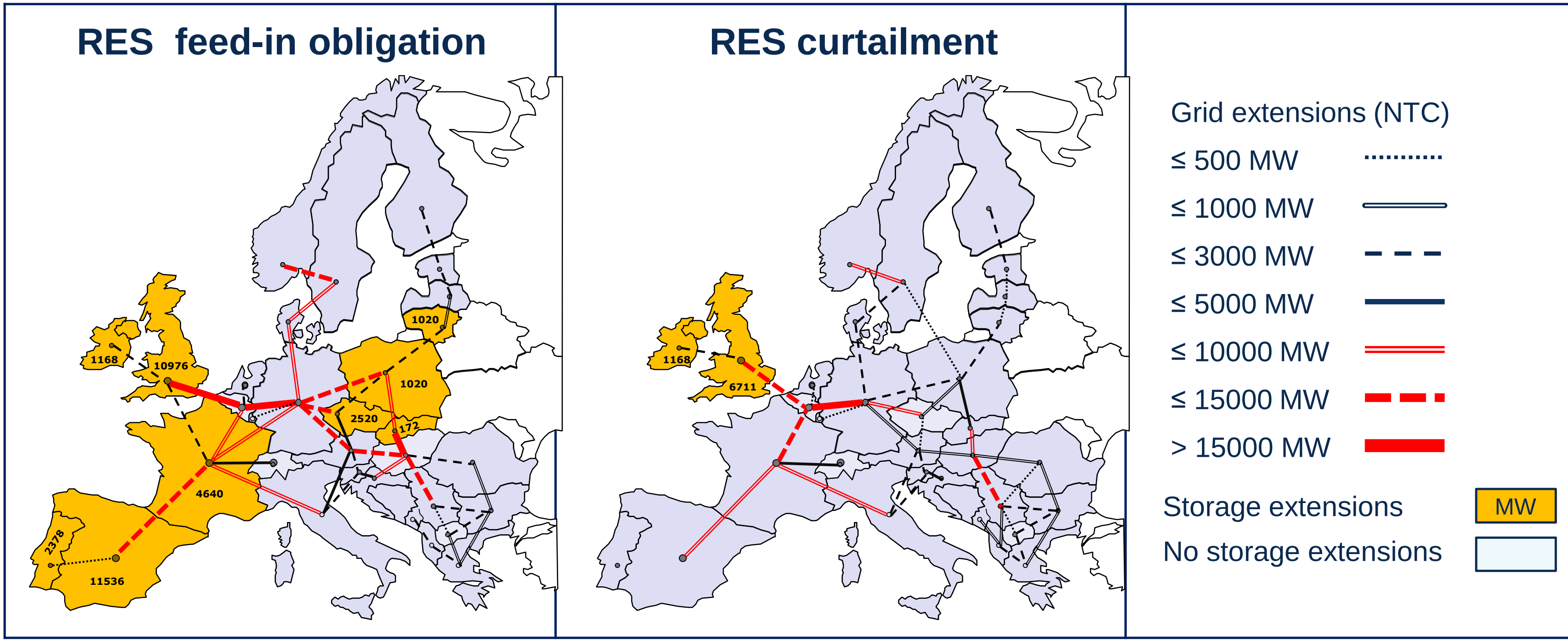

- **RES feed-in obligation:** every available unit of RES has to be integrated
- **RES Curtailment:** the surplus of RES supply can be curtailed

=> *RES priority feed-in significantly influence the need of further storages and transmission capacities.*

Removing the feed-in obligation and its impact on grid and storage extension

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	feed-in obligation	curtailment
Non integrated RES surplus supply without grid and storage extensions	10.2%	11.9%
Non integrated RES surplus supply with grid and storage extensions	0.9%	3.7%
Additional transmission capacities up to 2050 (NTC)	252.2 GW	143 GW
Additional storage capacities up to 2050	35.7 GW	7.9 GW

- Mandatory feed-in versus curtailment has a low impact on integrated RES generation

  => *However: significant difference for grid and storage extensions settings*

Central statement:

- From the economic point of view it is not optimal to integrate all available RES generation
- RES should be demanded for system stability and further market integration.

=> Mid term perspective: grid extension and stronger market integration, then storage…

Impact of RES-E share and CO_2-prices on the need of storage capacities in the system

Share of RES-E generation

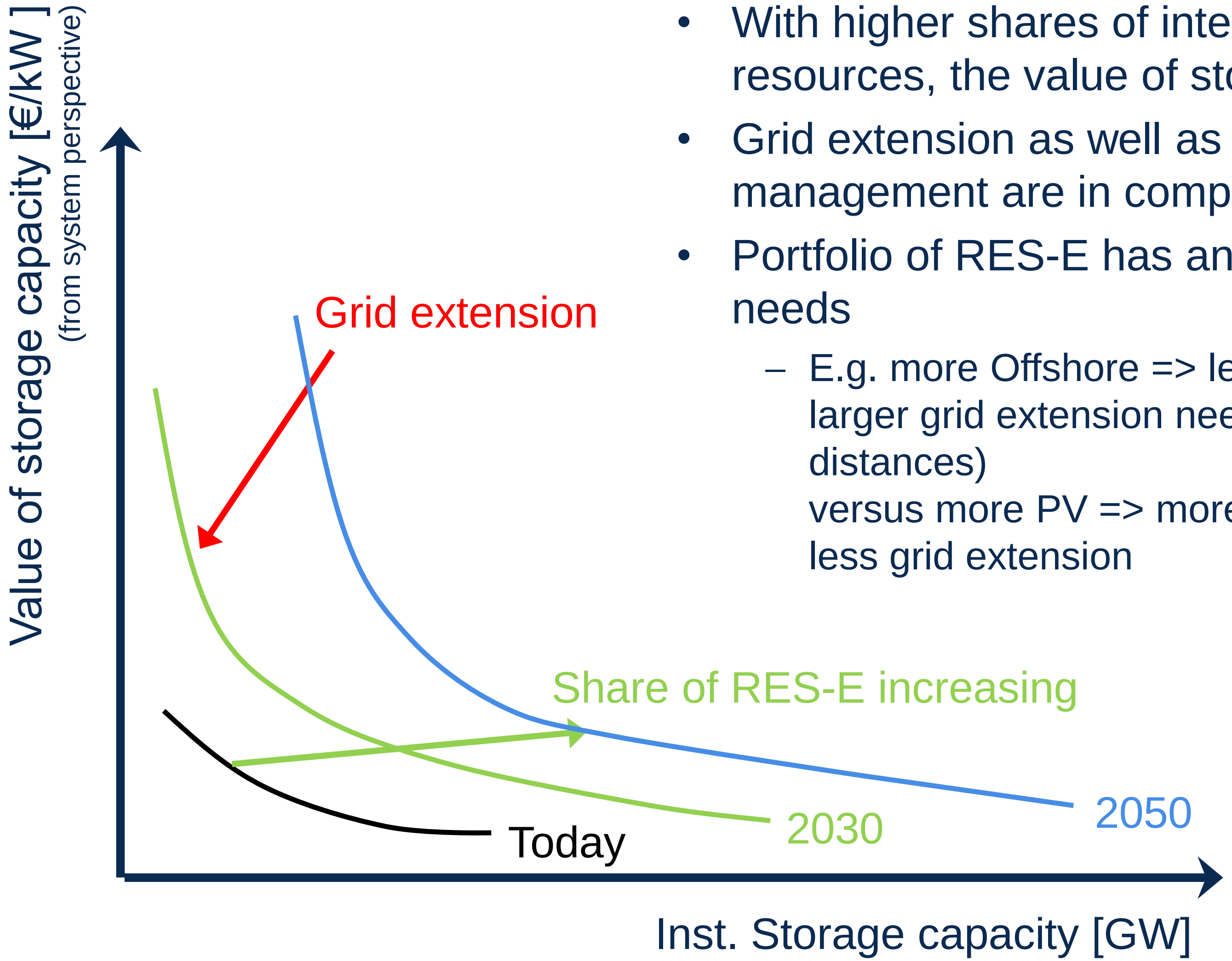
- Mid-term (< 40%): Nearly no change in storage demand
- Long-term (>60%):
  Increase of storage demand, but still moderate
- Long-long-term (>85-90%)
  Significant increase of storage demand!

Cost of CO_2

- Low CO_2-price (<15 €/t): Good for storage power plant (cheap base-load)
- High CO_2-prices (>40 €/t): Amount of storage at 50% RES-E at about todays storage level

=> Storage need is quite sensitive to RES-E share and CO_2 costs, but unfortunately in a contradicting way!

Economic value of storage
(simplified illustration)



- With higher shares of intermittent renewable resources, the value of storage increases
- Grid extension as well as demand side management are in competition with storage
- Portfolio of RES-E has an impact on storage needs
  - E.g. more Offshore => less storage need but larger grid extension need (due to larger transport distances)
    versus more PV => more storage favourable but less grid extension

Large differences in profitability of large- and small-scale storage due to regulation

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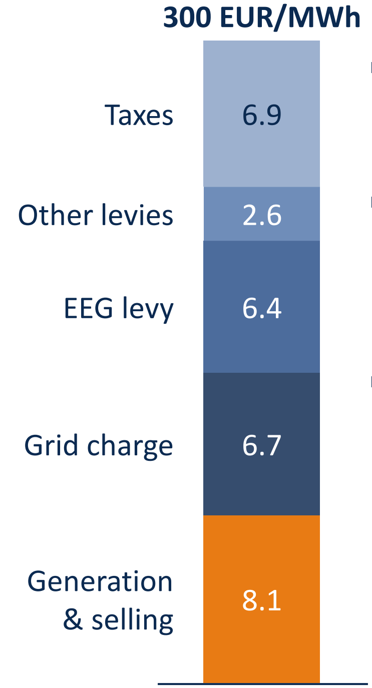
Large-scale storage

- Diminishing spreads compromise profitability of storage and do not justify new investment

Large-scale storage investment hardly profitable due to small spreads

Decentralized PV storage



- Large-scale storage has to earn money on market spreads
- Self-consumption from decentralized PV allows to save on grid charge, levies and taxes
- **>40% of new PV installations <10 kW contained battery storage in 2015** (only 14% in 2014)

Domestic PV storage profitable dependent on the regulatory environment

=> Decentral storage options have about 5 times higher incentives in GE

but strongly dependent on regulation (grid fees, feed-in tariff, market rules, …)

decentral option: + higher willingness to pay will lead to market uptake …

Source: EPEX Spot, BNetzA: Monitoring Report 2016, RWTH Aachen: Wissenschaftliches Mess- und Evaluierungsprogramm Solarstromspeicher 2016

Maximise „self-consumption“ and autarky from April to October…

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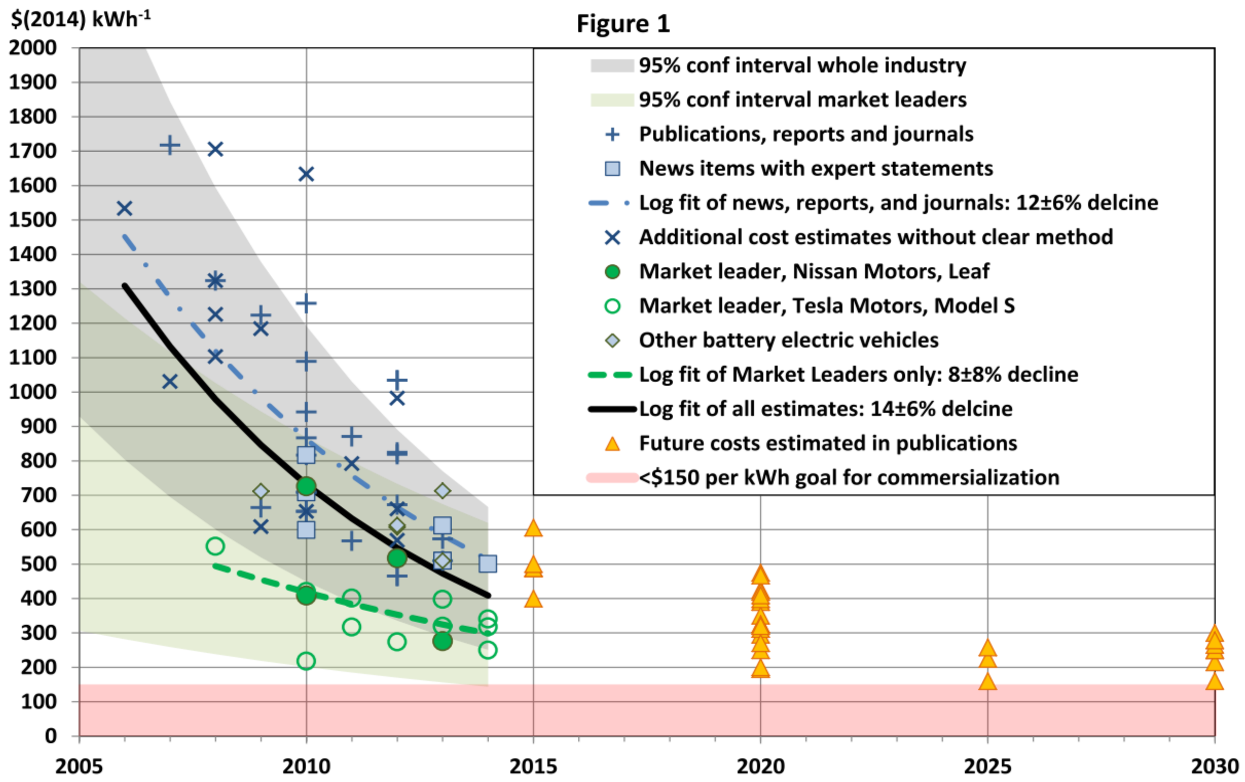
Learning curve Lithium-ion batteries



Source: B. Nykvist, M. Nilsson: Rapidly Falling costs of battery packs for electric vehicles, Nature Climate Change

Cycle stability is (still) of crucial importance!

Assumption:

- 1000 - 2500 cycles
  => e.g. 10 a * 250
- 150 €/kWh
  (before 2020)

=> 6 - 15 Ct/kWh
(+ battery management and installation)

+ approx. 8 Ct/kW PV generation
<< 30 Ct/kWh el. supply

=> Mid-term perspective: decentralised storage systems will be economically very attractive under current tariff structure

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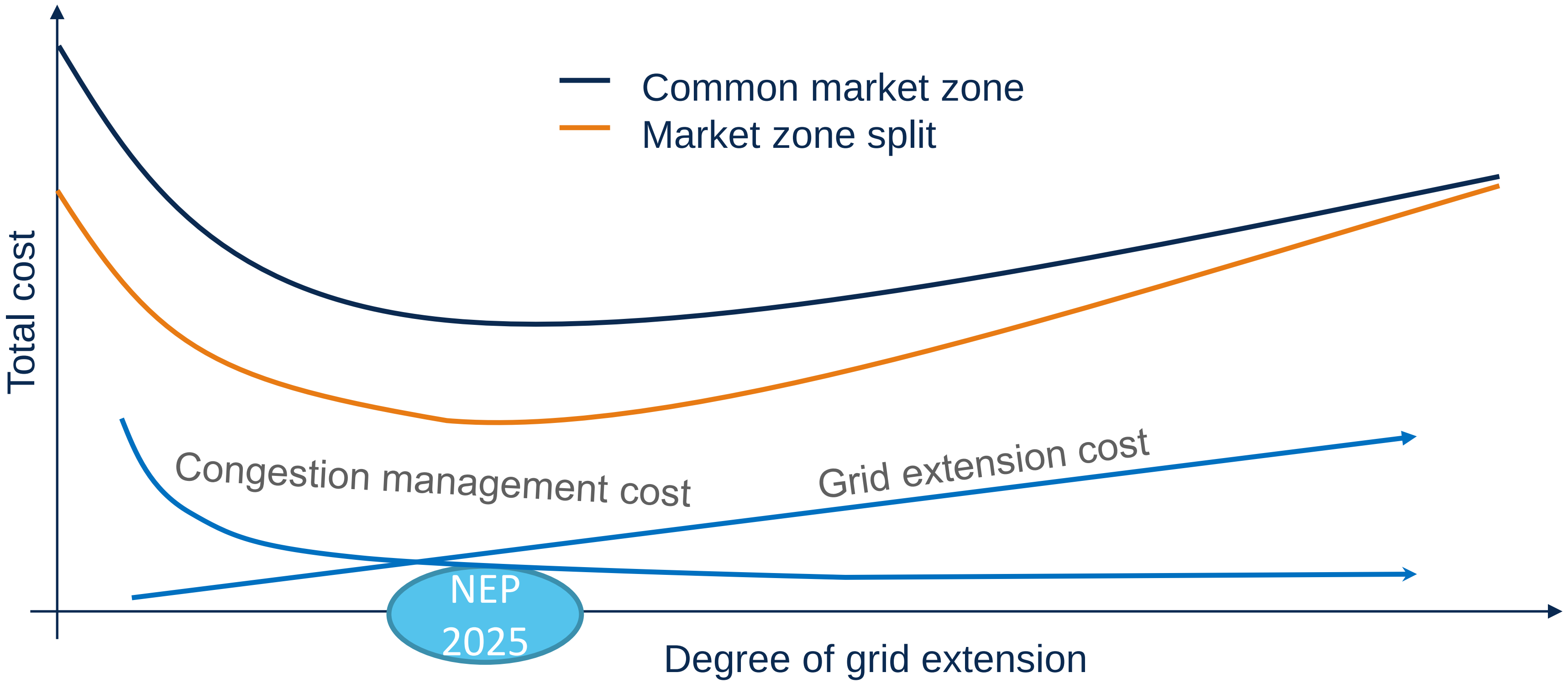
Trade-off between grid extension, congestion management and market splitting



Own calculations show that NEP2025 seems to be a reasonable degree of grid extension

- interested in details? => see presentation of Hinz, Wednesday in session 7B!

Additional transport requirement necessitates grid extensions and leads to cost increase

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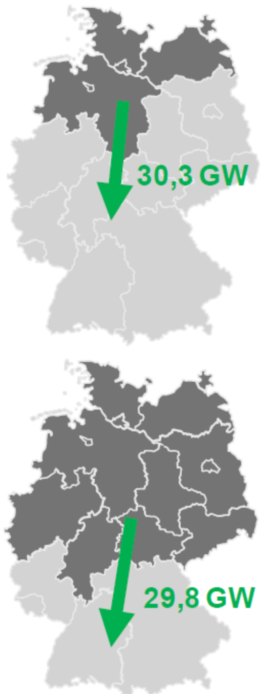
Transport requirement

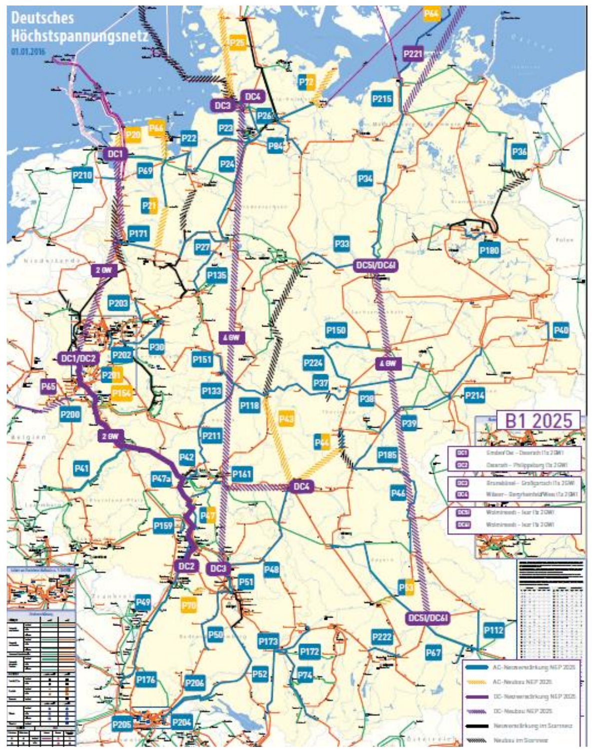
NEP B1 2035



Source: Consentec (2016), Netzstresstest

- Distribution of RES causes add. transport require-ment from North to South

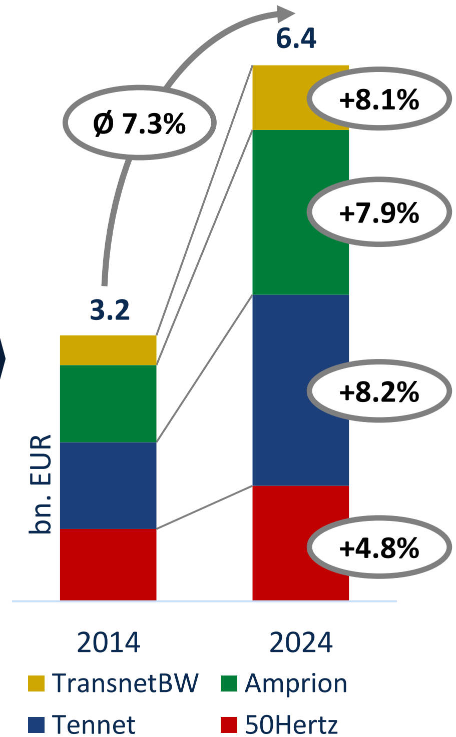
Grid extensions



Source: NEP2030

- Grid extension requirement quantified and concretized by TSOs

Cost increase



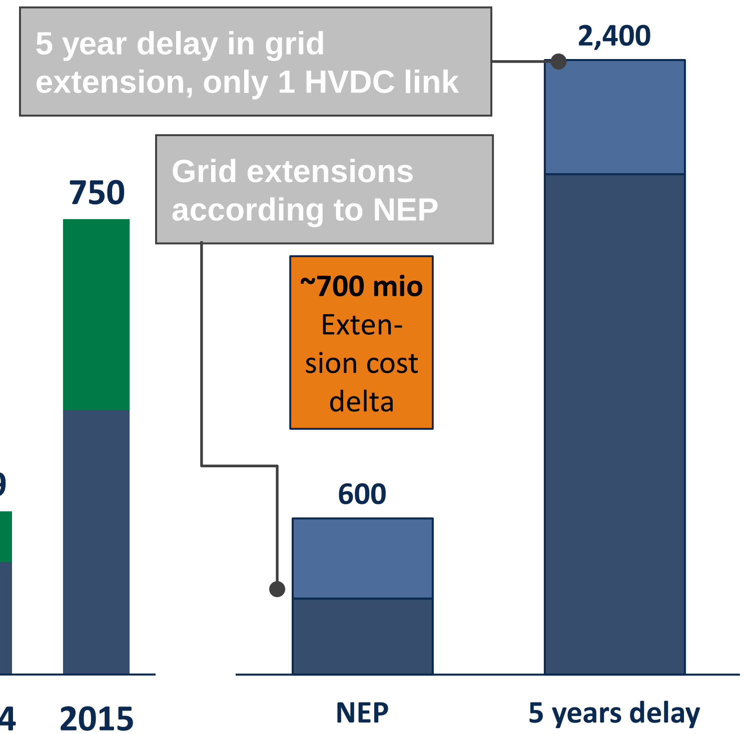
Source: Own calculations based on NEP2024

- 100% increase in transmission grid cost within ten years

Omission of necessary investments causes high congestion management cost

Historic congestion management cost

Projection 2025



- Strong increase in redispatch and curtailment cost due to
  - Horizontal congestions in the transmission grid (North → South)
  - Vertical congestions in the distribution grid

- 5 years delay in grid extension causes additional cost of 1.8 bn. EUR
- Respective invest delta: 10 bn. EUR (700 mio. EUR annual cost)

Source: BNetzA Monitoringreports, own calculations based on ELMOD grid model

International Germany

Long-term: NEP 2025 is not the end, but the beginning of further infrastructure investments

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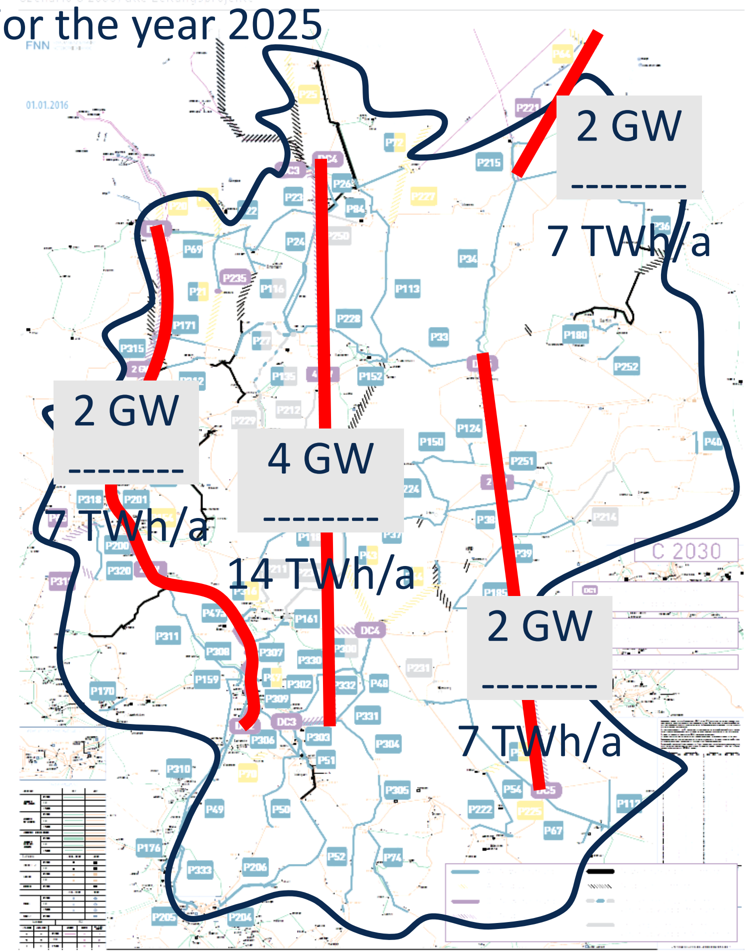
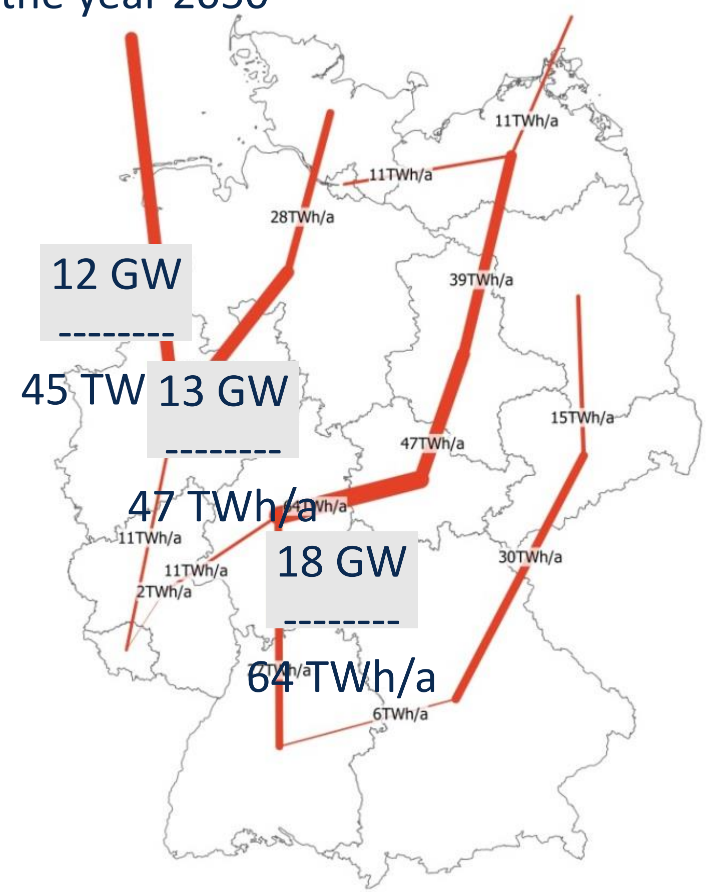
Necessary grid extension based on NEP
For the year 2025



Estimated grid extension for
the year 2050



Assumption: medium utilisation of 40% of each line

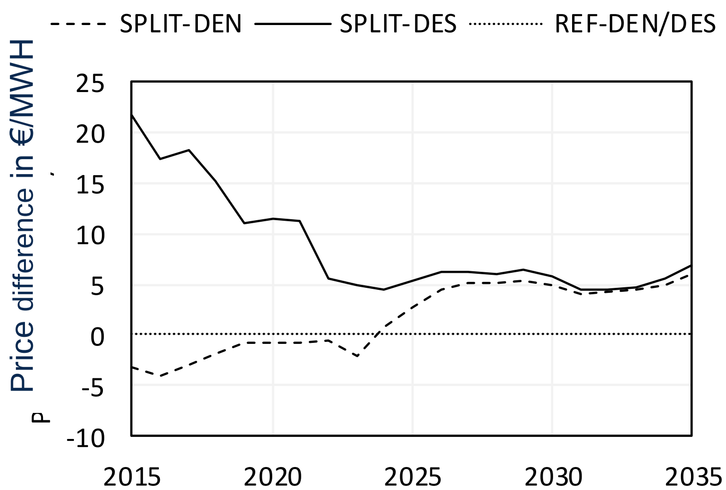
=> But grid extension strongly dependent on assumptions concerning renewable extension

Source: IEEH, TU Dresden

Two price zones in Germany?
Model-based analysis of long-term impact

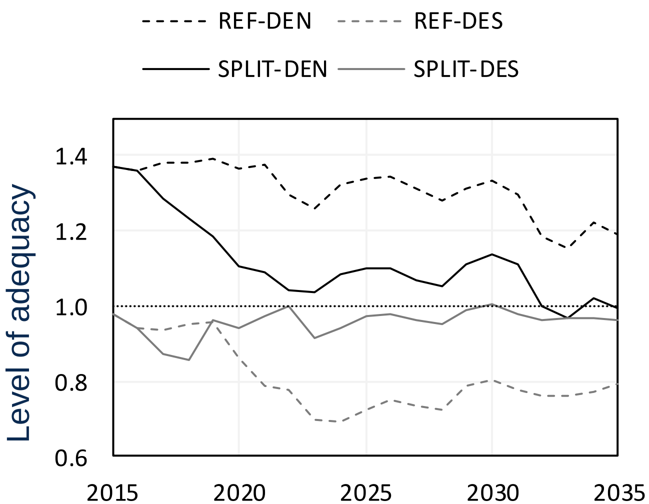
Analysis with a fundamental model within Avers-project

Development of price difference



=> Prices converge due to optimal planning

Development of level of adequacy



=> Optimal capacity installations increase regional level of adequacy

Explanation
DEN … Germany North, DES … Germany South SPLIT-DEN/DES … two market zones DEN/DES

Source: Avers-project:
Hladik, D., Fraunholz, C., Kunze, R.: Zwei Preiszonen für Deutschland, Optimierung in der Energiewirtschaft

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Some final thoughts and conclusions

Are there any principles that exist for a long time and do we ignore them because we are used to them?

- Electricity prices
  - Markets: Supply and demand are well functioning („technically“)
  - But: speed of change and expectations for subsidies prevent a market equilibrium
- Complexity of political measures
  - One policy mechanism (market engagement) pulls next to itself
  - Objectives are often conflicting (fragmentary, incomprehensible) and system perspective is missing
- Market created with liberalization and systematically hollowed out ...
  - When do grid operators build power plants?
  - Tendency that state defines „right“ technologies

⇒ Renewable integration necessitates broad portfolio of technologies and correct price signals!

⇒ Power grids play an important role for renewable integration!

⇒ Interdependencies in the system have to be considered!

=> How can Europe benefit (more) from the „Energiewende“?

»Wissen schafft Brücken.«

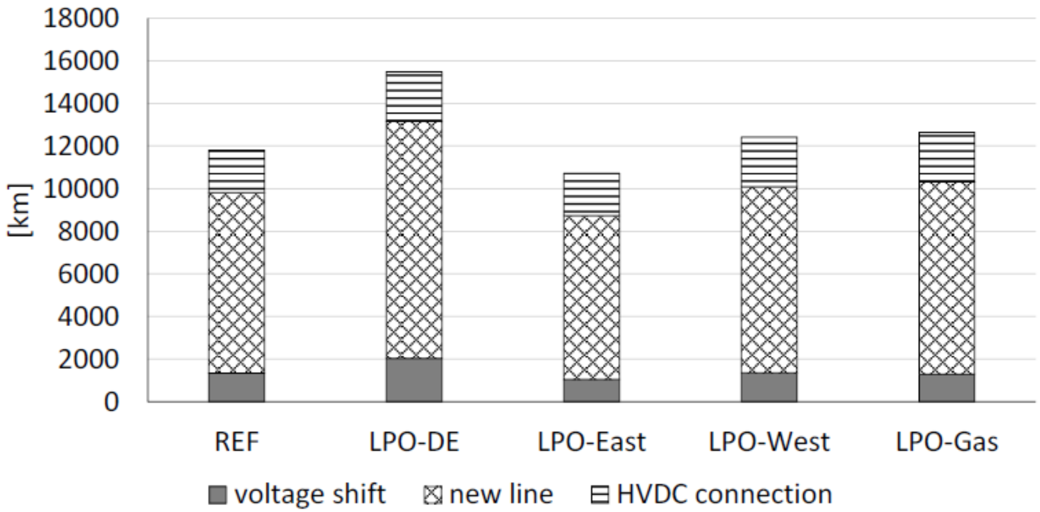
Grid extension is necessary …

- „Early“ Coal-phase-out until 2030 is possible, but:
  - not with the expected grid extensions of NEP!

  => New/additional power lines are necessary!
  - Additional: back-up capacities at some locations necessary!

  => Current electricity prices: Who are the investors (without subsidies)?

Necessary investments in new lines (in km) for different lignite-phase-out scenarios



REF … no lignite-phase-out **LPO-DE** … lign.-phase-out GE
LPO-East … lign.-phase out in East-GE **LPO-West** … in West-GE
LPO-Gas … substitution of lignite by gas power plants