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Impact of renewable energies on markets and future design of electricity markets

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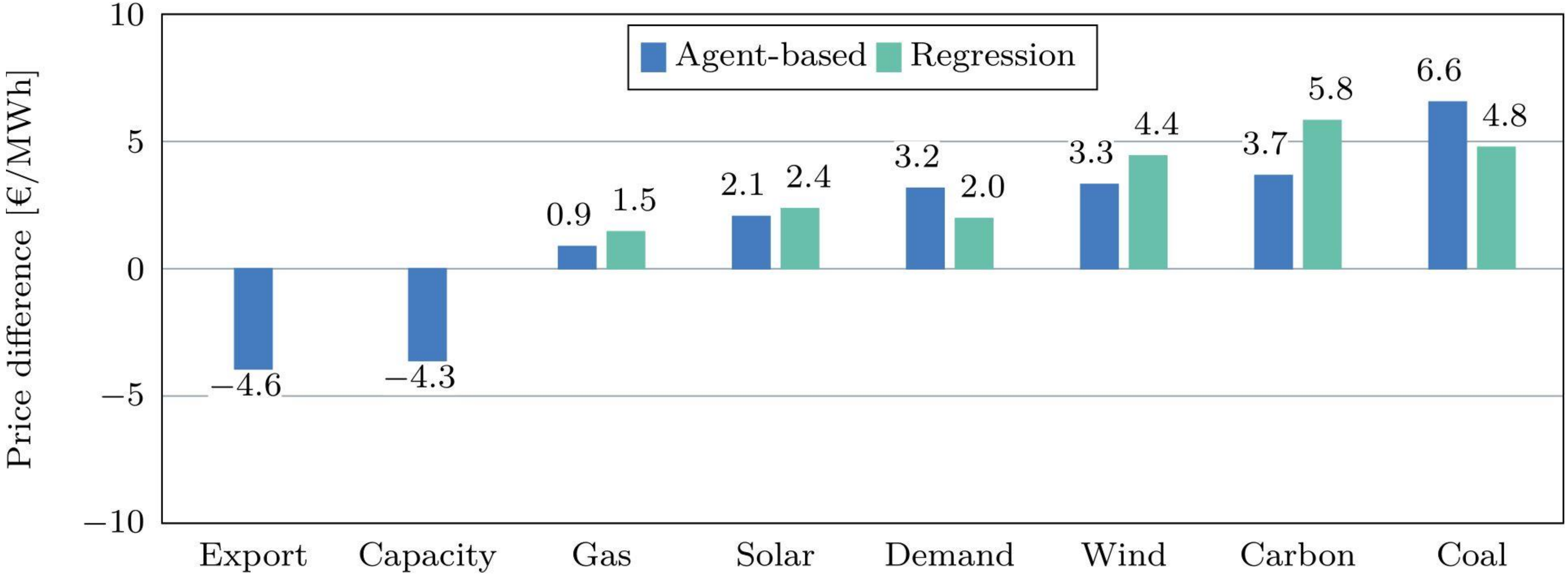
Agenda

- Discussion about renewables and market design
- Model overview
- Input data and evaluation criterion
- Results on investments, prices and load serving
- Conclusions

Impact of renewables and other price drivers

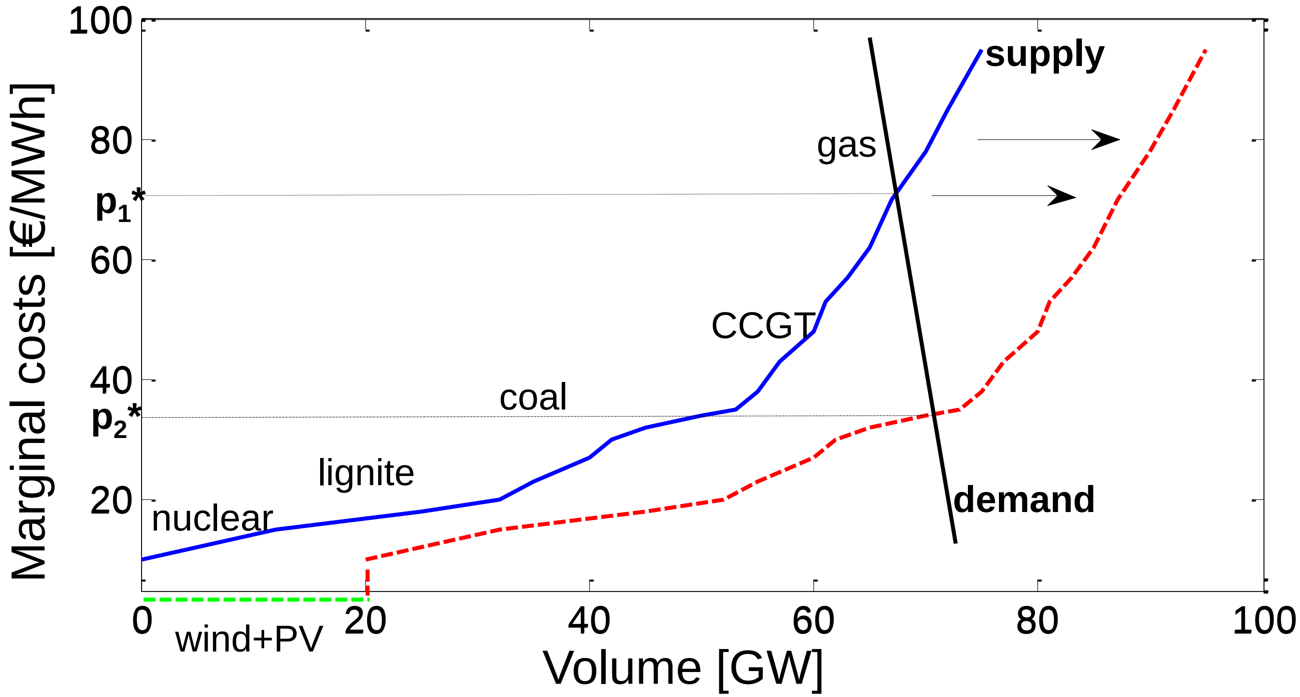
Contribution to the price drop of wholesale electricity prices in 2011 - 2015:



- Strong decline of wholesale electricity prices mainly driven by decreasing coal and carbon price
- Renewables have a growing price effect, reducing the earnings of power plants

Merit order effect of renewable energies

- Current market design: Energy-only market (EOM) (**day-ahead market, ...**) only short-term reserve power market
- Price settlement at the day-ahead spot market and merit order effect



→ Can the EOM incentivize new investments or is a capacity remuneration mechanism necessary to ensure investments and thus to provide <u>generation adequacy</u>

Overview of discussed capacity mechanisms

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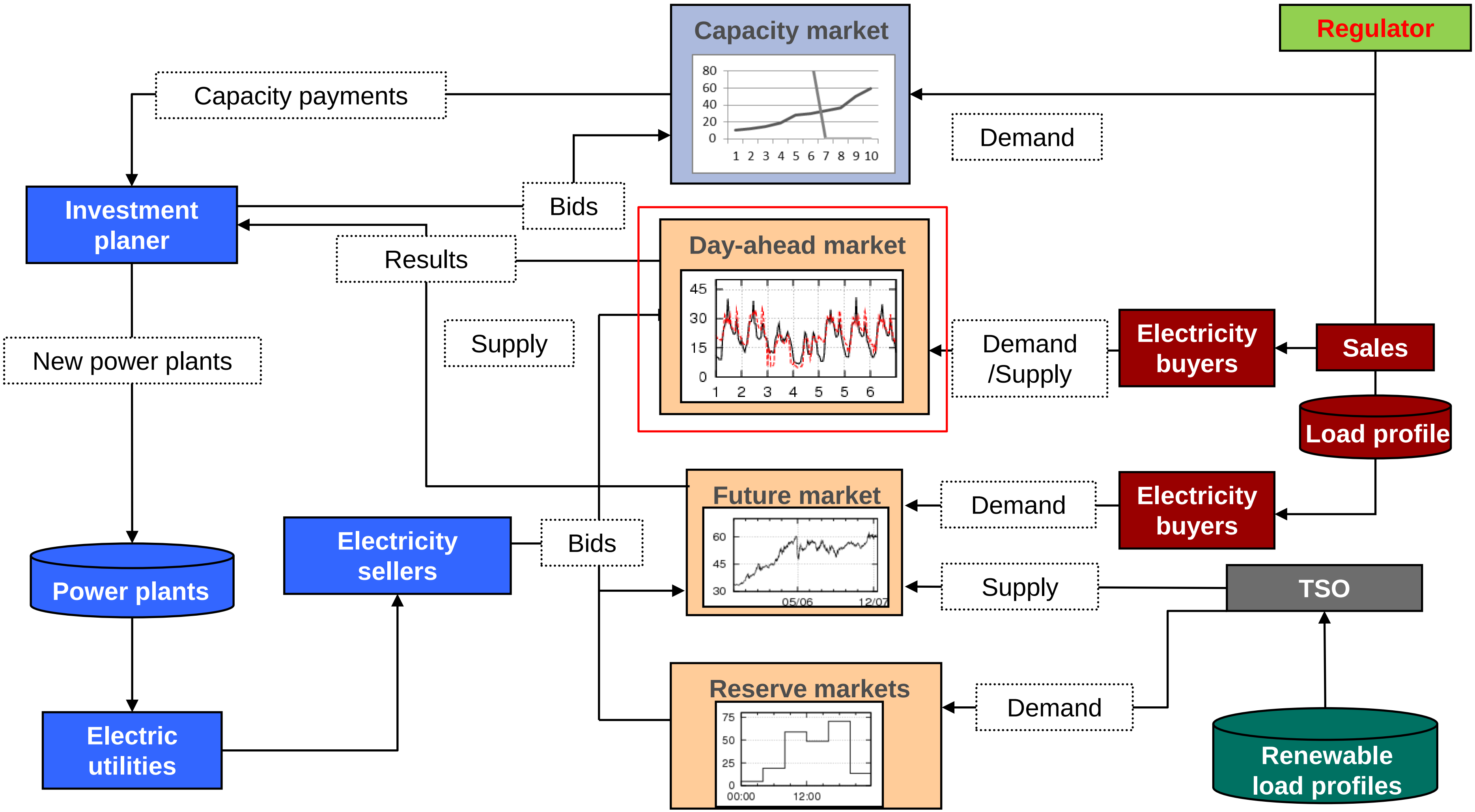
	Proposal
Strategic Reserve ("Sicherheitsbereitschaft") (BMWi)	▪ Centralized purchase of a strategic reserve (about 5% of peak load), e.g.by TSO ▪ Dispatch, only of all other capacity is used, price equal to p^{max} ▪ No-way-back rule ▪ Climate reserve (2.7GW of old lignite capacity)
Centralized capacity market (applied in New England, PJM)	▪ Comprehensive capacity market, open for all technologies ▪ Central purchaser (regulator, TSO) ▪ Generators get capacity certificates according to their secured capacity ▪ Fluctuant RES have low capacity credits
Decentralized capacity market (VKU, BDEW -energy suppliers)	▪ Decentralized purchase of certificates by LSEs and industry ▪ Scarcity event leads to proof of certificates ▪ Penalty for lack of certificates (3-4 times higher than certificate prices)

Market simulation model: PowerACE



Data and evaluation criteria

- Analysed period: 2015-2050
- Key input parameters from different public sources or well-known studies, renewables are from optimisation model

Year	2020	2030	2040	2050
Coal prices [Euro/MW]	13.7	15.4	17.0	18.7
Gas prices [Euro/MW]	28.7	30.8	31.1	31.8
CO2 Emission Allowances [Euro/t CO2]	7.3	23.5	47.9	51.0
Total yearly demand [TWh]	610.8	597.5	668.9	667.4
Export [TWh]	53.8	15.8	-11.3	-15.4
Photovoltaics [GW]	47.5	47.4	80.7	80.7
Wind (onshore + offshore) [GW]	47.9	60.8	81.7	104.8

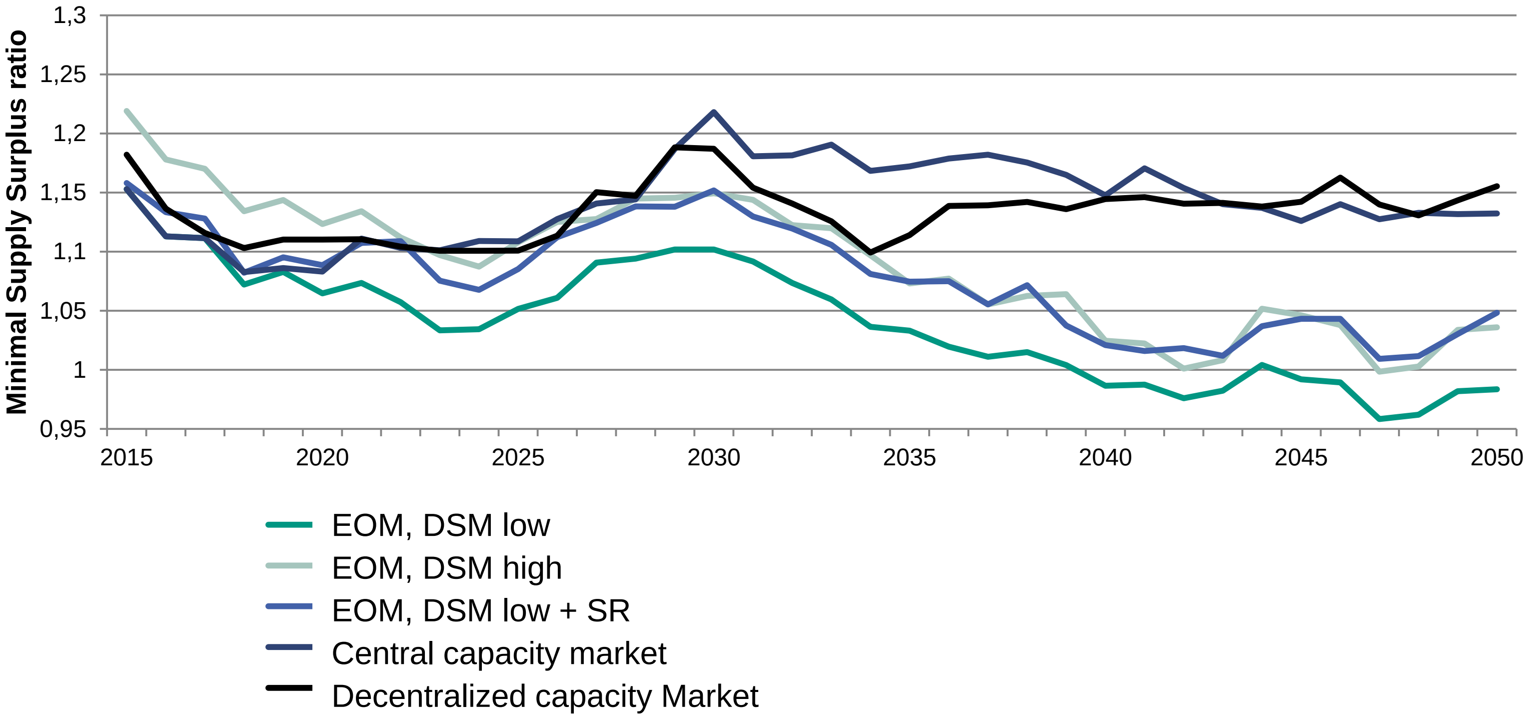
- Evaluation criteria: adequacy level (AL)

$$\mathrm{AL}\,(y) = \min_{h} \frac{\mathrm{AC}\,(h)}{\mathrm{RD}\,(h)}$$

Secure available capacity

residual demand

Selected results (Adequacy level)



- After 2030 not all mechanism are able to satisfy the demand at all time
  - Influence of high price interruptible loads in EOM
    → With 2.1 GW cannot be satisfied at all times, but with 8 GW interruptible loads
  - EOM is only with a strategic reserve of 5 GW delivering generation adequacy

Selected results (Cost comparison)

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- With a capacity market the cumulated payments to the supply companies increase by 20-30 billion Euro from 2015-2030 compared to EOM.
- However, scarcity prices diminish the costs advantages of EOM after 2030 .

Cumulative payments to all flexible generators [bill. €]

	EOM reference	EOM flexibility	Strategic reserve	Central capacity market
2015–2030	393.8	394.9	413.5	420.1
Capacity remuneration	-	-	2.9	61.6
Day-ahead market	393.8	394.9	410.6	358.5
2031–2050	479.1	457.8	494.6	454.1
Capacity remuneration	-	-	2.6	60.7
Day-ahead market	479.1	457.8	492.0	393.4
Total sum	873.0	852.8	908.2	874.2

-> But differences depend on parameters that currently are uncertain (markup prices, influence of market design on DSM capacities)

Conclusions

- Differences between EOM and capacity market in the investments in conventional power plant capacity

- EOM cannot guarantee the generation adequacy in several hours in the long-term, only if interruptible loads or strategic reserve are available

- Capacity market will meet requirements with adequate parameterization, mainly due to additional gas-fired power plants but: surplus capacities possible

- Recommendation:
  - EOM with strategic reserve in the short-term
  - Capacity market in the long-term

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Thank you…

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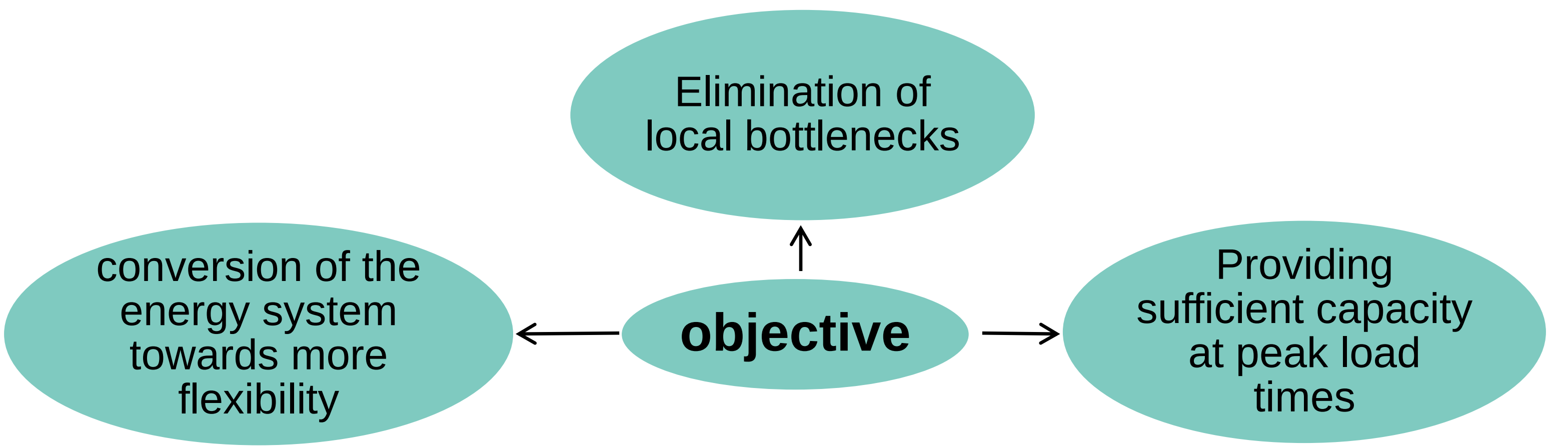
Backup

Discussion about the German market design

- Reason: concern about security of supply, currently increased number of decommissions of thermal capacities, yet only few new investments
- Concern that the energy-only-market will not provide insufficient investment incentives
- Uncertainty regarding the design of a capacity mechanism in detail



Analysis of market design options to ensure security of supply

Methodological approach

- Identification of market design options that are relevant for the German electricity market
- Implementation and simulation of the different design options with the agent-based simulation model PowerACE
- Impact analysis of the capacity mechanism on the development of production capacities, electricity prices until 2050
  → Comparison with EOM

→ **Analysis of the question: Is Interruption of load serving or market failure possible due to lack of capacities?**

Strategic Reserve

- **Auction**
  - Yearly auction for upcoming year
  - Volume 5 GW
    (about 5% of the total thermal capacities in Germany)
  - Single-price auction, selection of bids via capacity price
  - Maximum price equals CONE
- **Usage**
  - If day-ahead market cannot be cleared, full capacity of strategic reserve is offered at maximum market price (3000 Euro/MWh)
  - Variable costs are reimbursed to power plant owners, profits remain with regulator
- **Participating power plants**
  - Technical requirements: Power plants need to be available 10 h after request
  - Power plants once in the strategic reserve are not allowed to participate in other markets (no-way-back)

Decentralized capacity mechanism

- **Auction**
  - Price and volume determined by market players
  - Willing to pay for certificates depends on expected penalty and scarcity expectation
  - In case of surplus capacities, price can drop to zero
- **Regulator**
  - Issue certificates to power plant owners
  - Check if consumers have enough certificates, in case of trigger event e.g. price or market scarcity reaches a certain predetermined level
  - If customers require more electricity than their certificates allow them to do, they have to pay a penalty (a multiple of the certificate price)

Central capacity mechanism (I)

- Step 1: Regulator
  - Determination of conventional capacity demand ConCap:

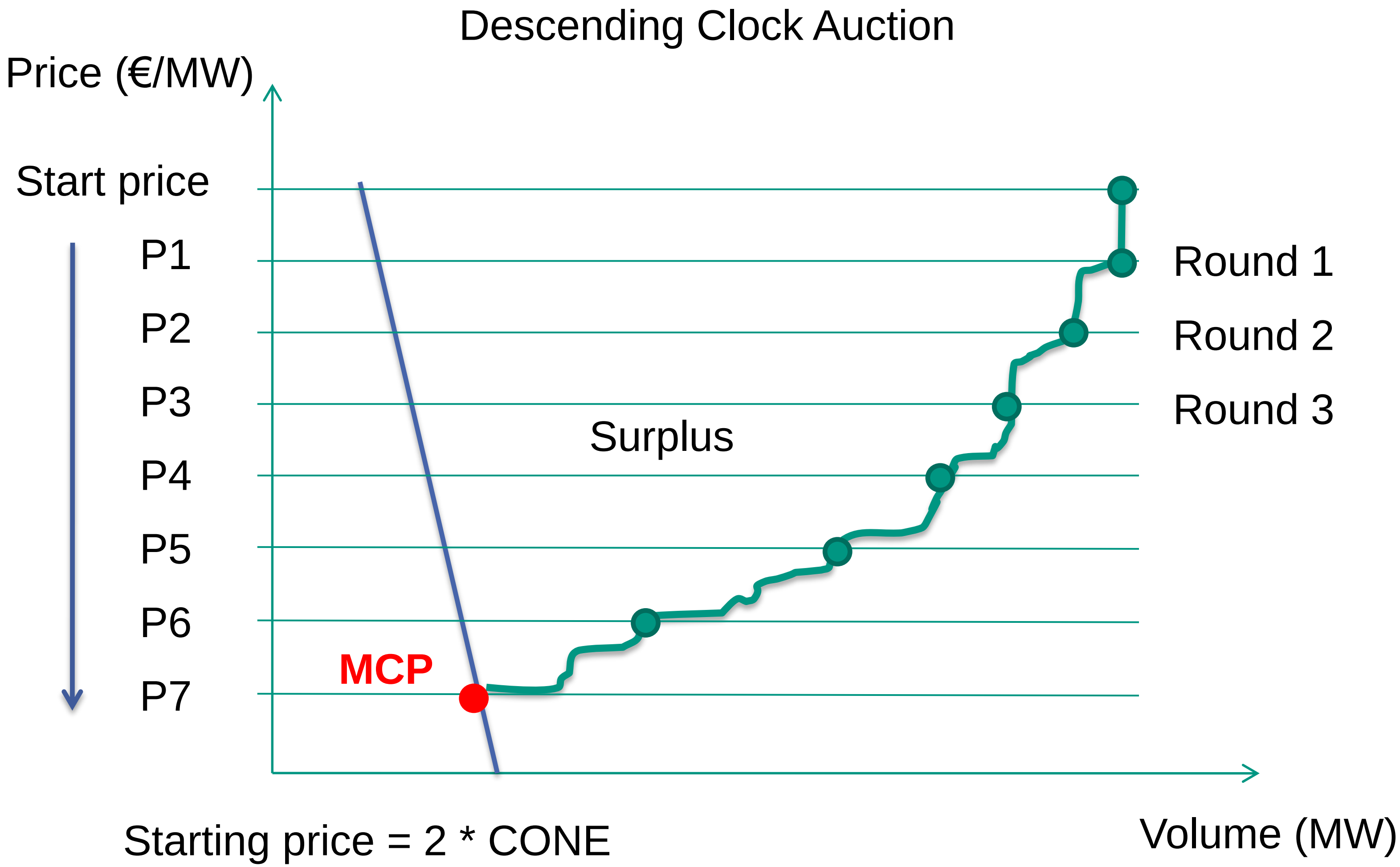
    $$ConCap_{t+x} = (1 + R_{t+x}) * (D_{peak,t+x} - EE_{t+x} - Imp_{t+x})$$

  - Determination of power required by each energy supply company (Capacity Obligation CO): $CO_{t+x} = share_{peak} * ConCap_{t+x}$
  - Calculation of Peak Energy Rent: Contribution margin of a reference gas turbine; deducted each year from the capacity revenues
- Step 2: Energy supply companies
  - Preparing offers for the capacity auction
- Step 3: Capacity auction

  $$\text{NPV} = \underbrace{-I_0 + \sum_{t=1}^{n} \frac{(db - c_{fix})}{(1+z)^t}}_{\text{Highest net present value so far}} + \underbrace{(af * p_{cap}) * \sum_{t=1}^{t+x} \frac{1}{(1+z)^t}}_{\text{y years fix price}} + \underbrace{(af * p_{prog}) * \sum \frac{1}{(1+z)^t}}_{\text{z years predicted price}} = 0$$

  - Descending Clock Auction
  - Floor and starting price based on the Cost of New Entry (CONE) of a reference gas turbine

Central capacity mechanism (II)



Starting price = 2 * CONE
MCP: Market clearing price

Selected results (Capacity markets)

- Central capacity market
  - Relatively even investments in conventional capacities, capacity level is higher than in an EOM (up to 19 GW)
  - Adequacy level most of times about 110 % (with suggested capacity credits and reserve margin)

- Decentralized capacity market
  - Volatile capacity prices can lead to some investment cycles and volatile capacity levels
  - Trigger event can be used to steer capacity level, more frequent control leads to higher capacities

- Danger of inefficient parameterization (e.g. capacity credits for renewables) exists for both capacity markets

Selected results (Cost comparison)

- Due to given uncertainties no definite conclusions about most cost-efficient market design can be drawn
  - In years of scarcity, day-ahead price in an EOM is up to 10 Euro/MWh higher than in capacity markets (incl. capacity payments)
  - Investors require higher markup prices for investments in an EOM due to the higher uncertainties in an EOM design
  - In years without scarcity, EOM has lower costs

-> But differences depend on parameters that currently are uncertain (capacity markets) or are difficult to calibrate (markup prices, influence of market design on DSM capacities)

Outlook

- Integration of the European perspective
  e.g. influence of French capacity market on the German market
- Influence of extreme weather conditions
- Consideration of grid restrictions and regional security of supply
- Adapt capacity mechanism to real world developments e.g. strategic reserve that is to be implemented

Energy-Only-Markt (EOM)

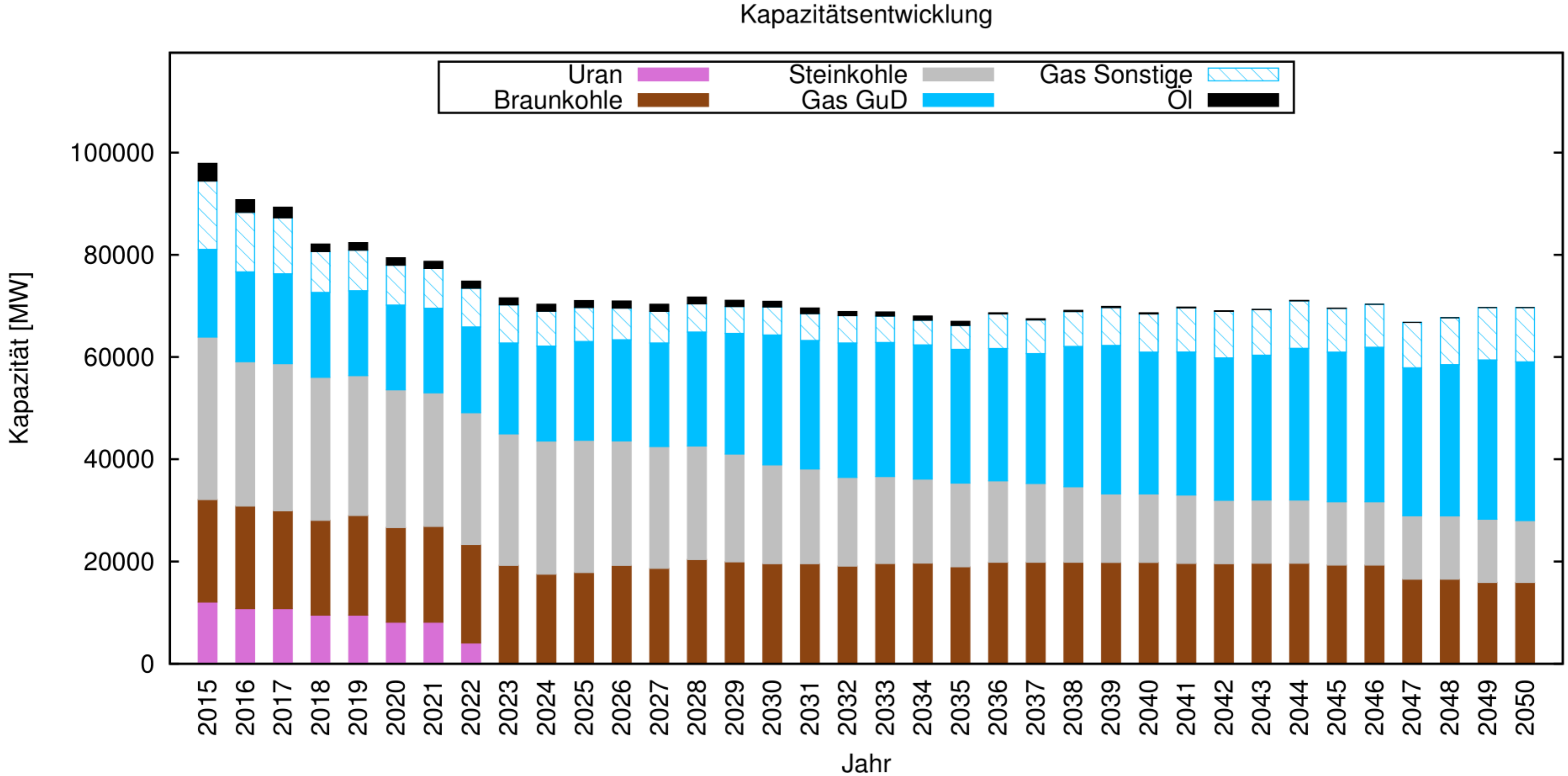
Ausgewählte Szenarien

Für den EOM wurden unterschiedliche Szenarien simuliert, davon seien hier die folgenden vorgestellt

Szenario	Markup	Verschiebbare Lasten	Abschaltbare Lasten
DSM (konservativ)	Ja	6 – 17 GW	2,1 GW
Flexibilitätsszenario	Ja	6 – 17 GW	8,1 GW
Kein Markup	Nein	6 – 17 GW	8,1 GW
Kein weiterer Braunkohlezubau	Ja	6 – 17 GW	2,1 GW

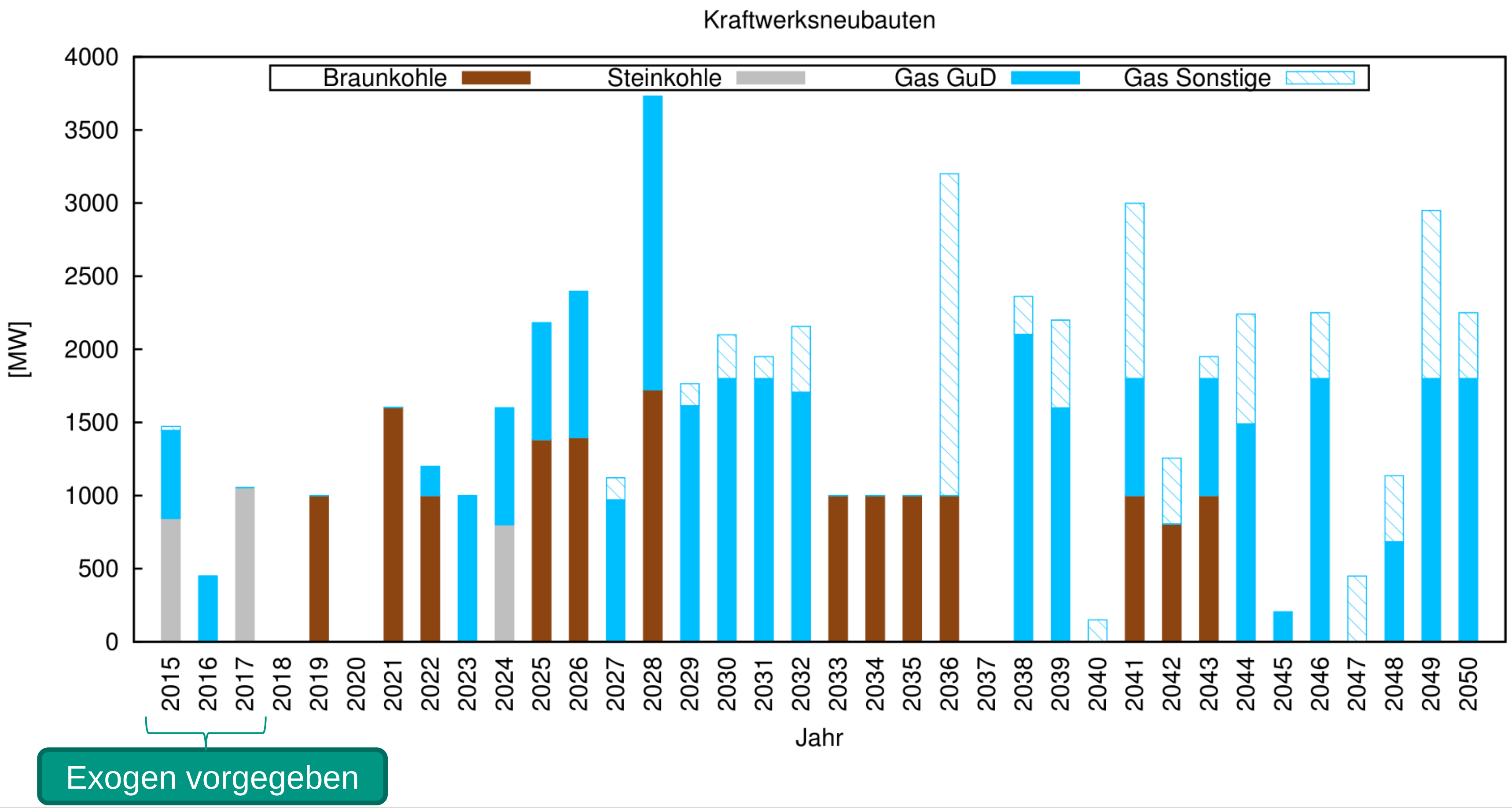
DSM (konservativ) – Kapazitätsentwicklung I

- Bis 2025 sinkt die benötigte konventionelle Kraftwerkskapazität durch den Ausbau von erneuerbaren Energien
- Ab 2025 bleibt die Kraftwerkskapazität weitgehend konstant zwischen 65 und 70 GW
  → steigende Nachfrage kompensiert durch Ausbau EE (Residuale Peaklast bleibt gleich)



DSM (konservativ) – Kapazitätsentwicklung II

- Bis 2028 wird in unterschiedliche Technologien investiert, danach vor allem in gasbefeuerte Kraftwerke (GuD und Gas-Turbinen)



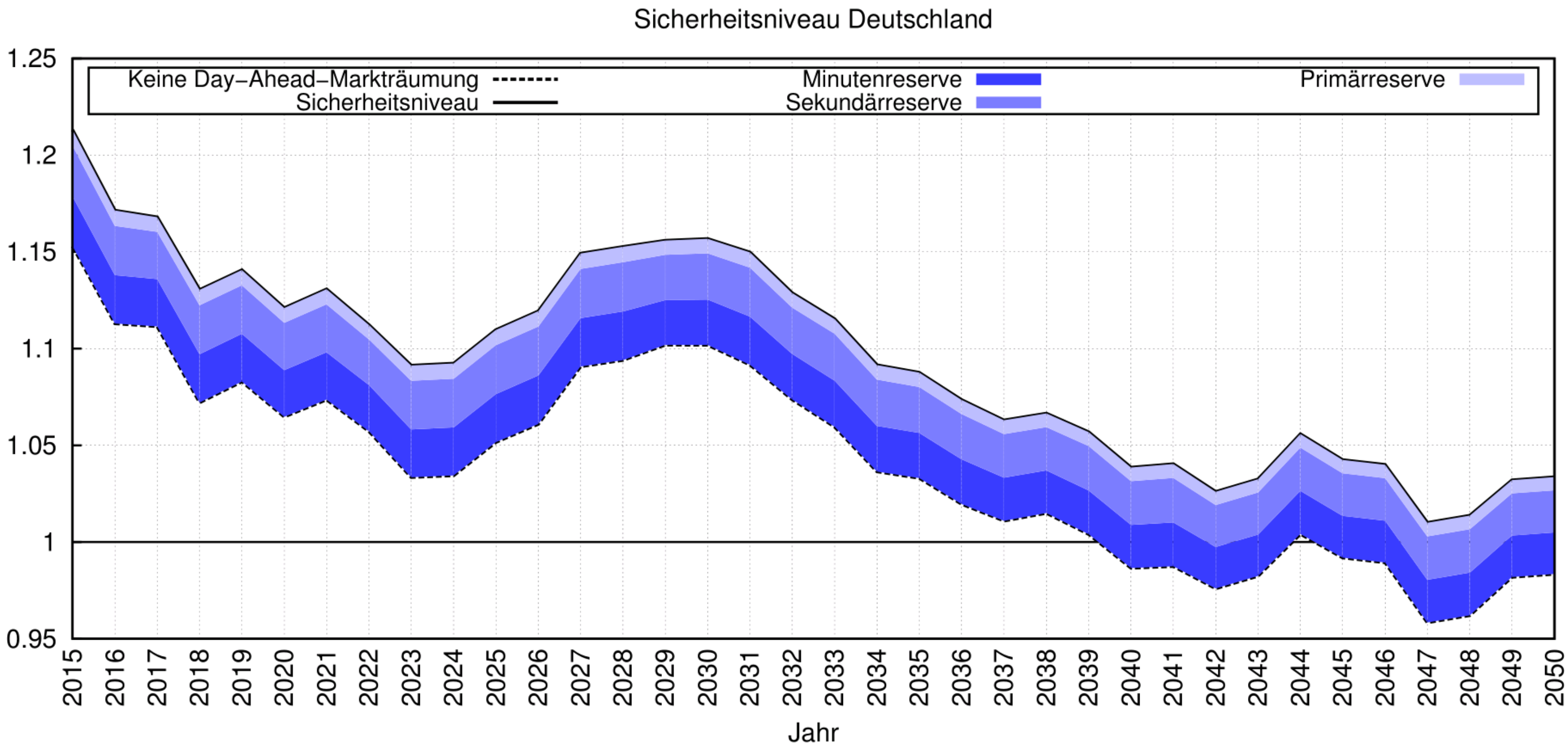
Exemplarische Ex-Post Analyse exogener Zubauten im Szenario „DSM konservativ“

- Kraftwerke werden über einen Investitionshorizont von 20 Jahren betrachtet bei einem Zinssatz von 8 %.

	Steinkohle	Gasturbine	GuD
Inbetriebnahme	2013	2013	2013
Durchschnittlicher Cashflow (20 Jahre) [T Euro/MW]	61,3	42,9	65,3
Kapitalwert [T Euro/MW]	-403,6	37,7	-207,1

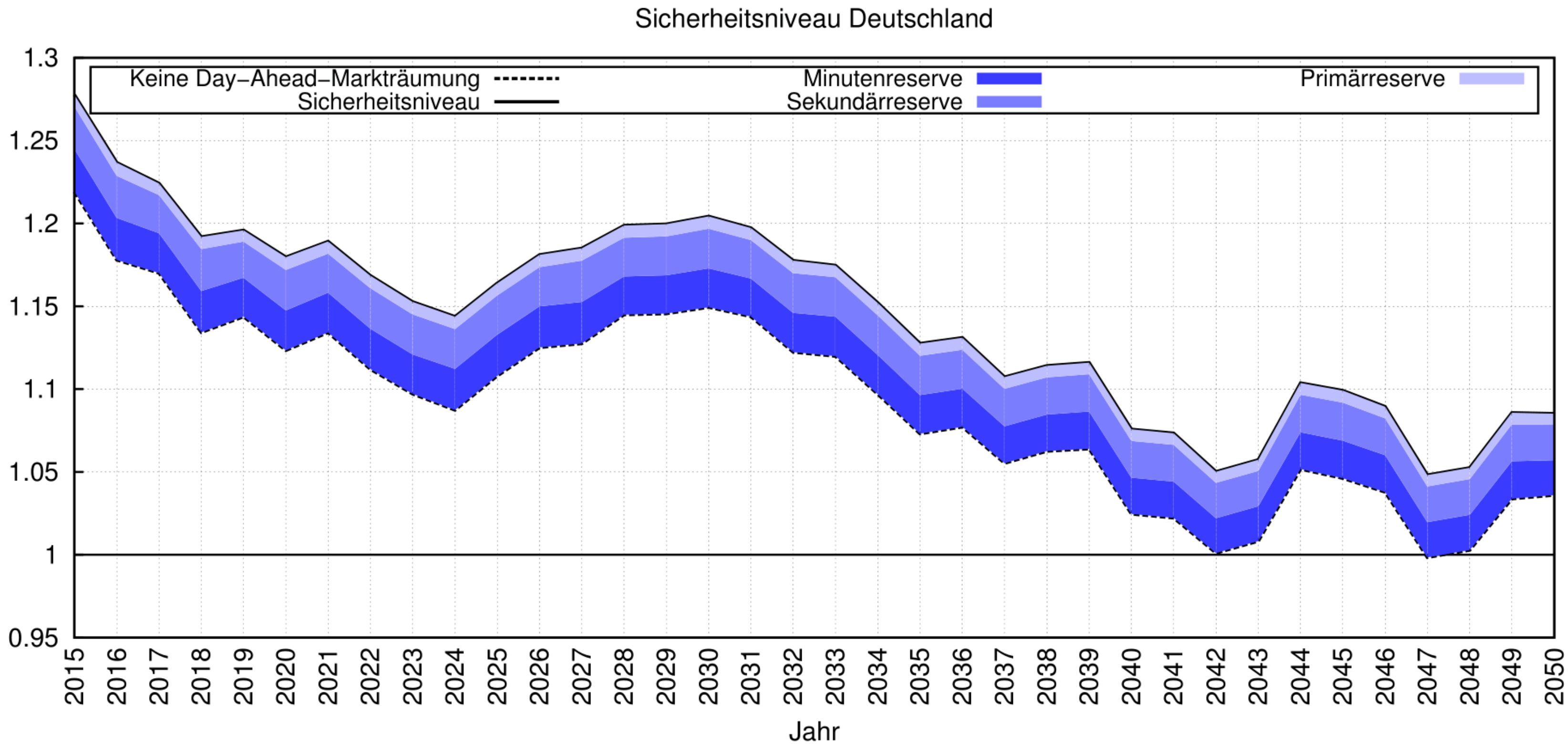
Sicherheitsniveau – 2 GW Abschaltbare Lasten

- Ab 2040 kommt Regelenergie zum Einsatz um Nachfrageunterdeckung zu vermeiden
- Durch den Einsatz von Regelenergie kommt es nicht zu Unterdeckung der Nachfrage



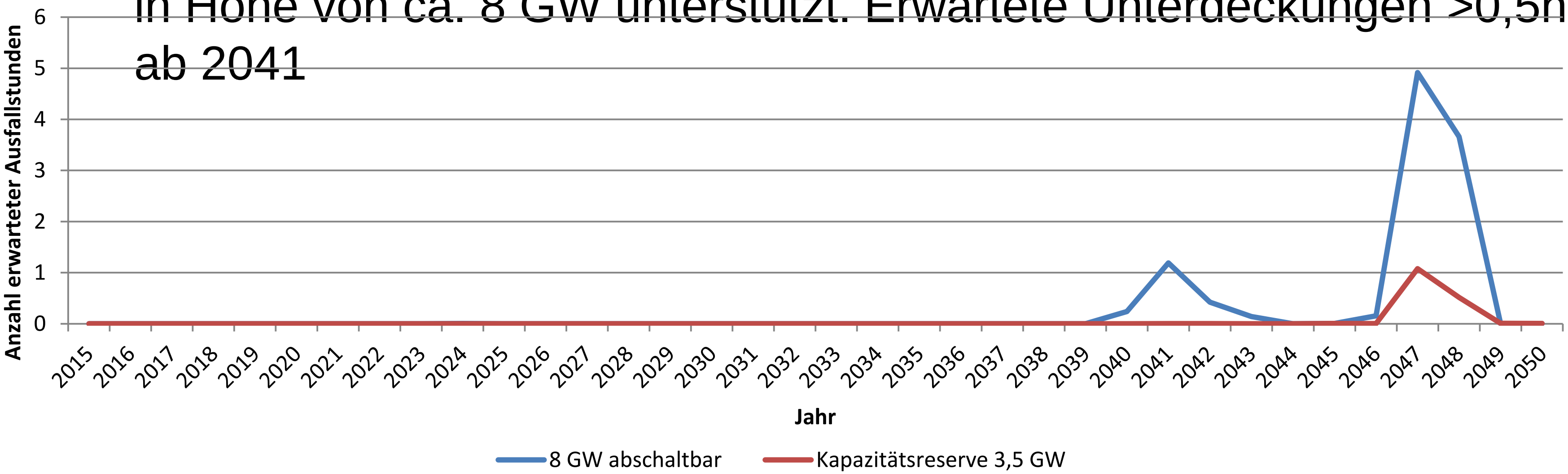
Sicherheitsniveau – 8 GW Abschaltbare Lasten

- Nur 2047 kommt Regelenergie zum Einsatz um Nachfrageunterdeckung zu vermeiden
- Mit Einsatz von Regelenergie kommt es nicht zu Unterdeckung der Nachfrage



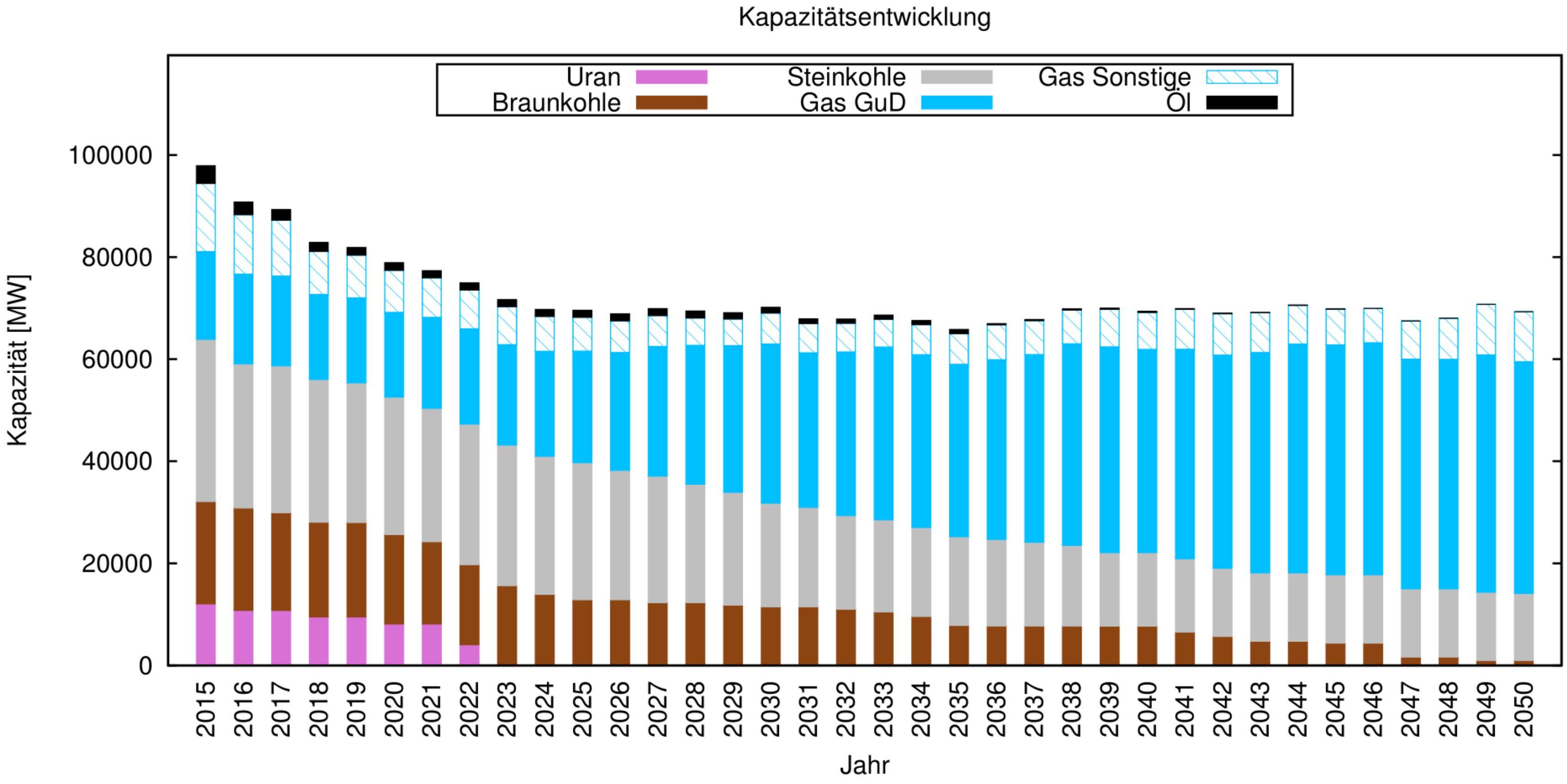
Analyse der Szenarien ohne Markup

- Keine Zulassung von Markups führt in den meisten Szenarien zum Versagen des EOM, auch schon vor 2030 mit folgenden Ausnahmen:
  - Die Märkte werden durch eine Reserve (3,5 GW) unterstützt. Dann werden erst ab 2039 >0,5h Unterdeckungen erwartet - auch für das Szenario ohne Braunkohle
  - Die Märkte werden durch höhere Kapazitäten abschaltbarer Lasten in Höhe von ca. 8 GW unterstützt. Erwartete Unterdeckungen >0,5h ab 2041



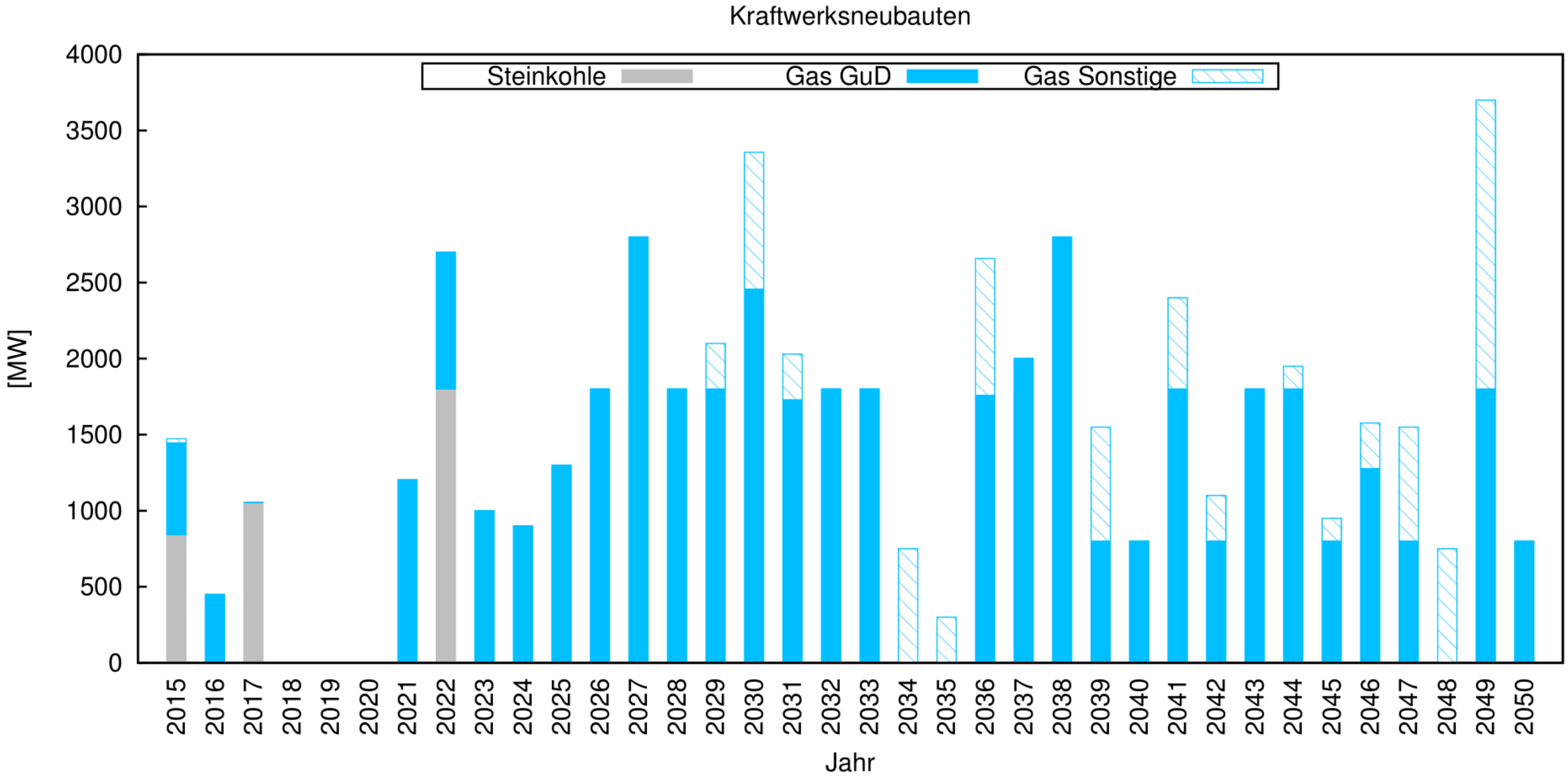
Kapazitätsentwicklung ohne Braunkohlezubau

- Mit 2 GW abschaltbaren Lasten
- Neuinvestitionen erfolgen nur in gas-befeuerte Kraftwerke



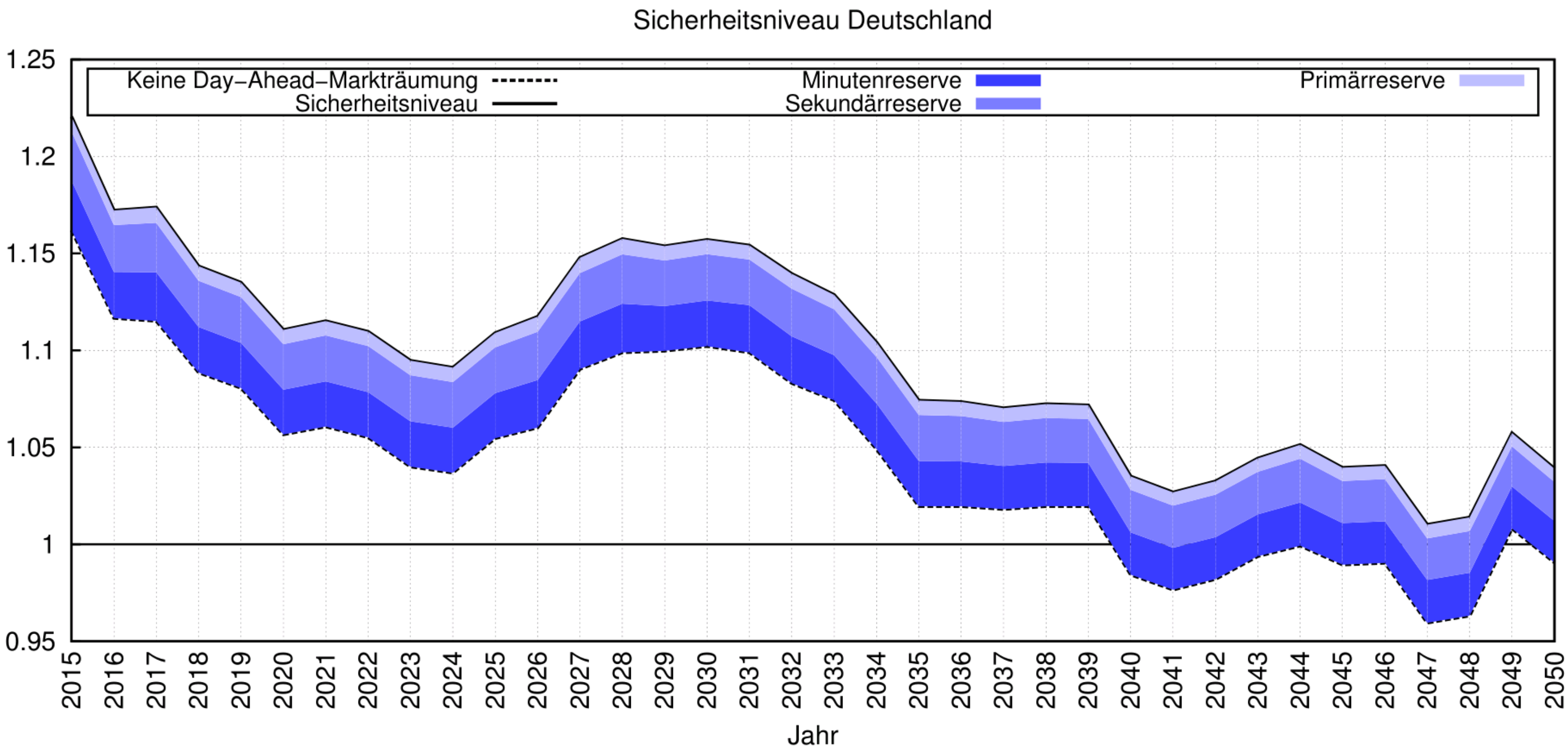
Investitionen ohne Braunkohlezubau

- Hauptsächlich ersetzen GuD-Kraftwerke alte Braunkohle-/Kohlekraftwerke



Sicherheitsniveau ohne Braunkohlezubau

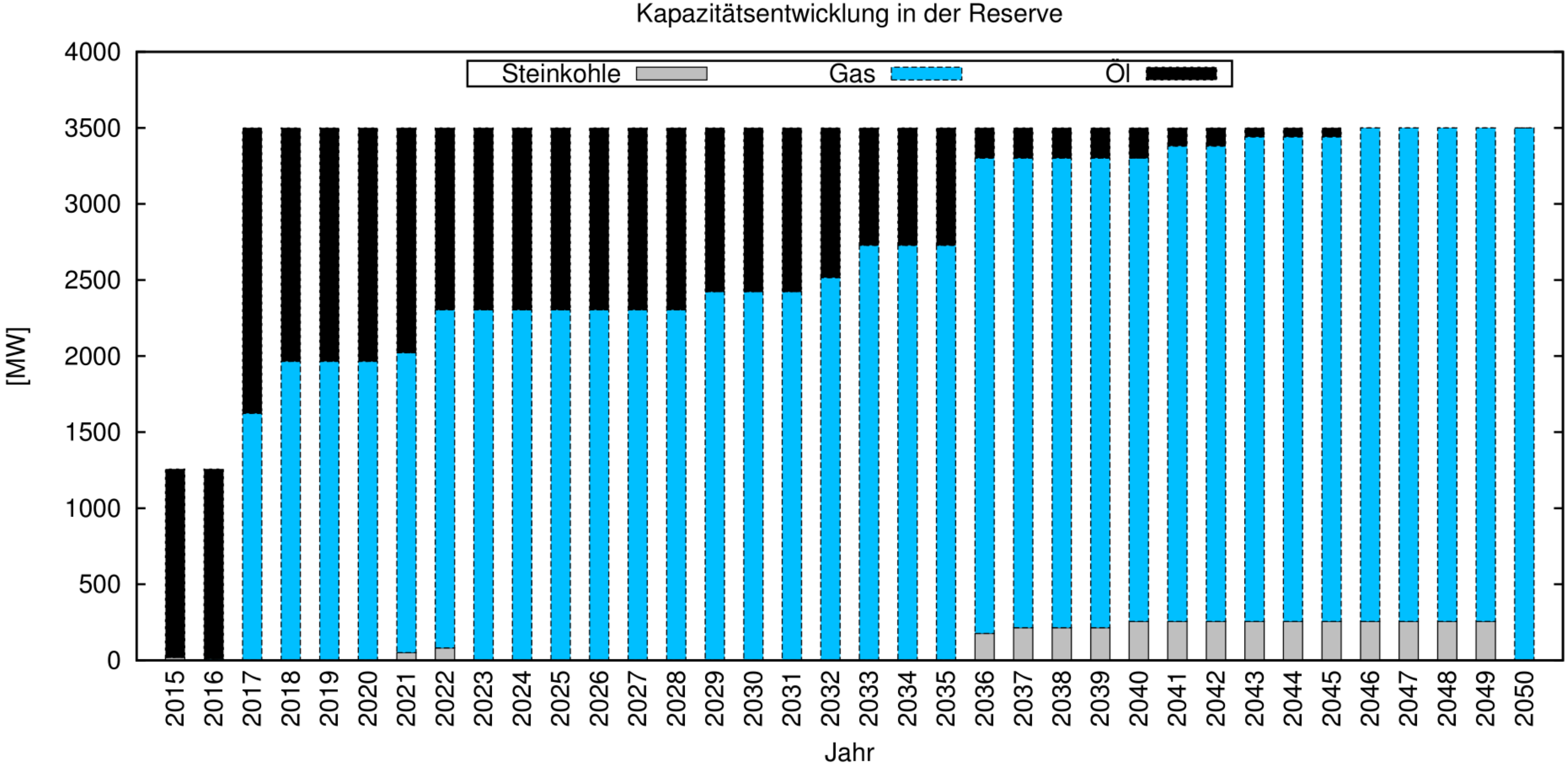
- Ab 2040 kann der Day-Ahead-Markt wiederholt nicht geräumt werden, Regelenergie wird zur Nachfragedeckung eingesetzt
- Geringe Änderungen im Sicherheitsniveau gegenüber Szenario mit Braunkohlezubau



Kapazitätsmechanismen

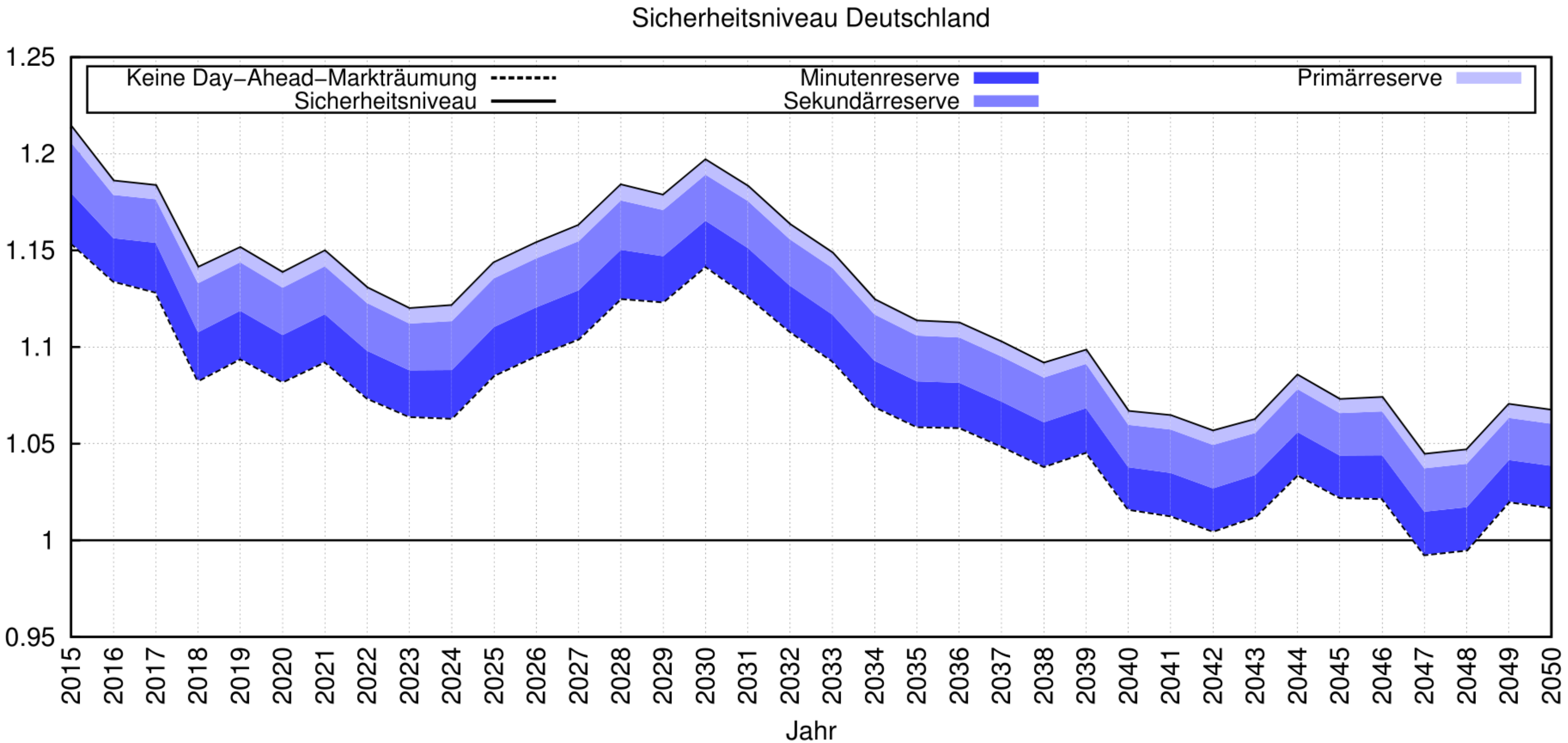
Reserve – Kapazitäten

- Es gehen hauptsächlich Öl- und Gaskraftwerke mit niedrigen Volllaststunden in die Reserve (später auch Steinkohle)
- Hauptsächlich Bestandskraftwerke und vereinzelt Neubauten



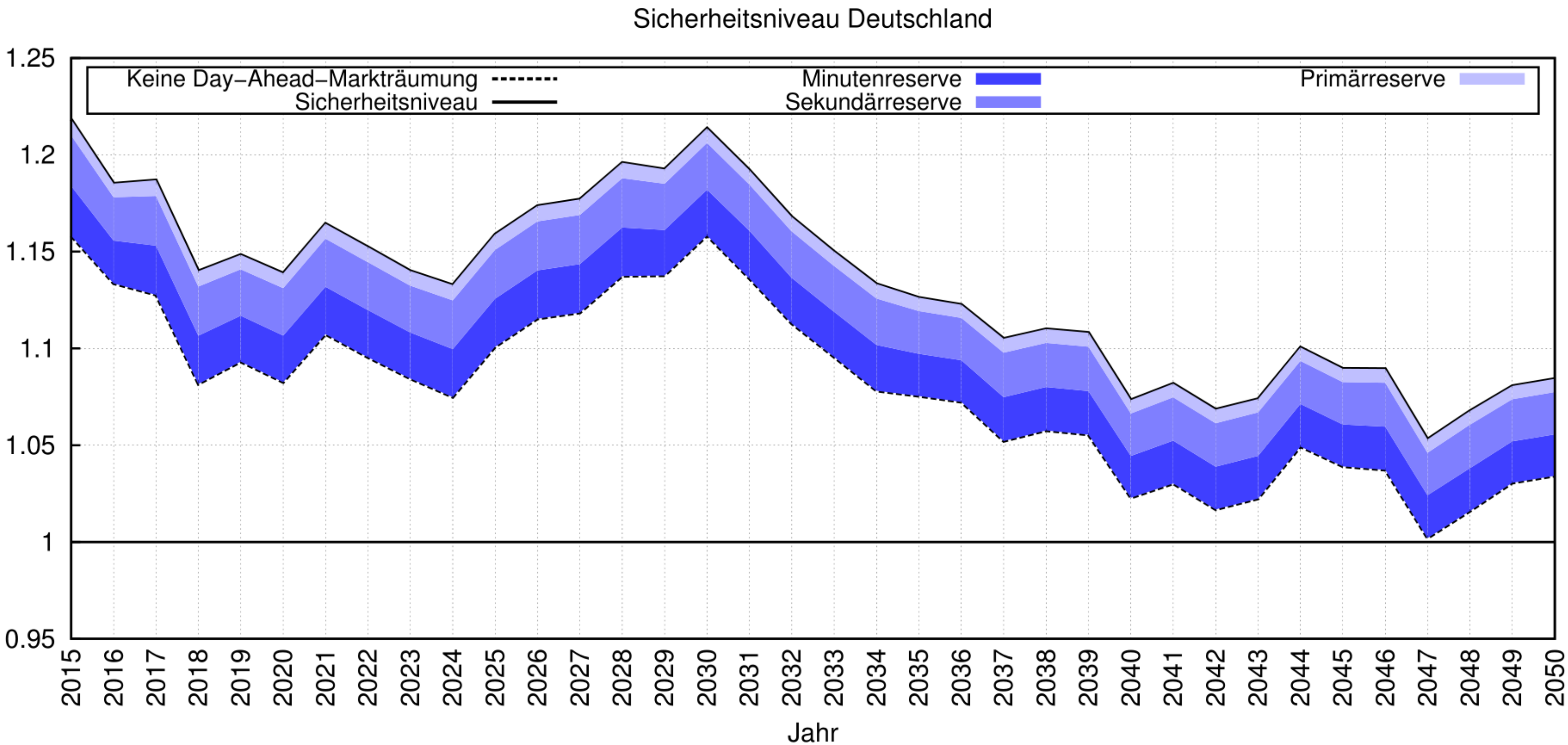
Reserve – Sicherheitsniveau 3,5 GW

- Mittleres Sicherheitsniveau bis 2035 durch Reserve deutlich erhöht
- Nur geringer Einsatz von Minutenreserve erforderlich, zum Unterdeckung der Nachfrage zu vermeiden



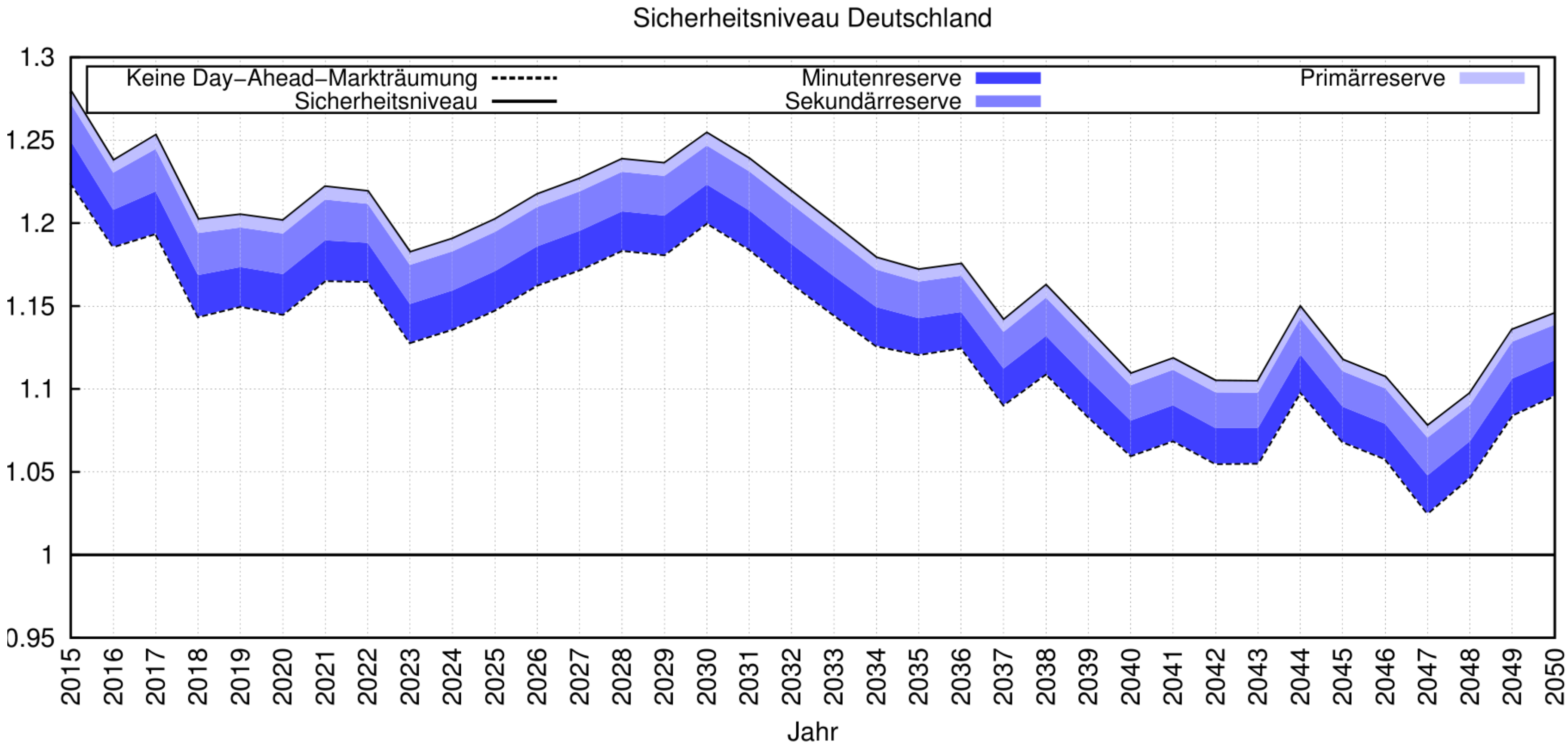
Reserve – Sicherheitsniveau 5 GW

- Sicherheitsniveau bis 2035 durch Reserve deutlich erhöht
- Keine Ausfälle durch Einsatz von Regelenergie



Reserve – Sicherheitsniveau 5 GW mit 8 GW Abschaltbare Lasten

- Immer ausreichend Kapazität verfügbar



Zentraler Kapazitätsmarkt

Kapazitätsentwicklung – LK niedrig

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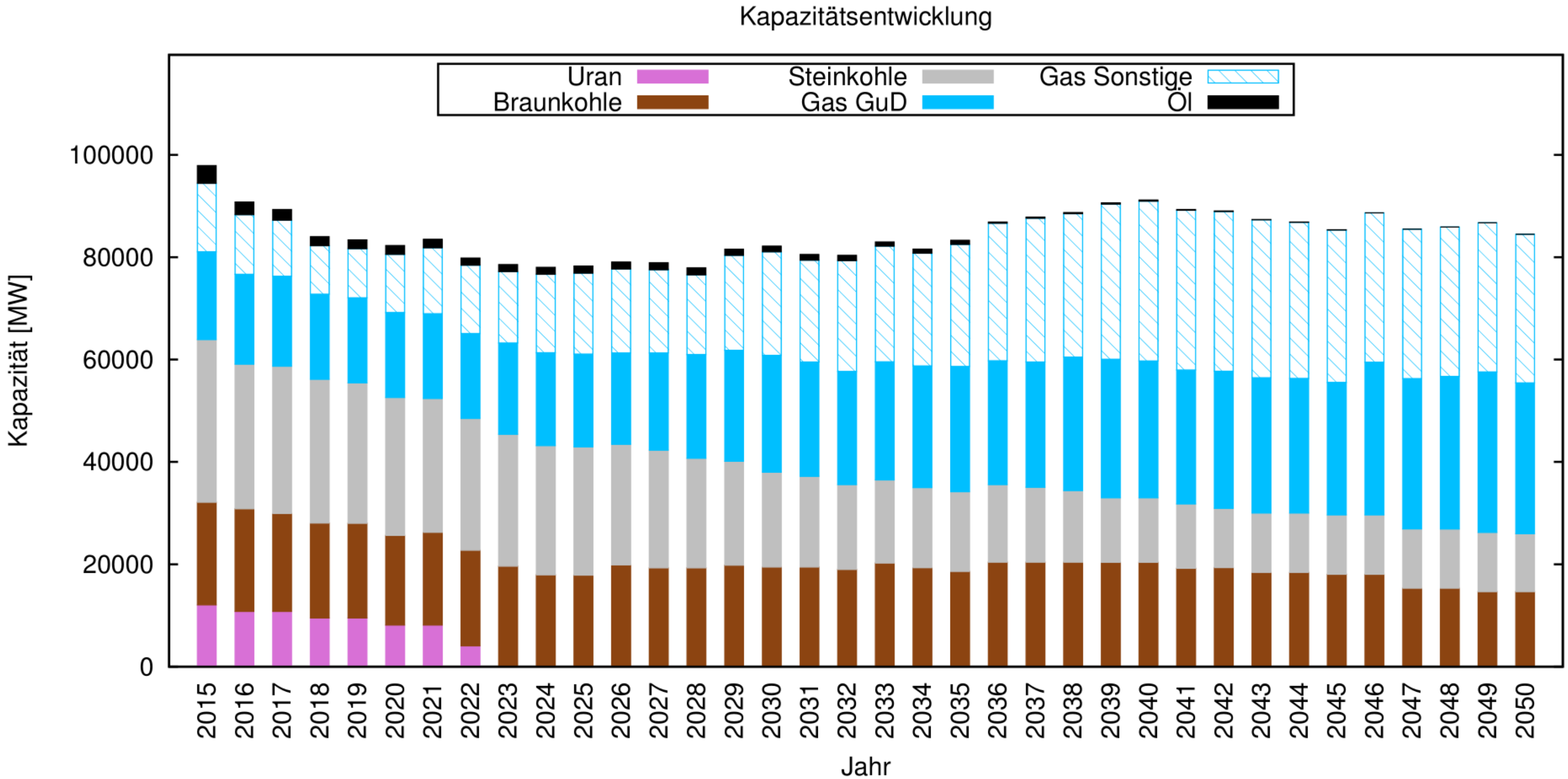
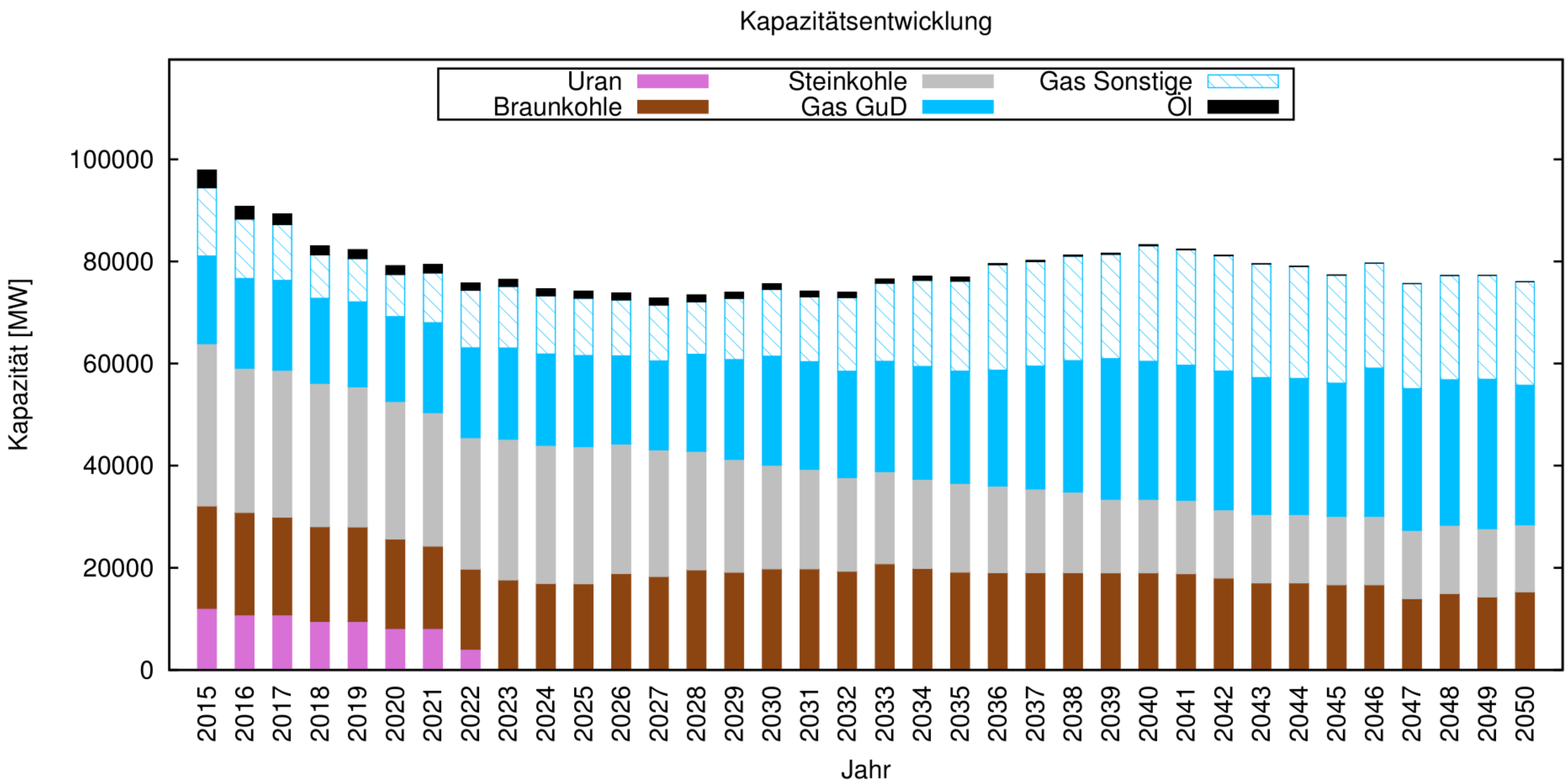
- Gleichmäßige Kapazitätsentwicklung in allen Szenarien mit zentralen Kapazitätsmarkt
- Höheres Kapazitätsniveau im Vergleich zum EOM



Reservemarge 5% EE-Leistungskredite: 1%PV, 6%Wind

Kapazitätsentwicklung – LK hoch

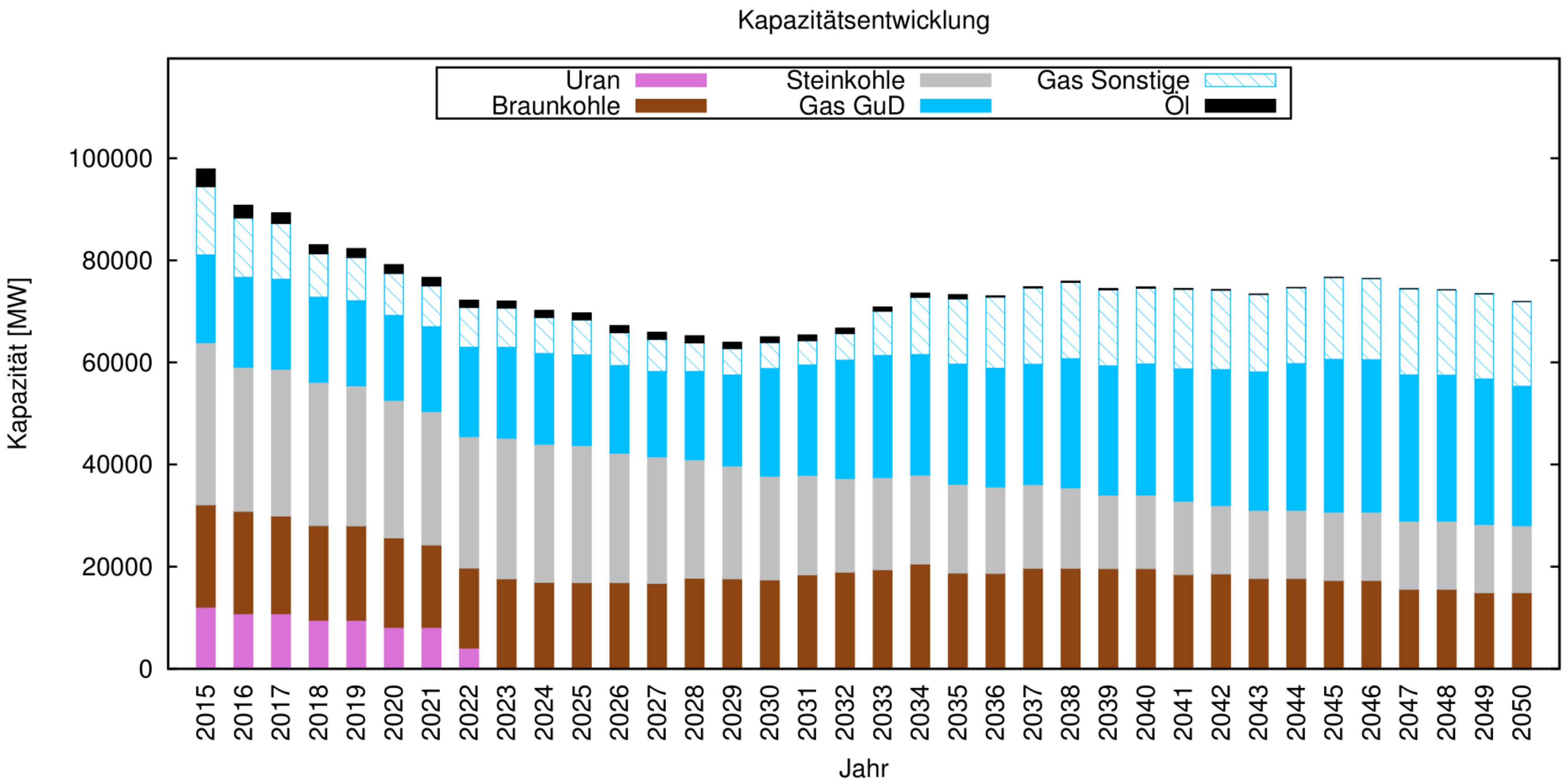
- Höhere EE-Leistungskredite (höhere Bewertung de EE-Einspeisung in der Peak-laststunde) führen zu weniger Kapazitätsnachfrage und somit zu weniger Investitionen



Reservemarge 5% EE-Leistungskredite: 6%PV, 10%Wind

Kapazitätsentwicklung – Exakte Einspeisung

- Bei Berücksichtigung der exakten Einspeisewerte der EE, nähert sich das Kapazitätsniveau dem EOM an



Dezentraler Kapazitätsmarkt

Dezentraler Kapazitätsmarkt

- Aufteilung der Nachfrageagenten in 3 Gruppen (risikoavers, -neutral, -freudig)

- Gebotserstellung der **Nachfrageagenten** und Lerneffekte:

$$Gebotspreis = Prognosepreis \cdot (Risikofaktor - Lernfaktor * Jahre_{ohneTrigger})$$

- Prognosepreis entspricht dem CONE einer Gasturbine

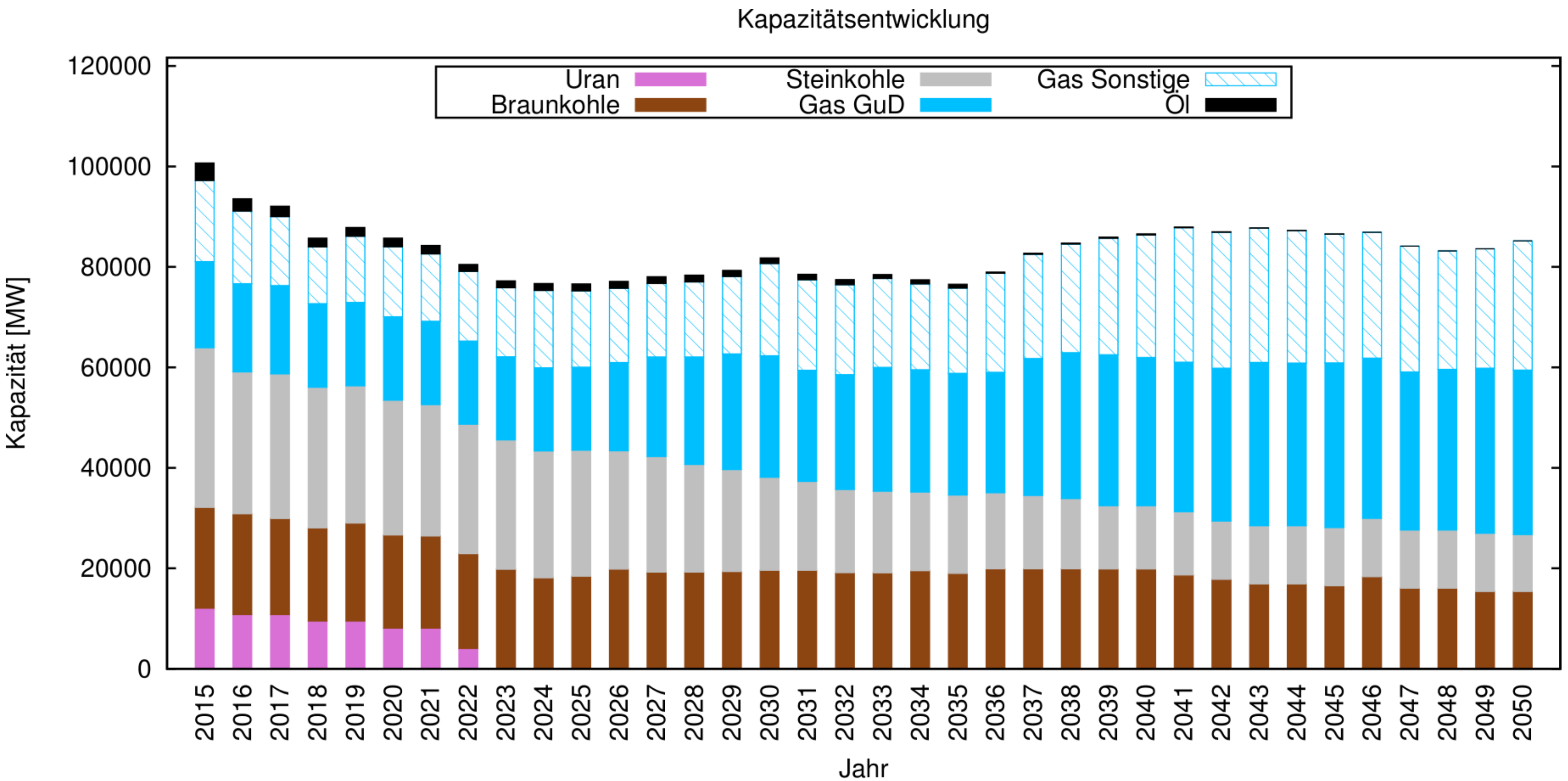
- Jeder Nachfrageagent hat einen persönlichen Risikofaktor, der die Risikoeinstellung ausdrückt

- Überwiegender Teil der Nachfrage ist risikoneutral

- Anzahl der Jahre ohne Triggerereignis (Knappheit) wirkt sich auf die Bereitschaft aus, Zertifikate zu beschaffen und damit auf den Gebotspreis

Kapazitätsentwicklung – LK niedrig

- Auftreten des Triggerereignisses (Knappheitssituation) wirkt sich auf Zertifikatspreise und damit auf das Investitionsvolumen aus



EE-Leistungskredite: Wind 6 %, PV 1 %, Triggerereignis 90 %-Knappheit