

27 March 2026

# When to charge demand? Refinancing capacity remuneration mechanisms

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TOMORROW TODAY

# Agenda

1. Introduction
2. Conceptual framework
3. Numerical model & results
4. Discussion & conclusions

# Demand charges in capacity remuneration mechanisms

## Growing tendency to introduce Capacity Markets (CMs) in Europe

- Most recent example of Belgium, ongoing discussions in Germany
- All else equal, the additional capacity procured in the CM may mitigate scarcity prices in the energy market (EM)
- Hence, the incentive for demand response in scarcity periods through the EM is reduced

## Refinancing capacity via demand charges has implications for demand response in scarcity periods

- With flat charges, there is no additional incentive for demand response
- By contrast, time-of-use and dynamic charges may provide additional demand response incentives

An analysis of the different demand charge design options seems lacking

## CM charge design options we study

Charge	Application period	Charge level	Conceptual framework	Numerical model
Flat	Always	Constant	Yes	Yes
TOU	Static periods based on probabilistic scarcity	Constant	No	Yes
Dynamic constant	Dynamic periods (based on stochastic actual scarcity)	Constant	No	Yes
Dynamic variable	Dynamic periods (based on stochastic actual scarcity)	Variable	Yes	Yes

### Research Question:

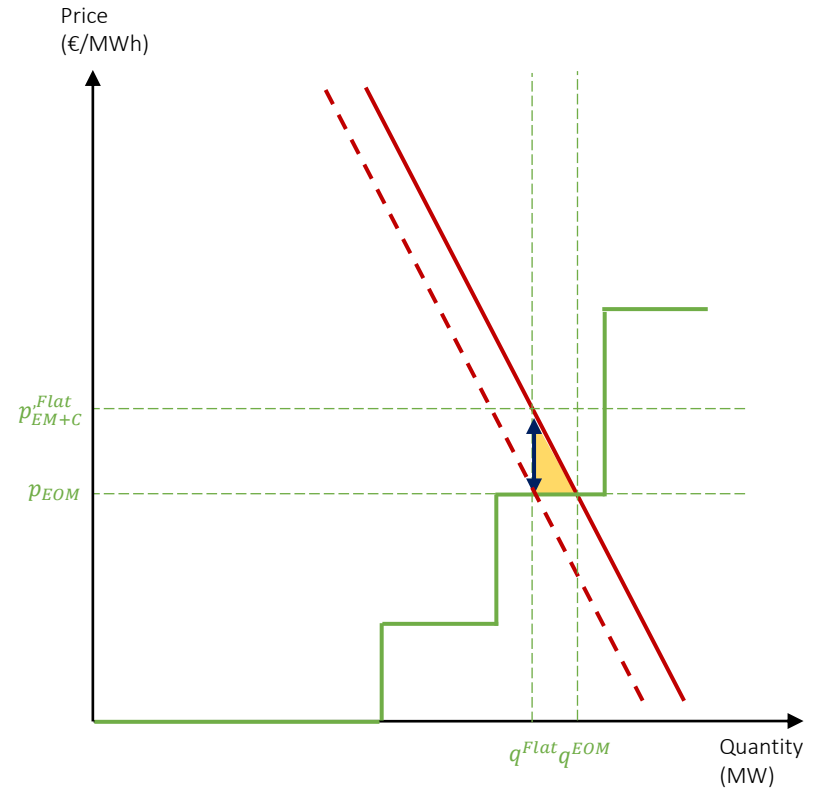
How do the selected charge designs affect firm capacity, technology mixes, market prices, and welfare?

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# Flat Charge – Regular Hours

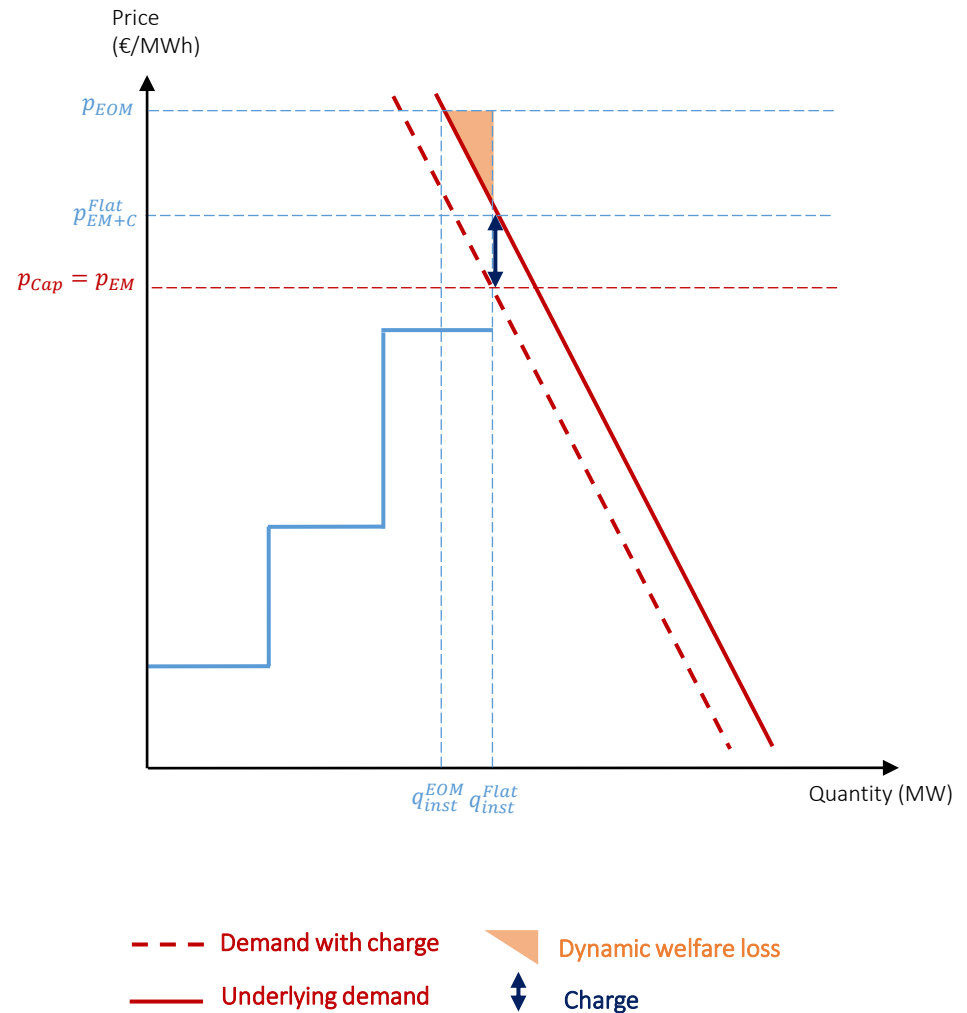
- Flat charge reduces demand uniformly across all hours by a small amount
- Inefficiencies in regular hours: sufficient generation is available to meet demand, but the charge suppresses consumption below the efficient level
- Results in a static welfare loss compared to the EOM



- Demand with charge
- Underlying demand
- ▲ Static welfare loss
- ↕ Charge

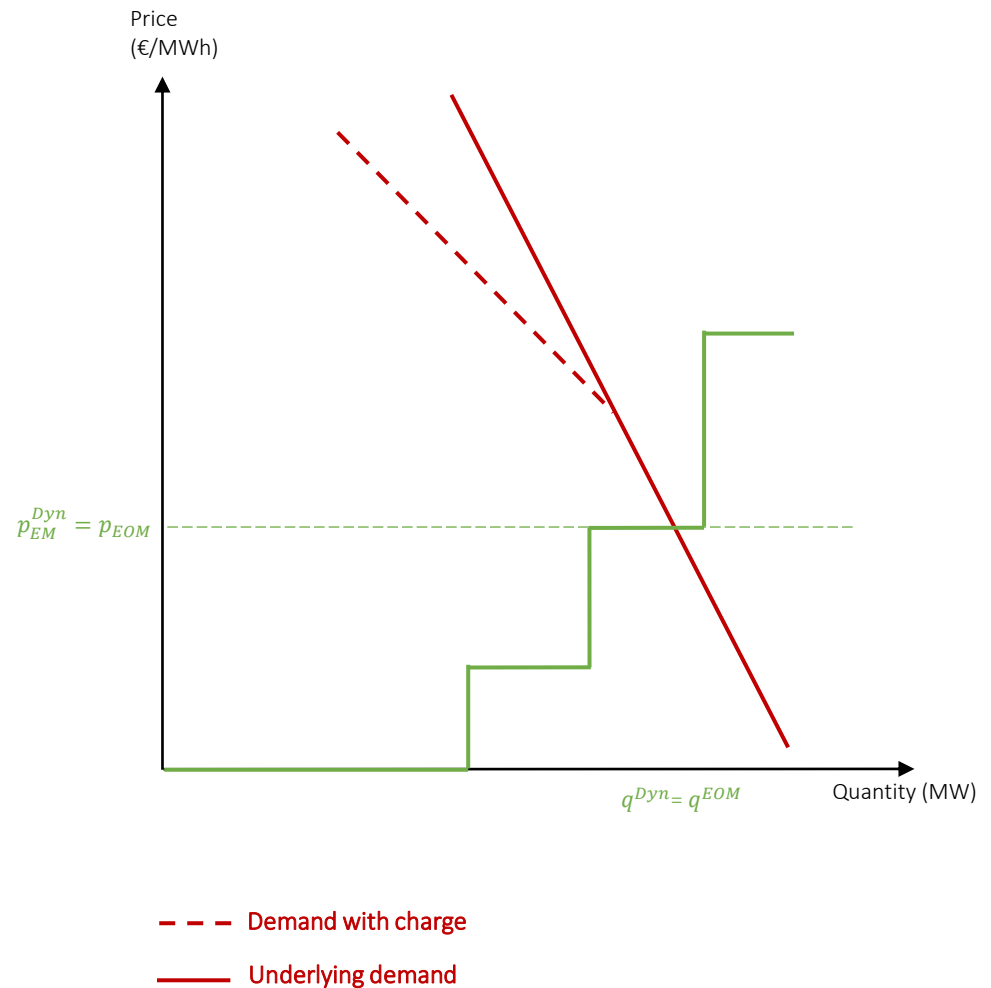
# Flat Charge – Scarcest Hour

- Scarcest hour: quantity demanded = quantity installed
- In this hour, the price in the EOM with scarcity pricing would be higher than the capped price of EM+flat charge
- Consequently, for the same reliability level, the installed capacity with CM + flat charge must be larger than the installed capacity in EOM
- Dynamic welfare loss relative to the EOM arises from the additional fixed costs incurred due to the inefficiently high levels of capacity



# Dynamic Charge – Regular Hour

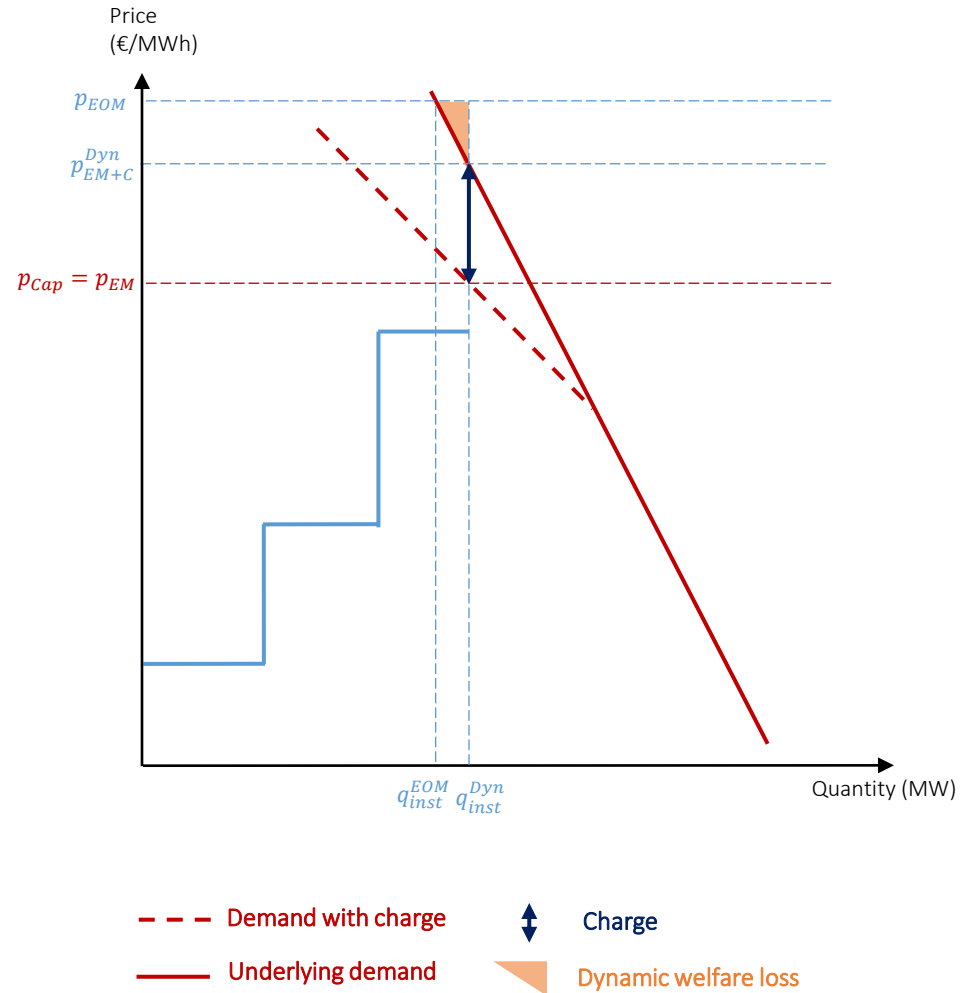
- A dynamic charge reduces demand only during the hours in which it is applied
- In regular hours, the charge is not applied, and demand does not change compared to the EOM
- There is no static welfare loss compared to the EOM



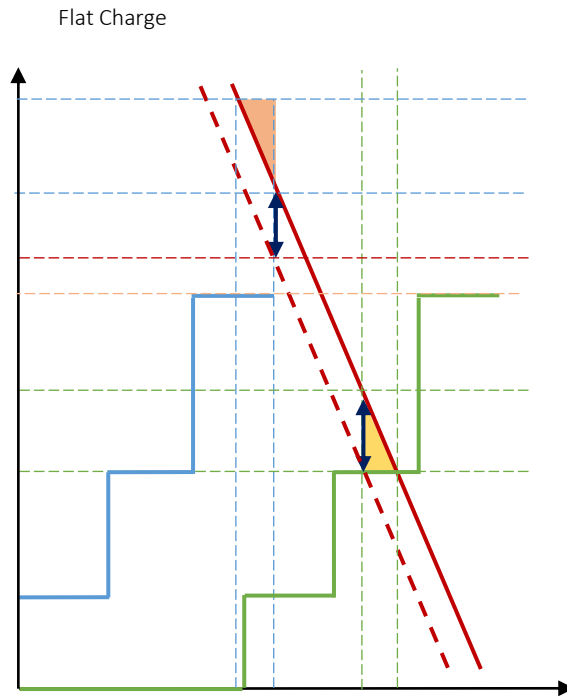
# Dynamic Charge – Scarcest Hour

Argumentation similar to flat charge:

- Capped EM price + dynamic charge lower than EOM scarcity price -> installed capacity with dynamic charge larger than installed EOM capacity
- Dynamic welfare loss relative to the EOM from the additional fixed costs incurred due to the inefficiently high levels of capacity

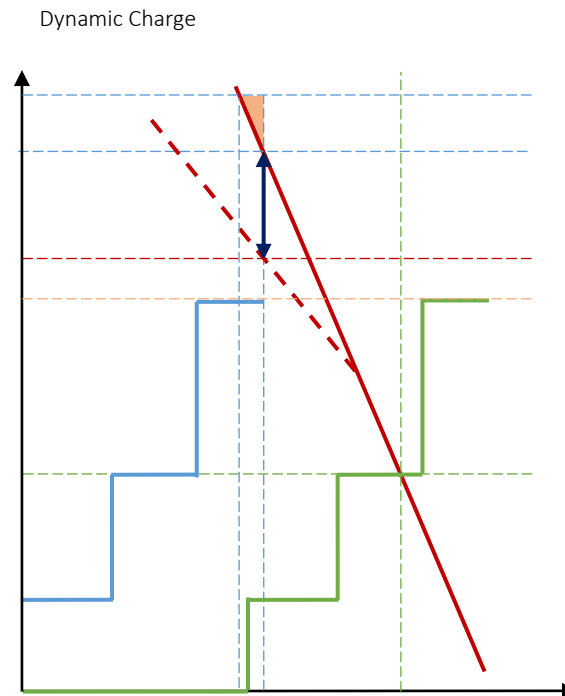


# Hypotheses



Installed capacity

$EOM < \text{Dynamic} < \text{Flat}$



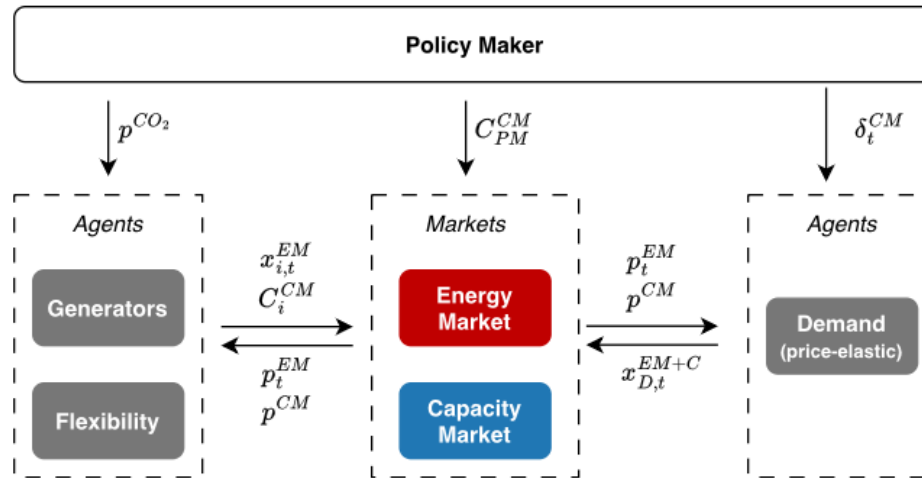
Welfare

$EOM > \text{Dynamic} > \text{Flat}$

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# Model



- Partial-equilibrium model with energy and capacity market
- Optimizing agents with perfect foresight: agents are making (brownfield) investment and dispatch decisions
  - Generators: onshore & offshore wind, utility-scale PV, run-of-river, OCGT, CCGT
  - Flexibility: battery storage
  - Demand: elastic response of aggregate demand to energy price and CM charge; arcsinh specification with 5% elasticity at average price 80 €/MWh (historical elasticity estimate from Arnold, 2023)
- Solution approach: alternating direction method of multipliers (ADMM)
- Modelled period: 4 representative weeks in hourly resolution

# Scenario and market setup

## Time series inputs

- Electricity demand 2040 (Germany, TYNDP baseline)
- Imports and exports as exogenous time series
- Climate year 2009 (representative)

## Capacities

- Brownfield initial capacity = TYNDP NT+ 2030
- Expansion up to 2040 constrained by TYNDP potentials

## Energy market (EM)

- Price cap at 500 €/MWh (politically motivated, not technical)

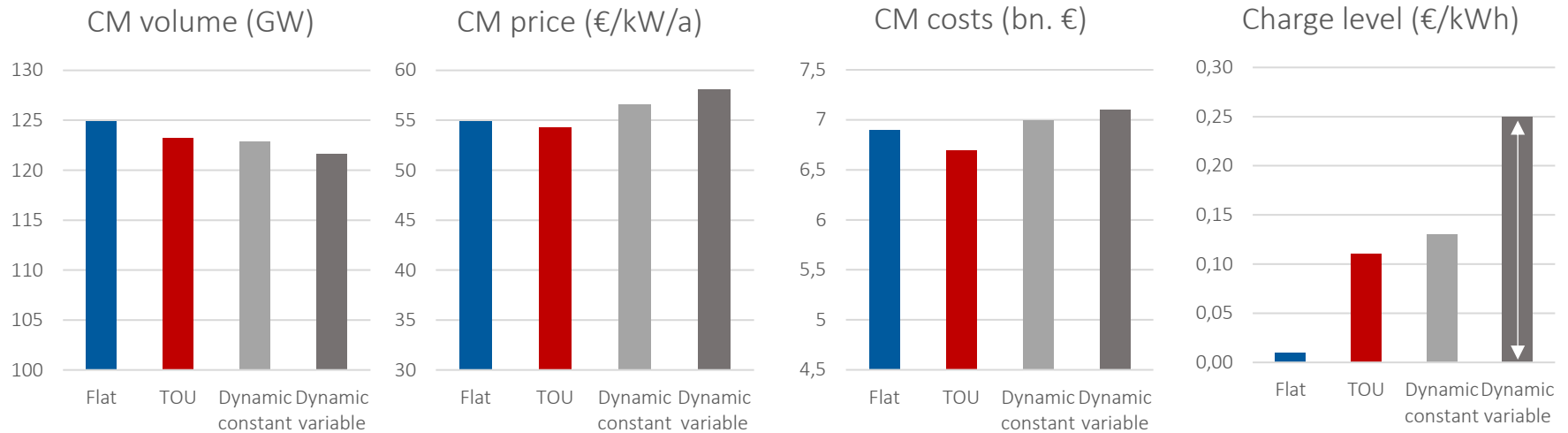
## Capacity market (CM)

- Reliability target: LOLE = 0 hours
- Technology-specific de-rating factors
  - RES → availability in 15 hours with the highest residual-load
  - Thermal & storage → values from Elia (Belgian TSO)

## Model determines endogenously

- Required CM volume
- CM clearing price
- CM charge level to recover CM costs

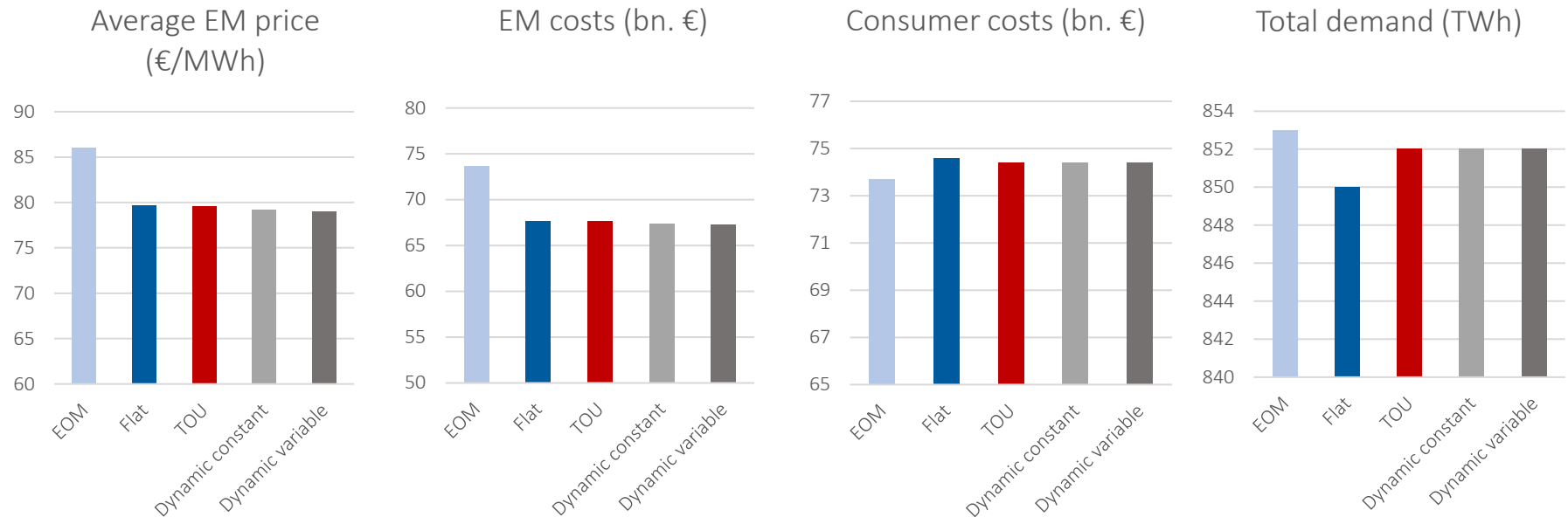
# Capacity markets results



## With increasing cost reflectiveness

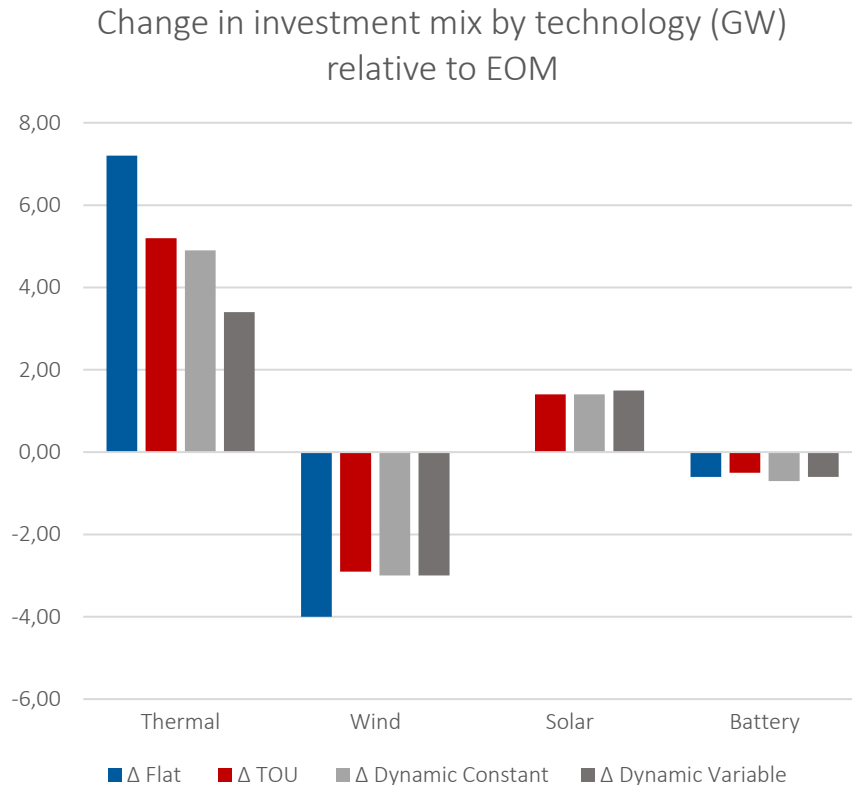
- CM volumes decrease, with overall effects remaining modest (3 GW).
- CM (clearing) prices show ambiguous effects, driven by scarcity prices in the EM.
- CM cost are ambiguous, reflecting opposing effects of CM prices and volumes.
- Charge levels increase, as expected.

# Interactions with the energy market



- **Average EM price:** higher in EOM (no price cap); small decline as the cost reflectiveness of the charge increases
- **EM-Costs:** significantly higher in EOM (no CM costs), small decrease for dynamic across charge designs
- **Consumer costs:** significantly smaller in EOM than in all charge scenarios (almost 1 bn€/a compared to flat charge), within charge designs more cost-reflective charges reduce costs (200 m€/a savings)
- **Consumer loss compared to EOM:** higher under flat charges than under more cost reflective designs, driven by 200m€/a higher consumer costs and roughly 2 TWh lower consumption

# Changes in the investment mix



## Flat charge vs. EOM

- Thermal investment increases  
→ The price cap increases the demand peak
- Wind investment decreases  
→ The charge suppresses consumption
- Solar investment unchanged, batteries slightly decrease  
→ Likely caused by imperfect de-rating

## Comparison across charge designs

- Thermal investment substituted by wind/solar for more cost-reflective designs
- Ambiguous results for batteries: net effect of capacity substitution vs. complementarity with VRE

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# Discussion

## Perfect foresight assumption

- In the very scarce hours—when forecasts are typically accurate—the dynamic variable design applies high charges
- In hours with uncertain scarcity, charges remain low, minimizing the impact of forecasting errors with the dynamic variable design
- Additional advantage of this design under uncertainty

## Demand elasticity estimate from Arnold (2023)

- Estimate reflects DR around average price levels (5%)
- Under scarcity conditions, response may be
  - Stronger, if higher prices trigger clearer demand reductions
  - Weaker, if available flexibility is already exhausted
- Historical elasticity values likely understate future flexibility (enabling technologies, smart meters, dynamic tariffs)

# Conclusions and further research

## Conclusion

- Compared to the (hypothetical) EOM, the introduction of CMs increases consumer costs and decreases total demand, resulting in consumer losses, while inflating capacity (primarily in thermals)
- Effects depend on charge design: more cost-reflective charges enable capacity substitution, lower consumer cost, and shift investment towards RES

## Further research

- What are the implications of uncertainty?
  - For the calculation and effect of different CM charges
- What is the demand response in scarcity prices?
  - Given the contradicting hypotheses on the previous slides
- Do dynamic CM charges make explicit demand participation in CMs obsolete?
  - Given the challenges with explicit demand response

# Thank you!

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Working Paper in progress!

