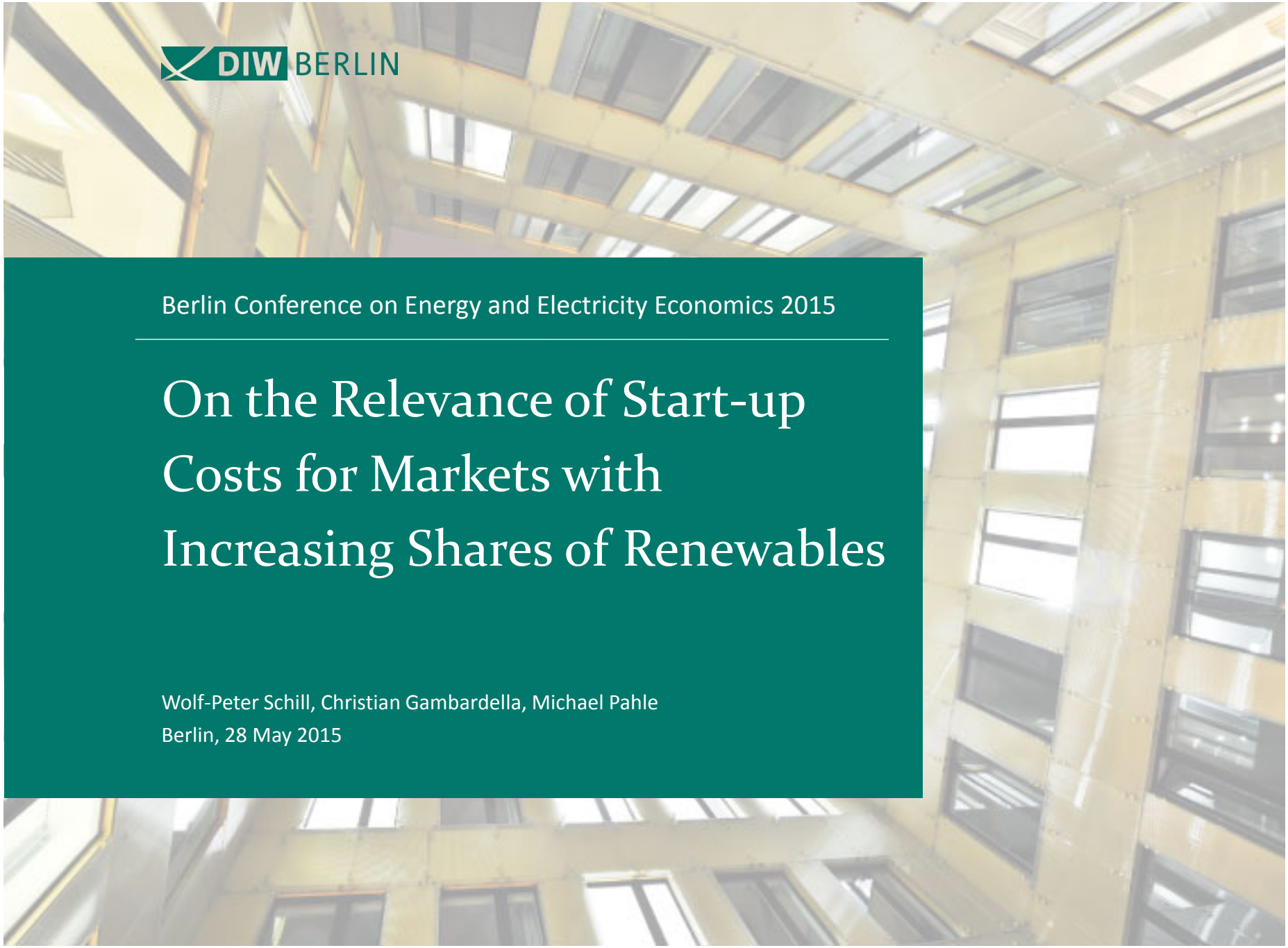

DIW BERLIN

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On the Relevance of Start-up Costs for Markets with Increasing Shares of Renewables

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Overview

1 Introduction

- Starting up thermal power plants incurs costs
- How does the relevance of start-up costs change in the context of increasing shares of fluctuating renewables?
  - Higher relevance because of higher fluctuations in residual load?
  - Lower relevance because of changing power plant portfolio?
- Implications for both market design and modeling practice
- Numerical illustration:
  - Application of a dispatch model to Germany
  - Different scenarios

2 The model

- Cost-minimizing hourly dispatch
- Linear setting with unit commitment formulation (MILP)
  - Start-up costs and minimum offtime with binary variables
- Exogenous parameters:
  - Hourly load (price-inelastic)
  - Hourly availability of fluctuating RES
  - Yearly energy cap for biomass
  - Cost and flexibility parameters
- Endogenous variables:
  - Dispatch of all capacities
  - Costs, start-up costs
- Implemented in GAMS and solved with CPLEX
  - Full year: 13 sequential blocks of 4 weeks each

2 Some equations

$$Cost = \sum_{i,t}(vc_i Q_{i,t} + sc_i ST_{i,t}) + \sum_{j,t} vstc_j Stout_{j,t} + \sum_t penalty^{Peak} Peak_t \quad (1)$$ Objective function

$$Q_{i,t} \leq qmax_i avail_{i,t} U_{i,t} \quad \forall i, \quad (2)$$ Upper generation constraint

$$Q_{i,t} \geq qmin_i avail_{i,t} U_{i,t} \quad \forall i,t \quad (3)$$ Lower generation constraint

$$ST_{i,t} \geq U_{i,t} - U_{i,t-1} \quad \forall i,t \quad (4)$$

$$U_{i,t-1} - U_{i,t} \leq 1 - U_{i,tt} \quad \forall i,t \text{ with } t \leq tt \leq t + stime_i - 1 \quad (5)$$

Relations between binary variables

$$Resint_{res,t} + Rescurt_{res,t} = resavail_{res,t} \quad \forall res,t \quad (6)$$

$$Rescurt_{res,t} \leq resavail_{res,t} \quad \forall res,t \quad (7)$$

RES curtailment

$$Bio_t \leq qmaxbio * availbio_t \quad \forall t \quad (8)$$ Upper bio constraint

$$\sum_t Bio_t \leq energymaxbio \quad (9)$$ Yearly bio energy constraint

$$Stlev_{j,t} = Stlev_{j,t-1} + Stin_{j,t}\eta_j - Stout_{j,t} \quad \forall j,t \quad (10)$$ Storage motion equation

$$Stlev_{j,t} \leq stlevmax_j \quad \forall j,t \quad (11)$$ Upper storage level

$$Stin_{j,t} \leq stinmax_j \quad \forall j,t \quad (12)$$ Storage loading constraint

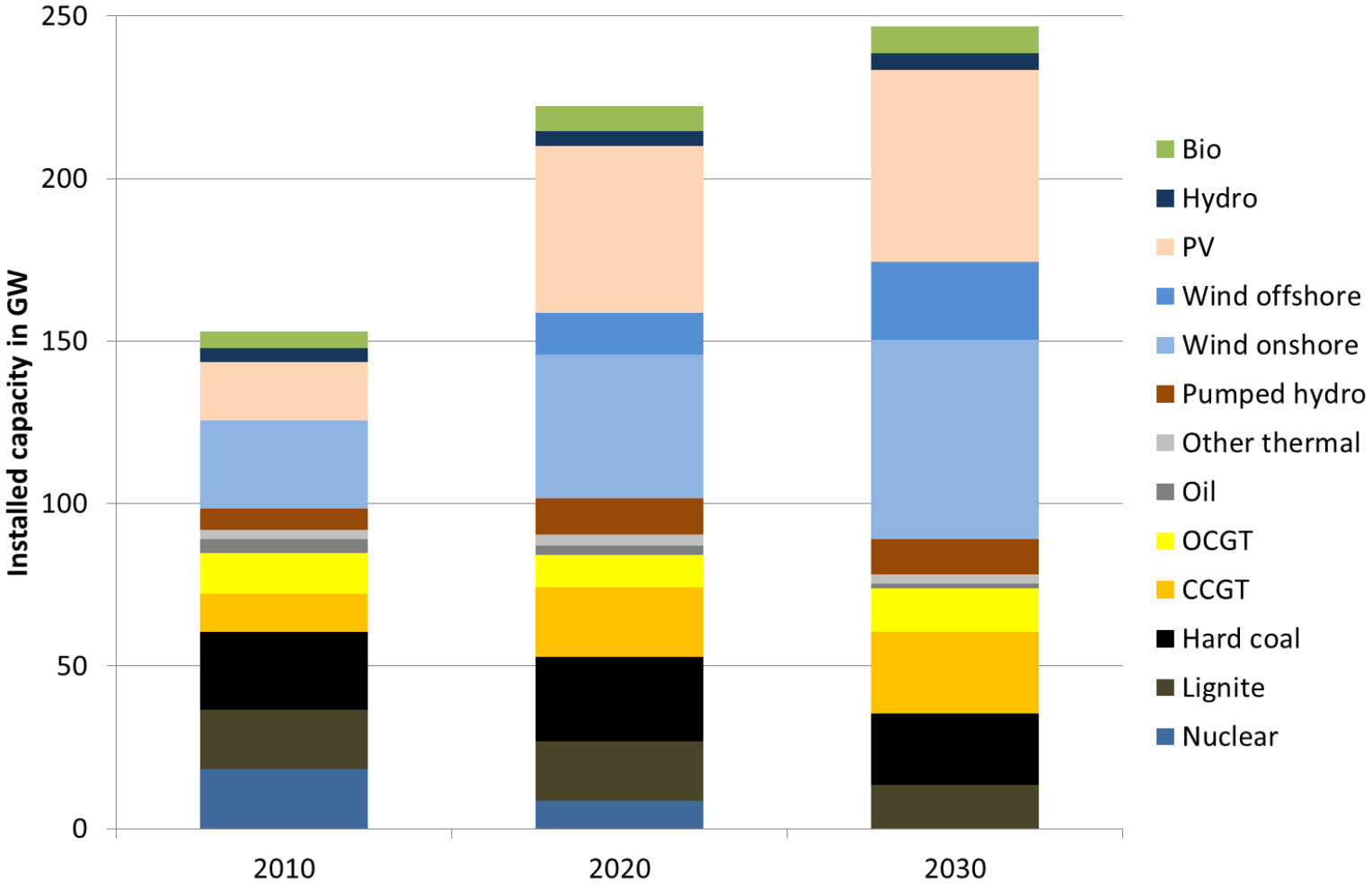
$$Stout_{j,t} \leq stoutmax_j \quad \forall j,t \quad (13)$$ Storage disch. constraint

$$\sum_i Q_{i,t} + \sum_{res} Resint_{res,t} + Bio_t + Peak_t + \sum_j (Stout_{j,t} - Stin_{j,t}) = dem_t + exchange_t \quad \forall t \quad (14)$$ Energy balance

3 Input parameters and data sources

- Generation capacities, techno-economic parameters:
  - Grid Development Plan (2013) and DIW database
  - 351 thermal blocks (2010)
  - Blocks < 100 MW aggregated to 100 MW blocks
- Hourly data based on 2010 levels:
  - Electric load (ENTSO-E)
  - Availability of onshore wind, offshore wind (2012) and PV (TSOs)
- Biomass:
  - Assumed to be inflexible in 2010
  - 50% flexible in 2020, fully flexible in 2030

3 Installed capacities

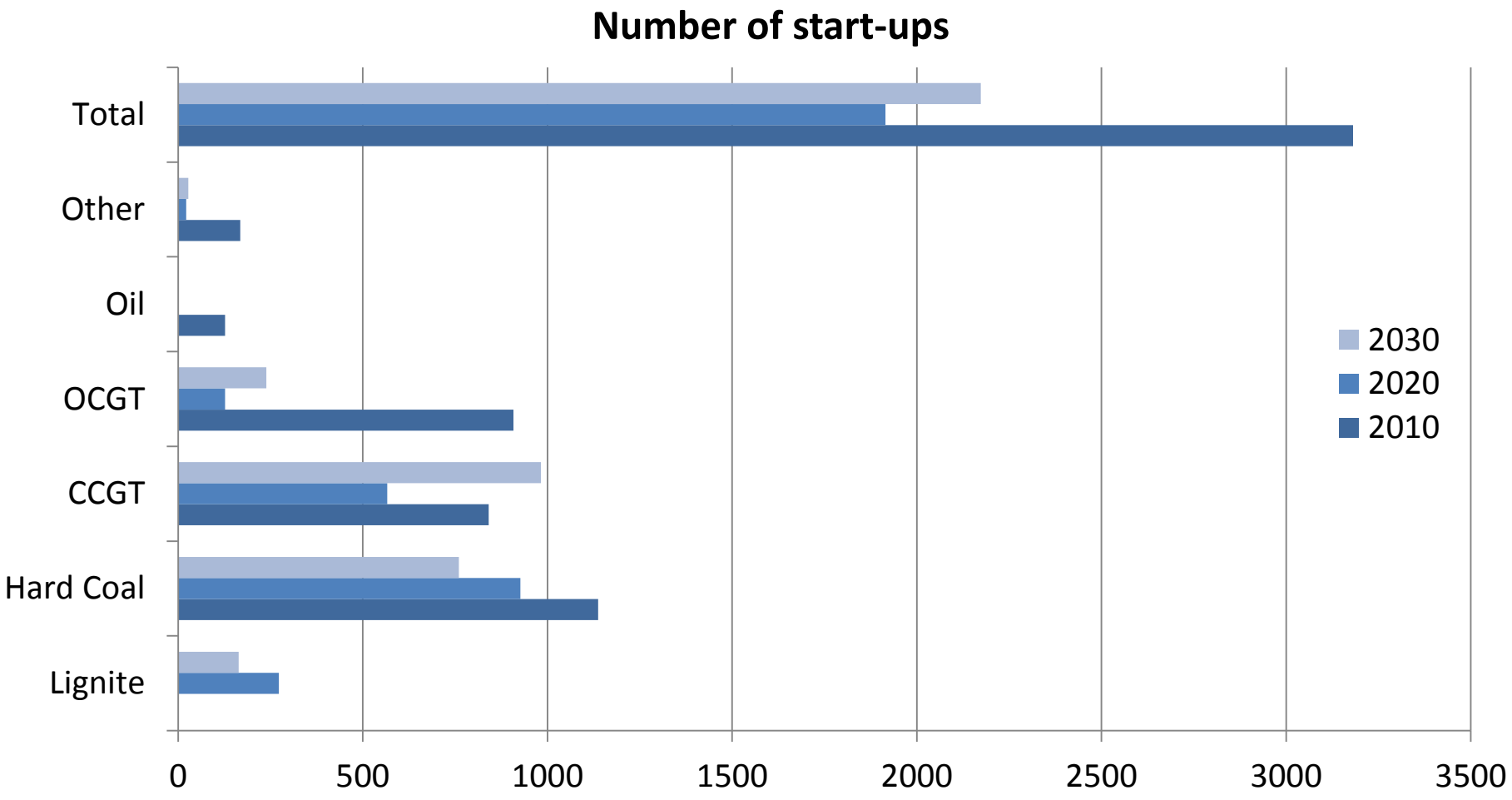


→ Capacities of fluctuating RES increase substantially

3 Scenarios

- Model calibrated to Germany
  - Exchange with neighboring countries fixed to 2010 levels
- Scenarios for 2010, 2020 and 2030
  - „Baseline“: capacities of German Grid Development Plan
  - „More RES“: 10% (20%) more wind and PV 2020 (2030)
  - „Less storage“: pumped hydro on 2010 levels
- Additional runs to seperate effects between 2010-2030:
  - RES expansion, biomass flexibility and pumped storage
  - With the thermal portfolio of 2010

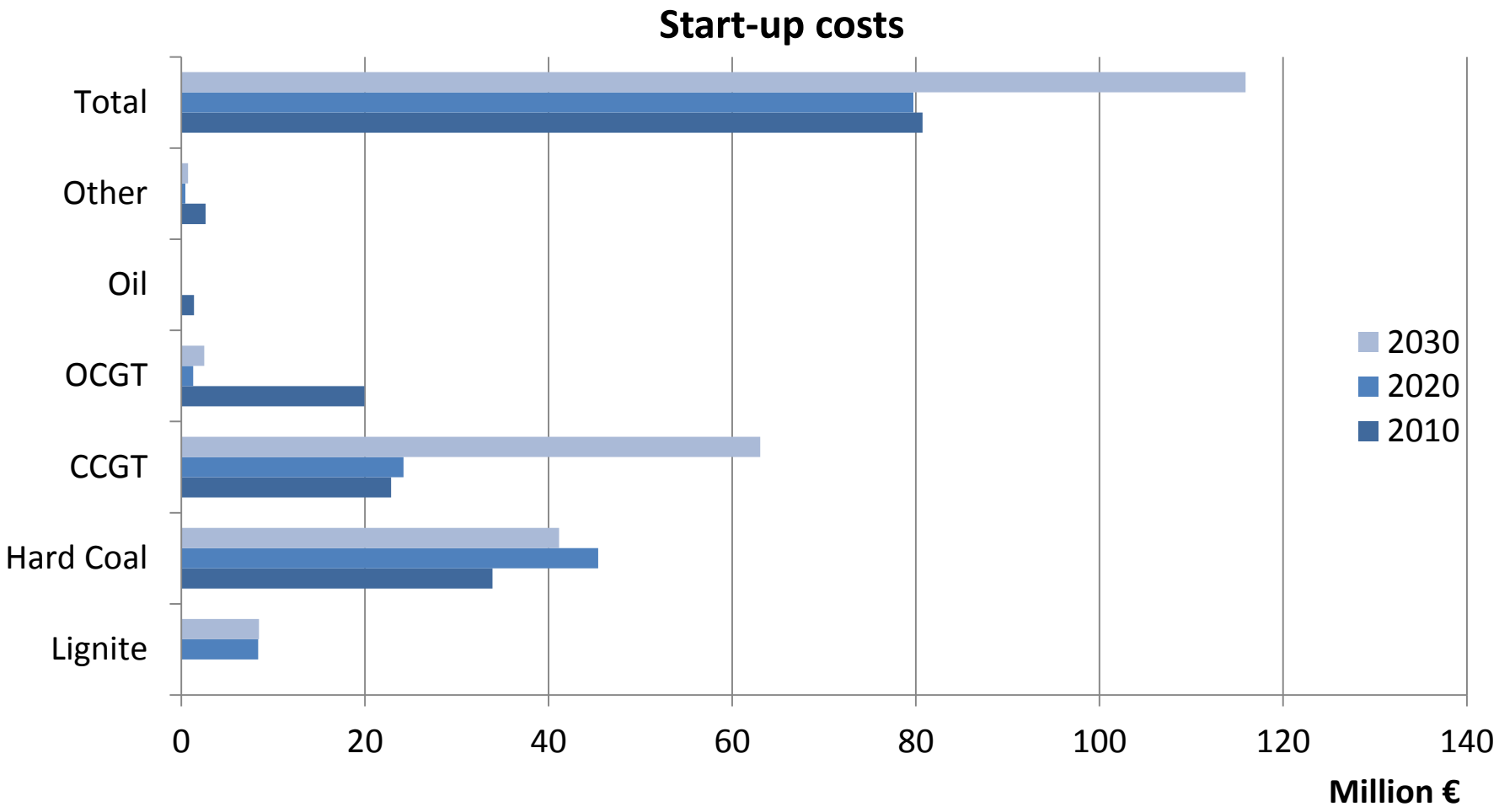
4.1 Results for baseline: number of start-ups



→ Frequent start-up of mid- and peak-load technologies

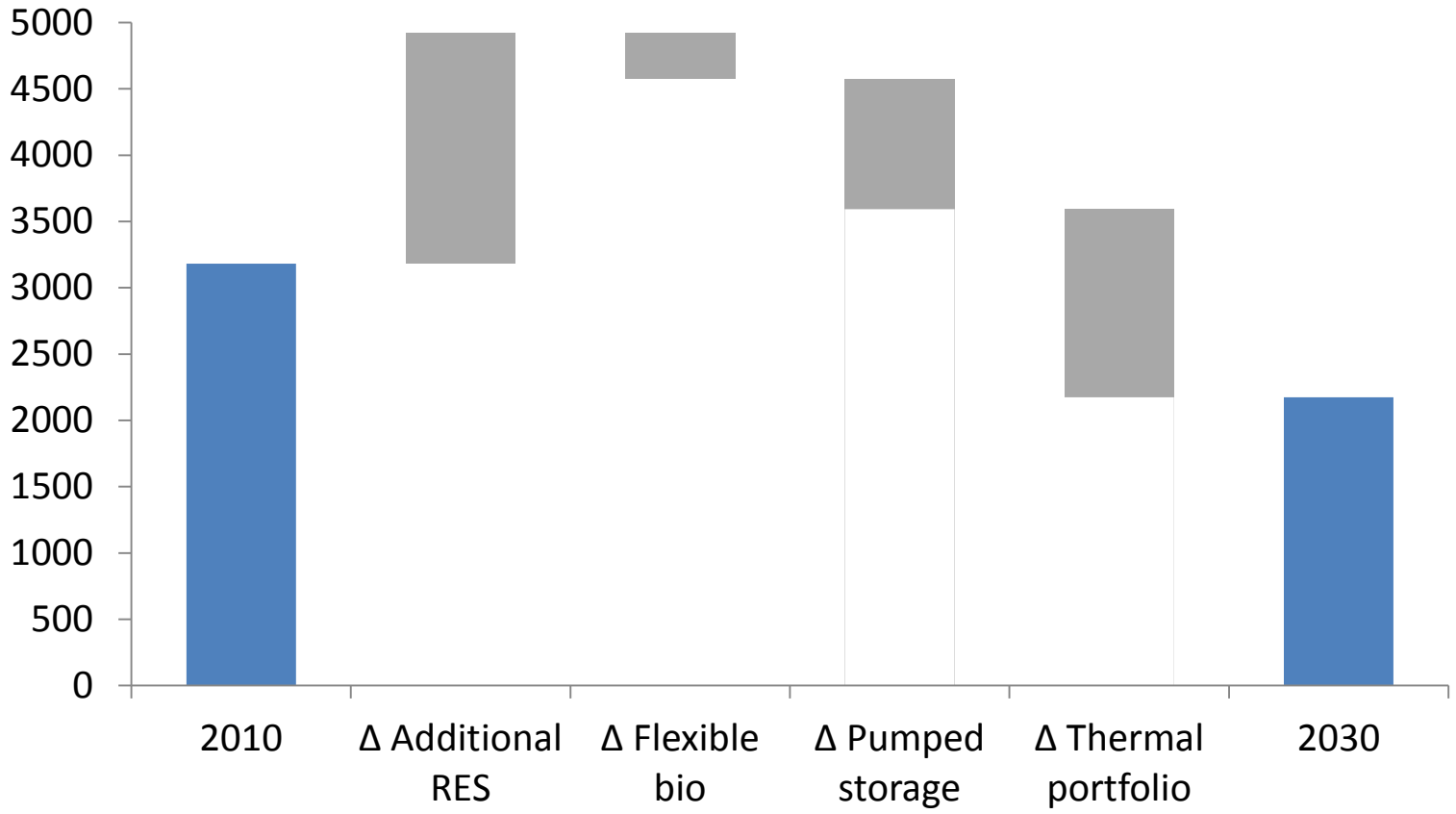
→ Overall, the number of start-ups decreases (also per block)

4.1 Results for baseline: start-up costs



→ Start-up costs tend to increase (rising fuel and CO_2 prices)

4.2 Separation of effects for total number of start-ups between 2010 and 2030

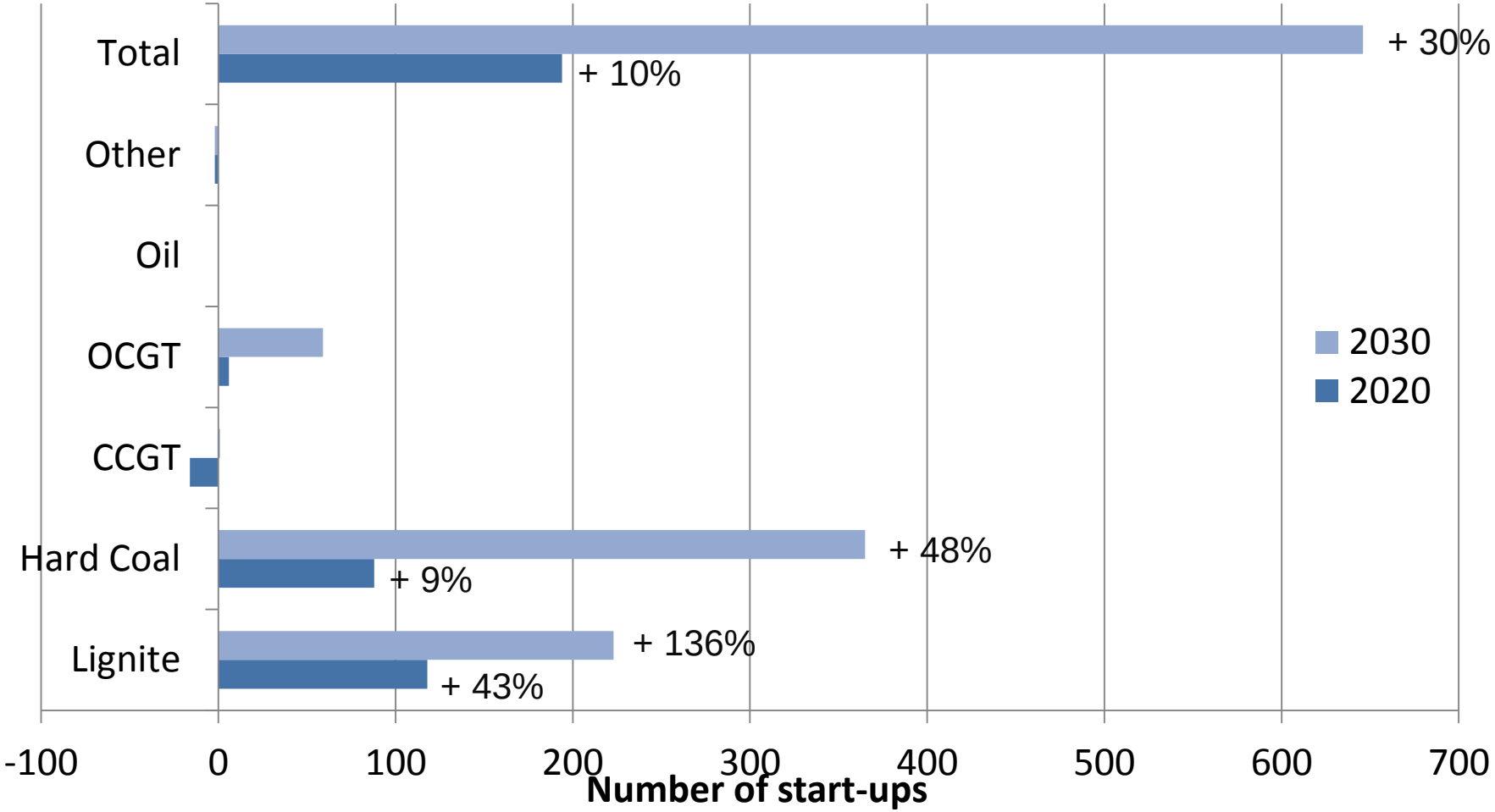


→ Increasing effect of additional RES

→ Decreasing effect of flexibility options and larger average block sizes

4.3

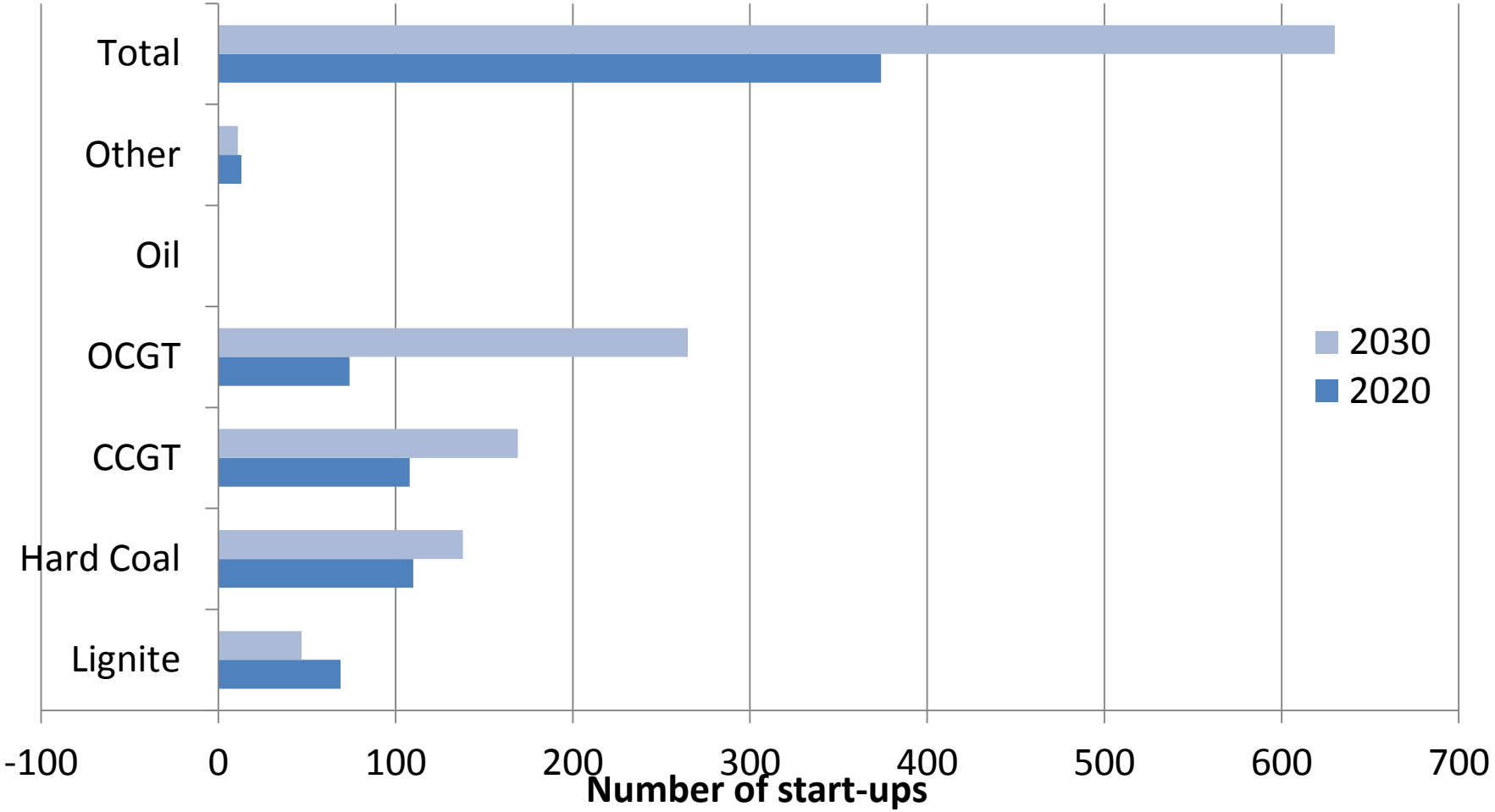
Sensitivity: More RES
Number of start-ups, differences to baseline



→ Disproportional increase, particularly for base-load plants

4.3

Sensitivity: Less storage
Number of start-ups, differences to baseline



→ Strong increase, particularly for mid-/peak-load plants

5 Summary and conclusions

- Findings:
  - Overall, number of start-ups decreases in the context of the *Energiewende*
  - Start-up costs tend to increase (ceteris paribus)
  - Overlapping effects
    - Increasing effect of additional RES
    - Decreasing effect of higher flexibility and larger average block sizes
  - Relevant interactions with storage and biomass flexibility

- Conclusions:
  - Implications for market design
  - Implications for power market modeling

5 Future research

- Make use of additional model features developed in other projects:
  - Controlled / uncontrolled loading of electric vehicles
  - Demand-side management
  - Provision of control reserves

- Other scenarios / sensitivities

Vielen Dank für Ihre Aufmerksamkeit.

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