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# Political Shocks and Efficient Investment in Electricity Markets

by

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# Our Paper …

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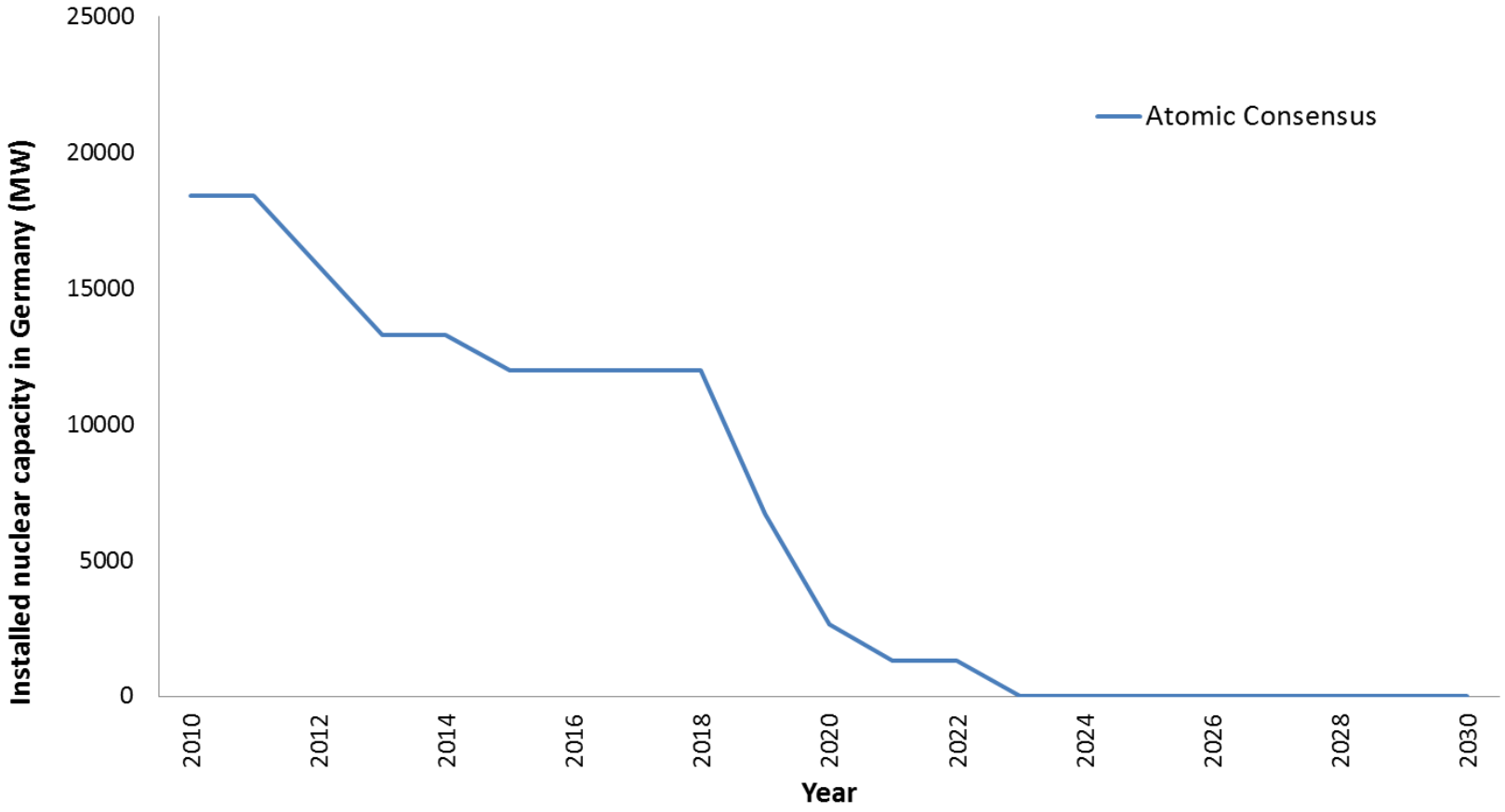
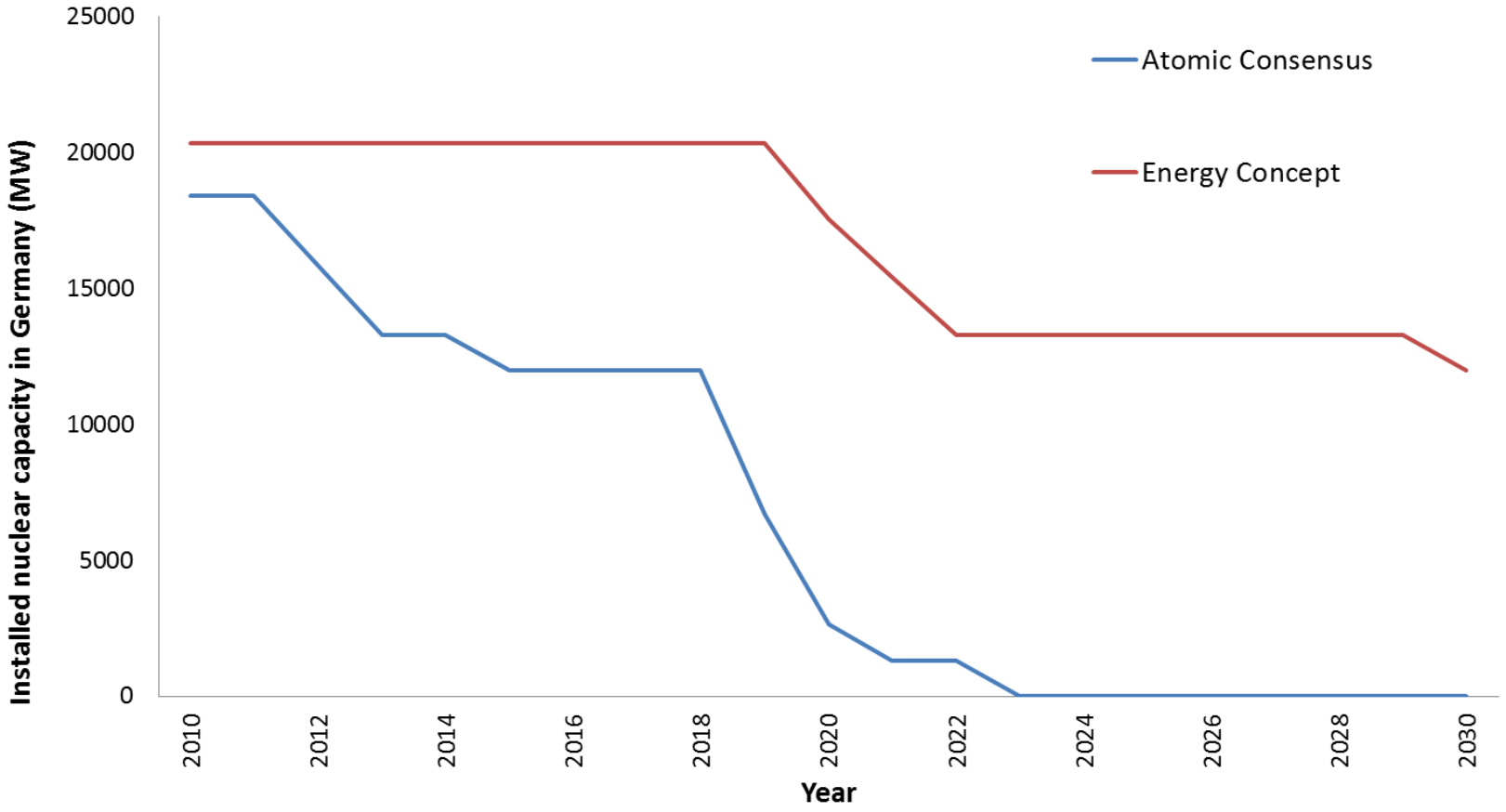
- presents a detailed power market investment and dispatch model (LP) with consistent electricity price estimators
- illustrates the effects of political uncertainty
  - using the example of the change in profit contribution
  - for a specific CCGT-power plant
  - due to the political decisions in Germany with respect to nuclear power

# Nuclear Phase-Out (June 2000)




- Decided by red-green coalition government in June 2000
- An average of 32 years of operation for nuclear power plants in Germany

# Energy Concept (2010 September)




- Decided by conservative-liberal coalition government end of September 2010
- Prolongation of running times by 8 and 14 years respectively

# Nuclear Phase-Out Nuclear Phase out (2011 June)

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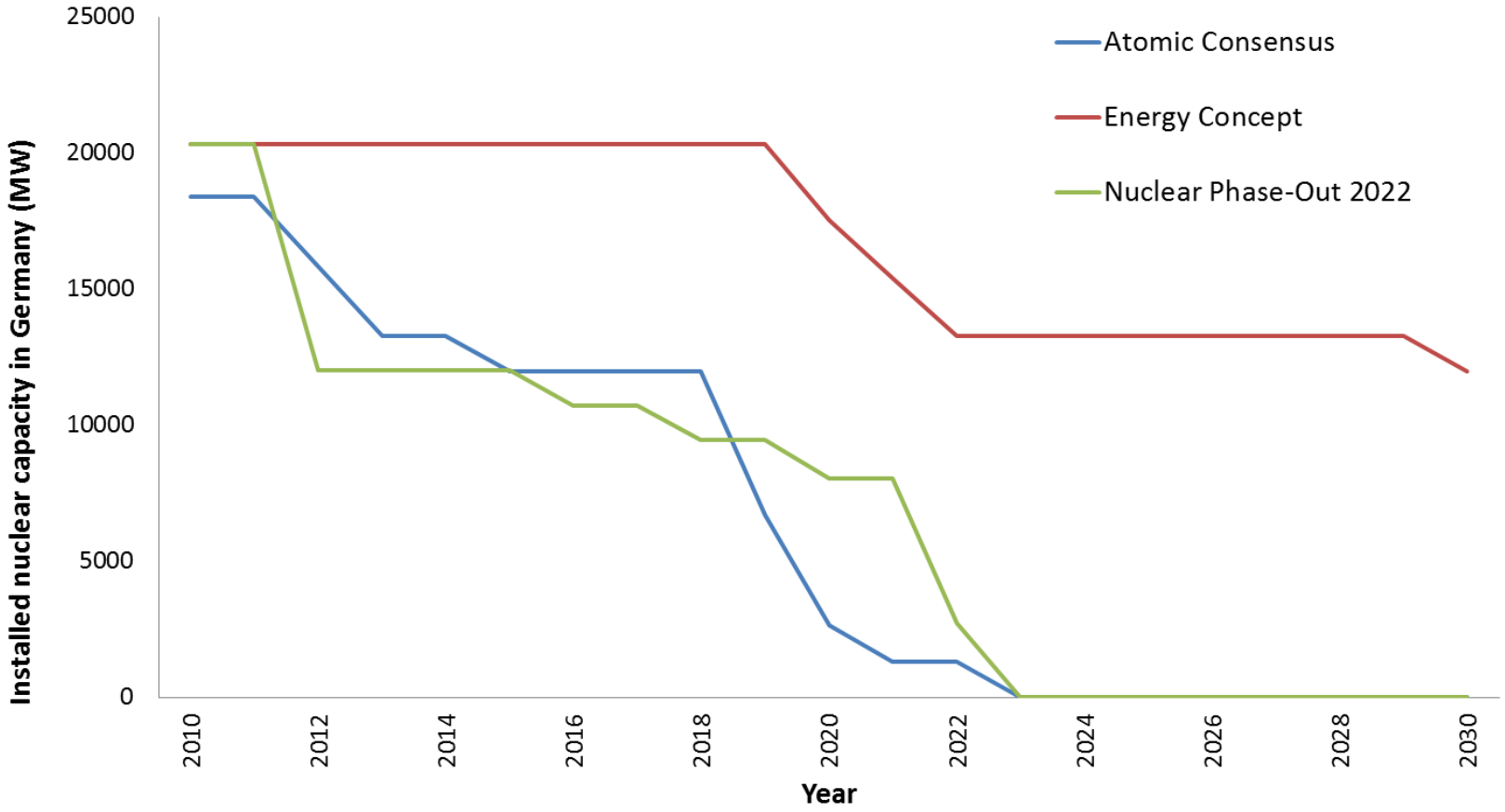
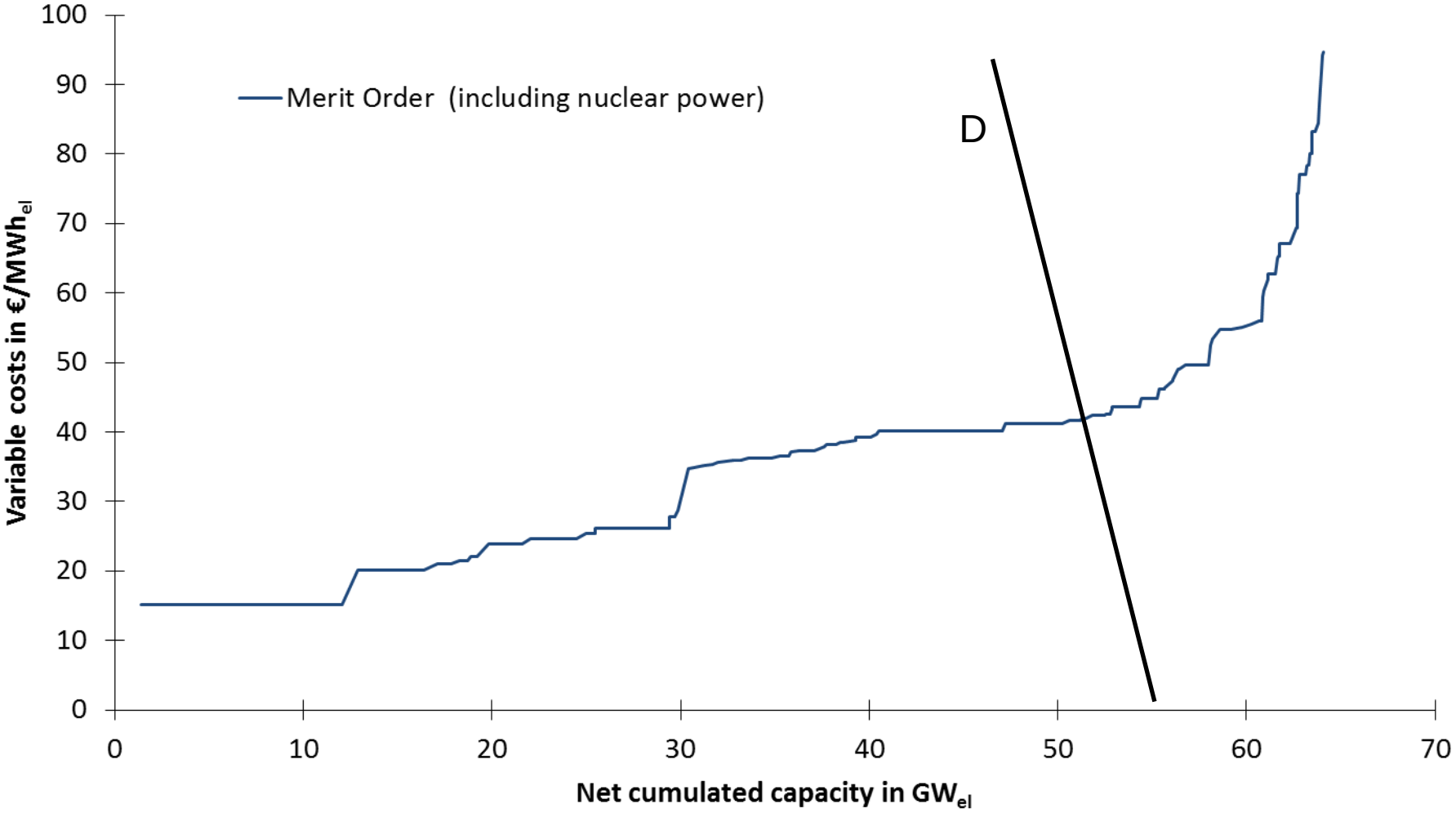



- Decided by conservative-liberal coalition government in June 2011
- Successive shutdown until 2022

# The German Merit Order (without CHP and RES)



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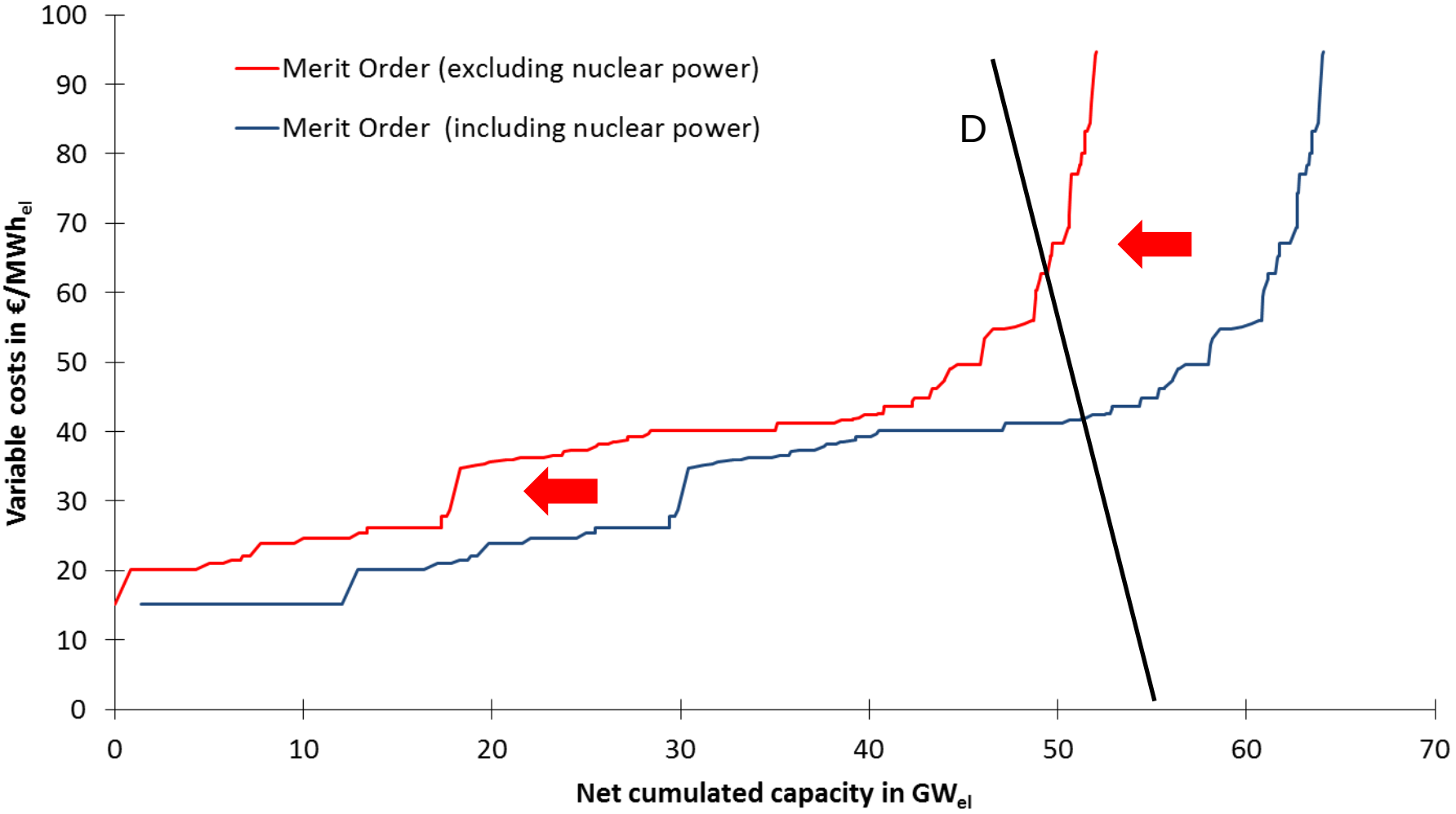

# In addition to the merit order, the model …

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- … considers non-dispatchable generation (wind, solar, CHP, …)
- … includes endogenously capacity additions (and reductions)
- … includes endogenously international power exchange by modeling several regions simultaneously
- … includes endogenously dynamic effects (e.g. start-up costs, balancing power, pump storage, planned power plant revisions, …)

# The Model

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- Long-term investment and dispatch model
- Fundamental optimization model (LP)
- Objective: minimization of total system costs
- Resolution
  - 10 reference years
  - 4,380 periods per year
  - 10 model regions (Germany and neighboring countries)
  - up to 23 technologies per region
- Shadow prices (i.e. marginals of demand constraint) used as price estimators

# European Electricity Market Model

## Objective Function

$$\min Z = \sum_y f_y^d(y) * (num\_years(y) *$$

*variable costs*

$$[\sum_{p,t} num\_hours * f_p^d(p) * z^{var}(y,p,t) * G_{PLANT}(y,p,t)$$

*startup costs*

$$+ \sum_{p,t} f_p^d(p) * z_{up}(y,p,t) * C_{UP}(y,p,t)$$

*shutdown costs*

$$+ \sum_{p,t} f_p^d(p) * z_{down}(y,p,t) * C_{DOWN}(y,p,t)$$

*fixed costs*

$$+ \sum_{t} z^{fixed}(t,y) * C_{INST}(y,t)]$$

*investment costs*

$$+ \sum_{t} s_{invest}^{cost}(y,t) * z_{invest}(t,y) * C_{ADD}(y,t))$$

# European Electricity Market Model

## Constraints (1)

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- **Capacity** of a technology determined by commissioning and decommissioning
- Certain part of the capacity in **overhaul** over the course of a year
- **Capacity ready-to-operate** determined through startups and shutdowns and limited to the installed capacity minus the capacity in overhaul (startups and shutdowns linearized) and unexpected outages
- **Generation**
  - upwards limited by the capacity ready-to-operate
  - downwards limited by linearized minimum load requirements (defined as share of capacity ready-to-operate)

# European Electricity Market Model

## Constraints (2)

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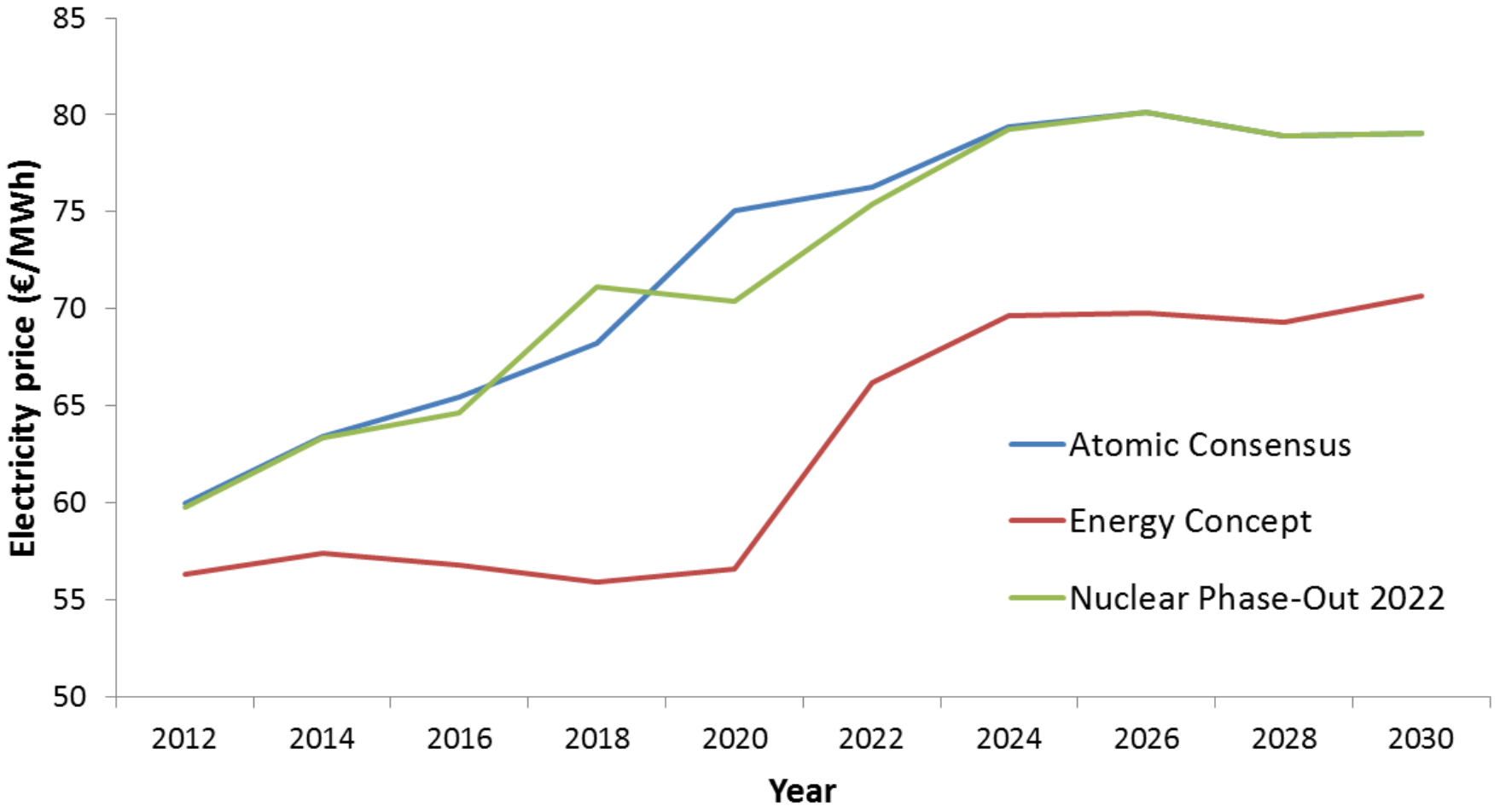
- **Generation** equals **residual demand** plus/minus **international exchange** plus **electricity consumption from pump storage**
- **Exchange** between countries limited by net transfer capacities
- Stored energy of (**pump) storage plants** determined by pumped and turbined energy amounts plus natural inflow

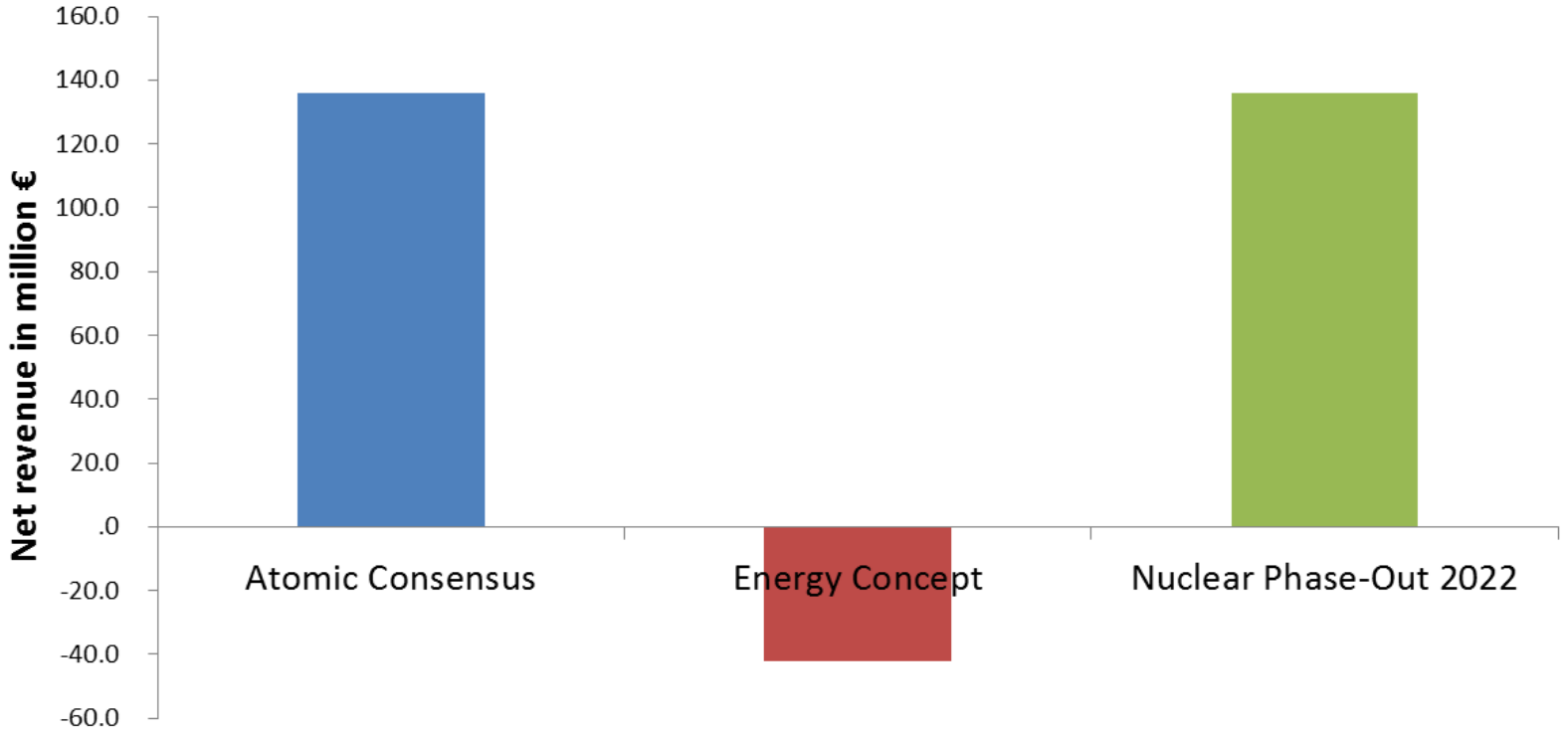
# Results
## System Marginal Costs of Demand



# Results

## Profit contribution for Trianel's CCGT power plant

- CCGT project in Hamm-Uentrop with 800 MW installed net generating capacity
- commercial operation since end of 2007 (expecting atomic consensus, i.e. nuclear phase out)



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# Thank you very much!

# Questions?

# Motivation
## Political Uncertainty

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- Changes in nuclear power policy affect the entire energy market
- Nuclear power
  - is a technology with low variable costs
  - covers base load (high full load hours)
- Shutting down nuclear power capacity
  - changes the merit order
  - increases electricity prices

# Results

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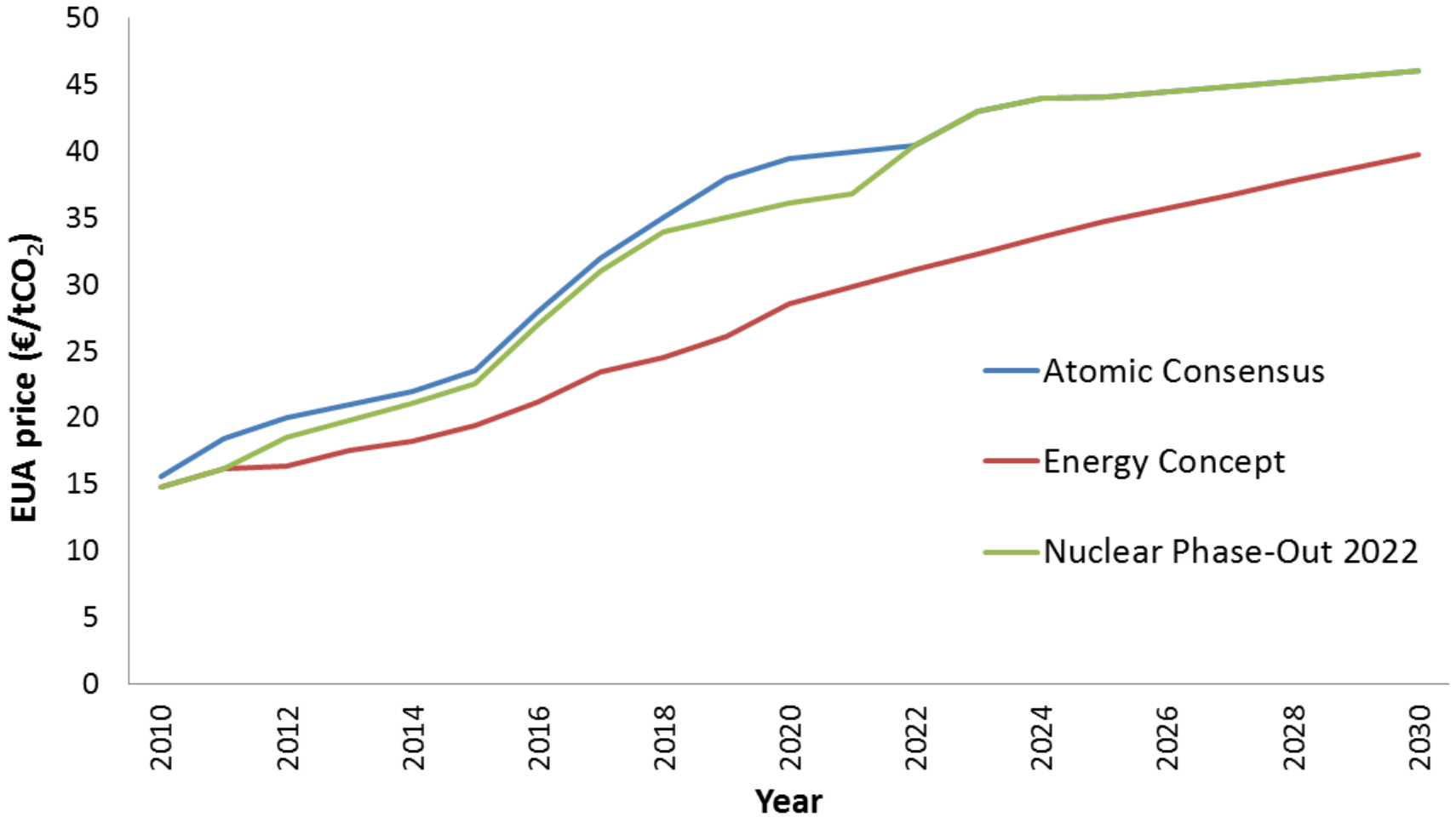
- Trianel CCGT
  - begin of operation at the end of 2007
  - expected time of operation 30 years (until 2037)
  - calculation horizon (2012-2037) - last 25 years of operation time

| | Atomic Consensus | Energy Concept | Nuclear Phase-Out 2022 |
|---|---|---|---|
| **Revenue electricity generation (million €)** | 2,646 | 1,430 | 2,610 |
| **Variable production costs (million €)** | -2,153 | -1,136 | -2,117 |
| **Startup and shutdown costs (million €)** | -87 | -66 | -87 |
| **Fixed costs (million €)** | -270 | -270 | -270 |
| **Net revenue (million €)** | **136** | **-42** | **136** |

➔ Significant effect on the profitability of the CCGT

# $CO_2$ Prices


50
45
40
35
30
25
20
15
10
5
0
EUA price (€/tCO2)
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
Year
Atomic Consensus
Energy Concept
Nuclear Phase-Out 2022