CHALLENGES OF INTEGRATING RENEWABLE ELECTRICITY GENERATION INTO MARKETS AND GRIDS - THE CASE OF GERMANY

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Agenda

- **Status Quo of RES-E in Germany**
- Challenges of Integrating RES-E
- Regulatory Framework
- Modelling Activity: Testing Regulatory Changes
- Summary

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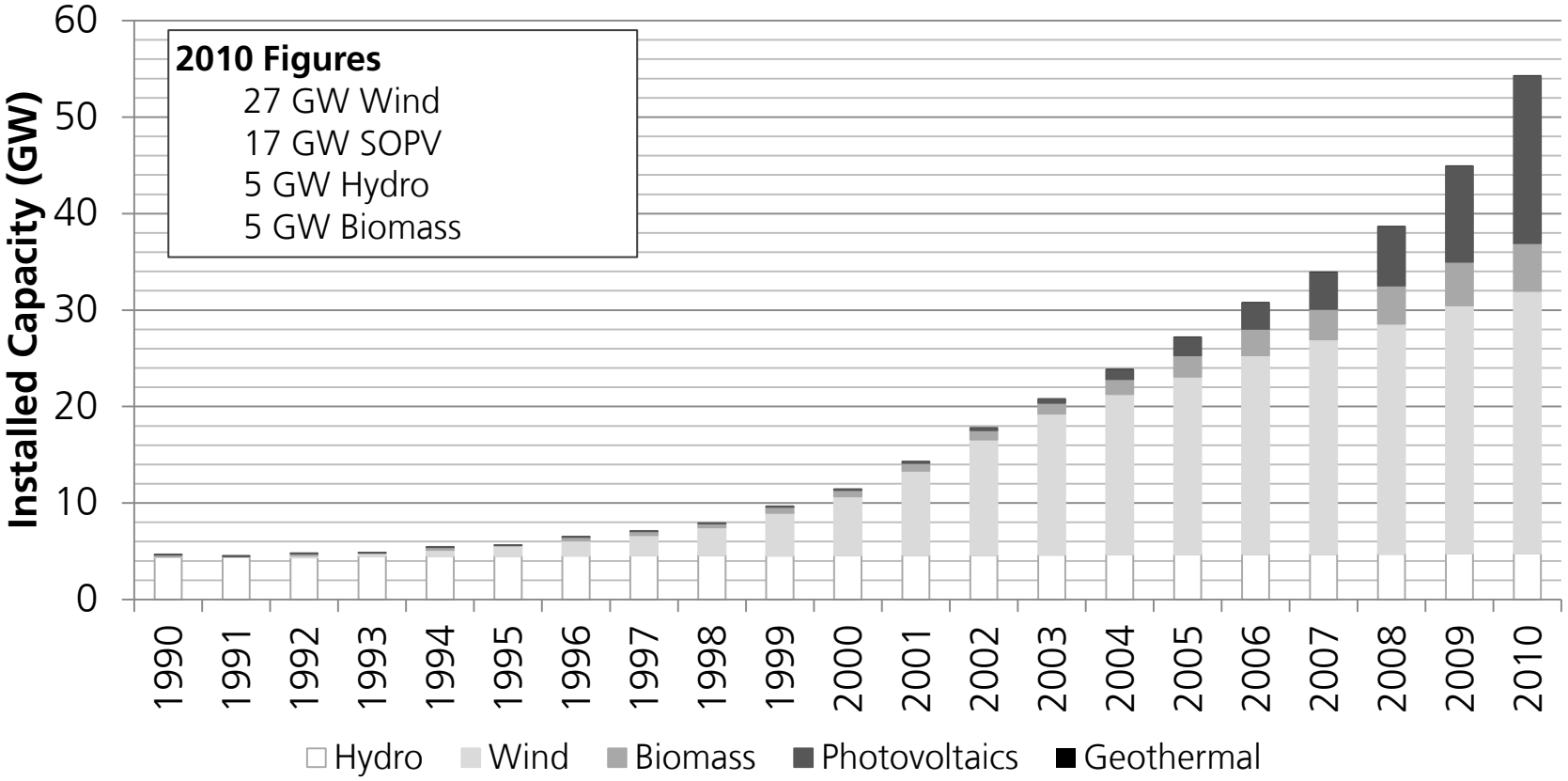
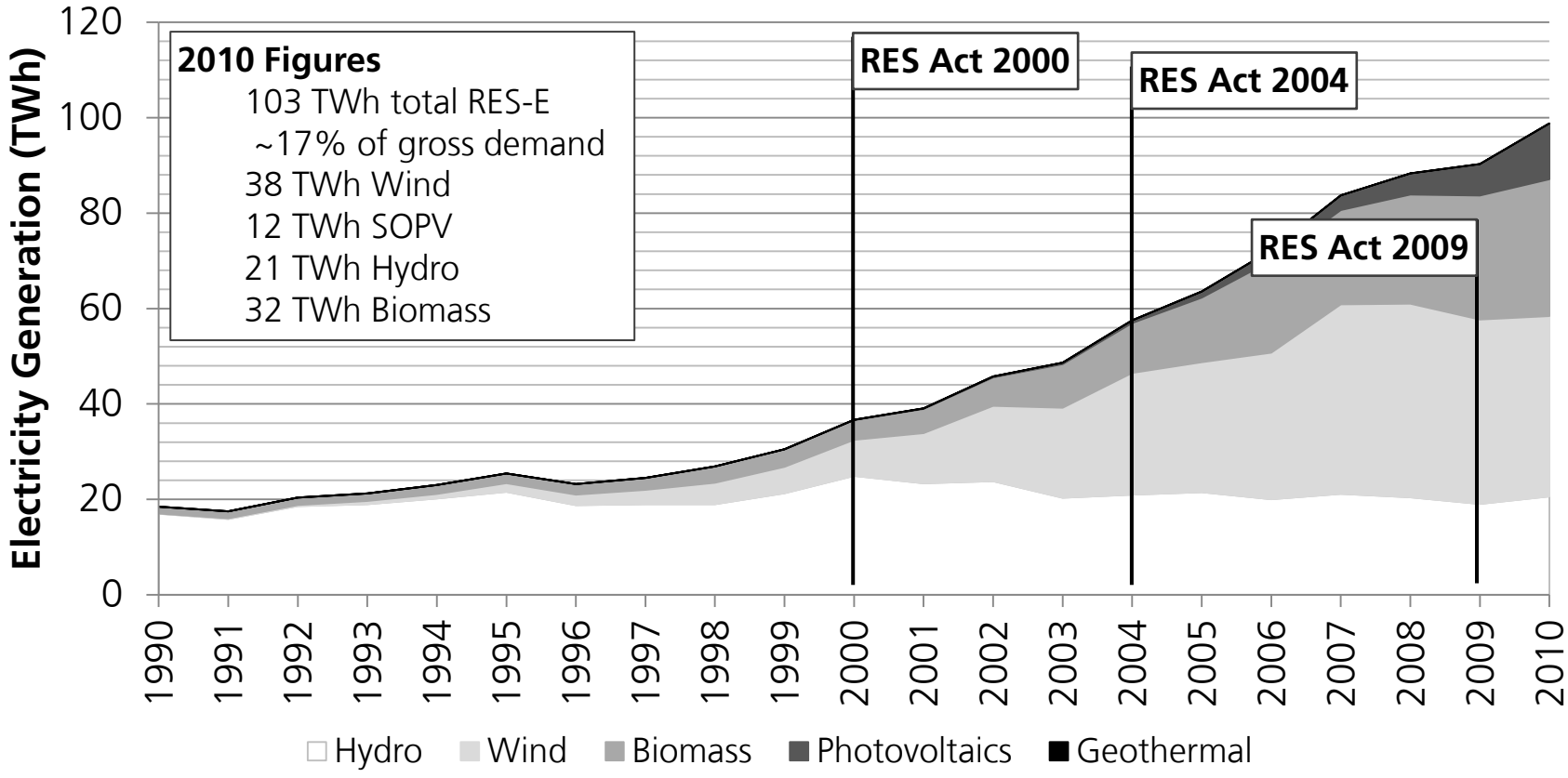
Status Quo
Installed Capacity



by the end of 2012, SOPV might surpass Wind (in terms of installed capacity)!

Status Quo
Renewable Electricity Generation



Future Targets

2030 ≥ 50% share

2050 ≥ 80% share

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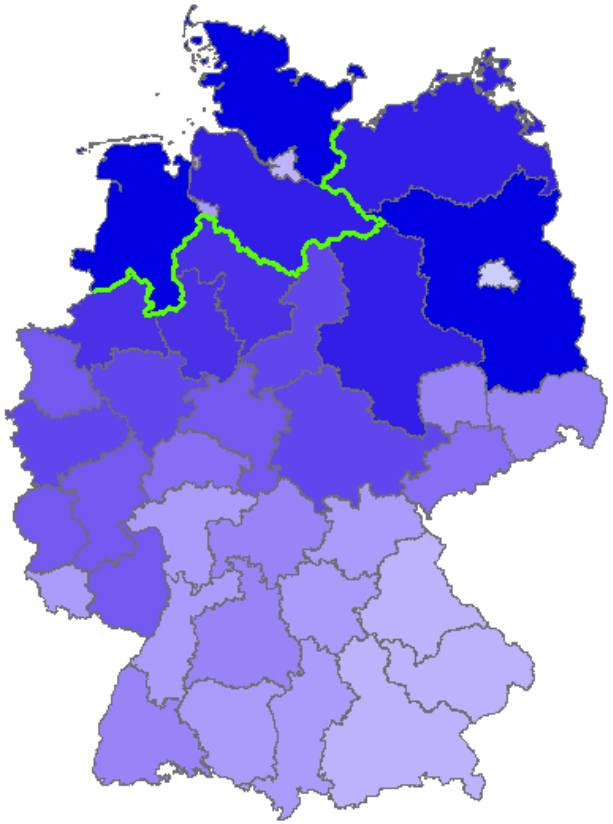
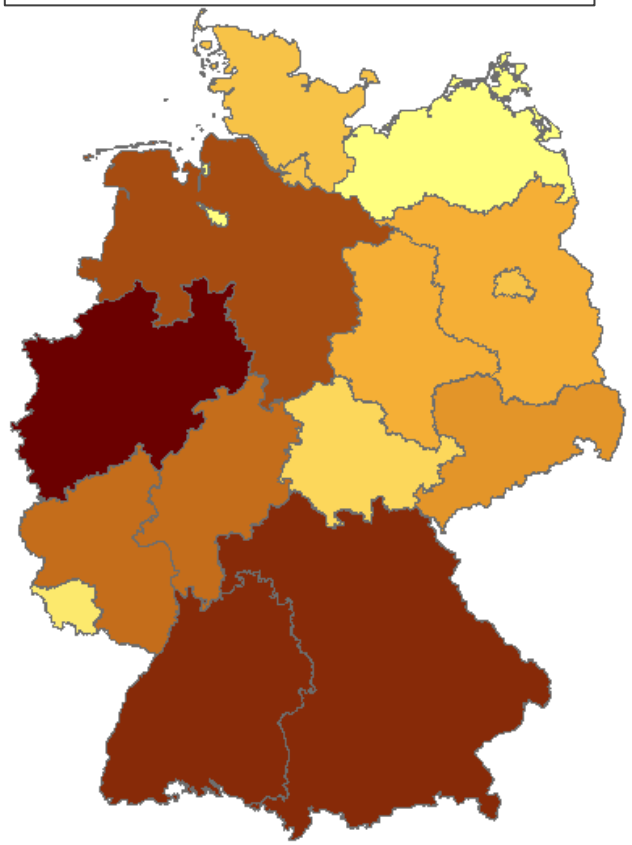
Challenge #1: Unbalanced Regional Distribution of Supply & Demand

Installed Wind Power Capacity



Future: Huge Offshore Capacities in NW and NE

Electricity Consumption



Future: Less Population in NE

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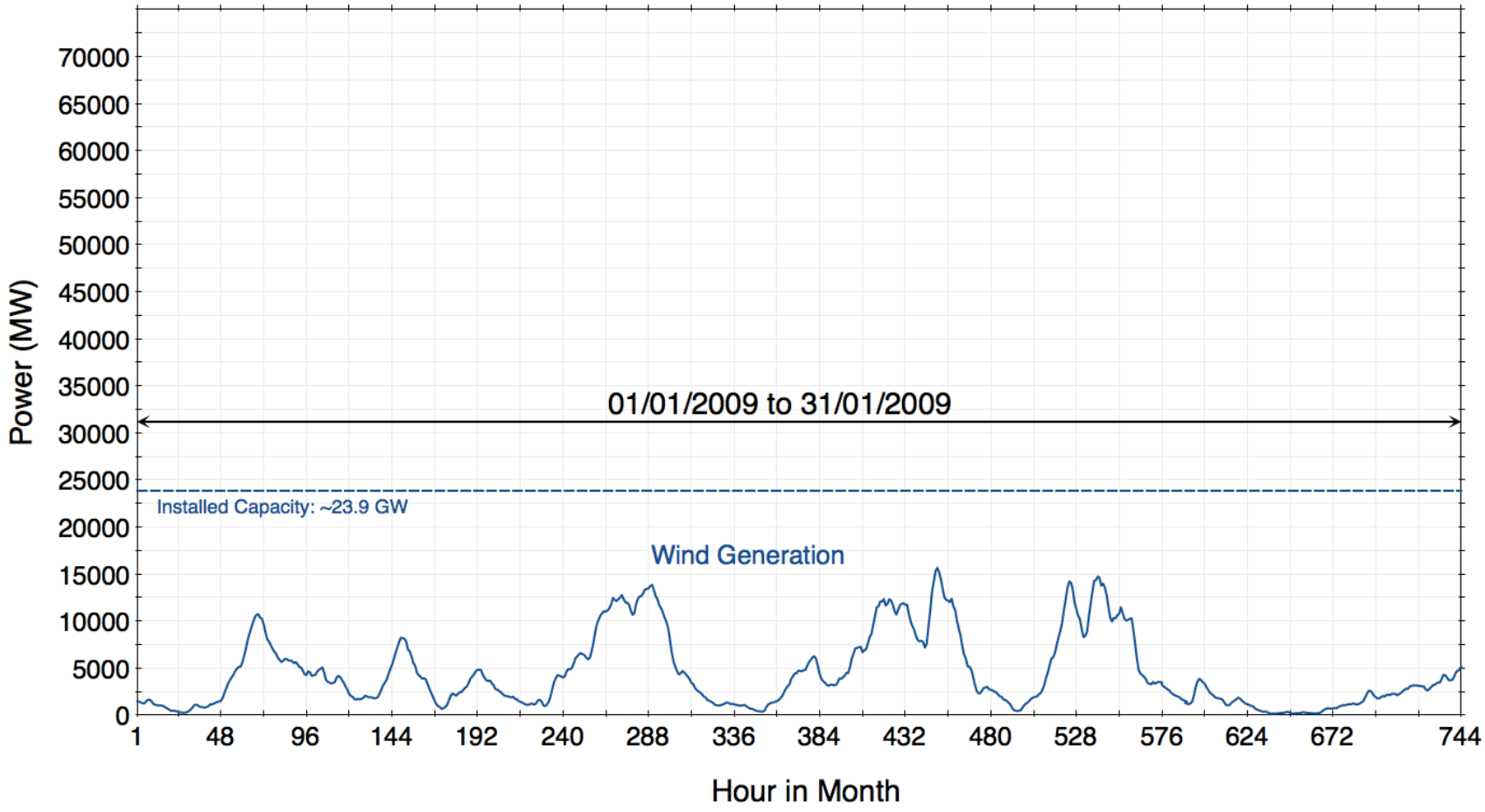
Challenge #2: Long Periods of Low Generation



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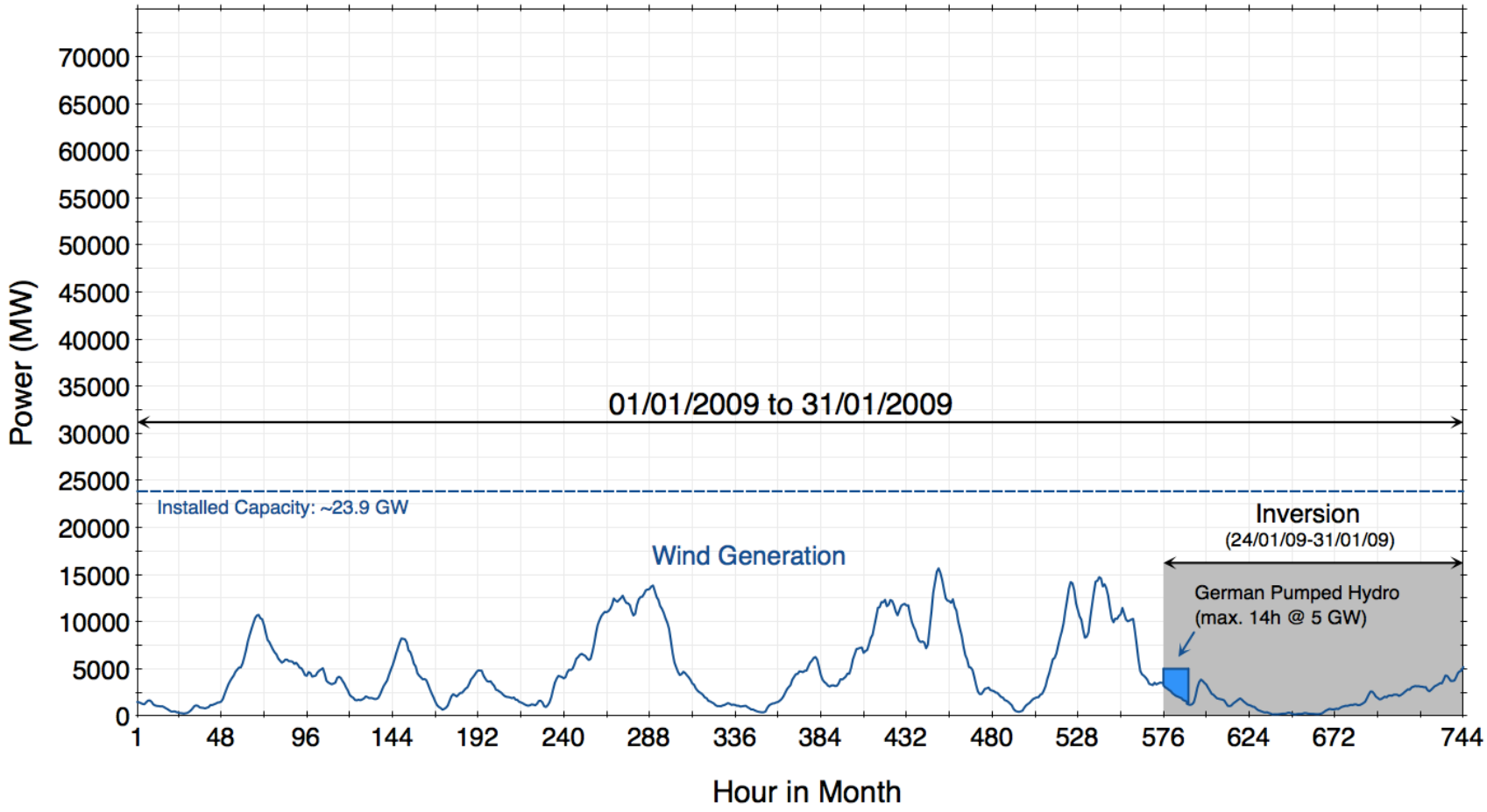
Challenge #2: Long Periods of Low Generation



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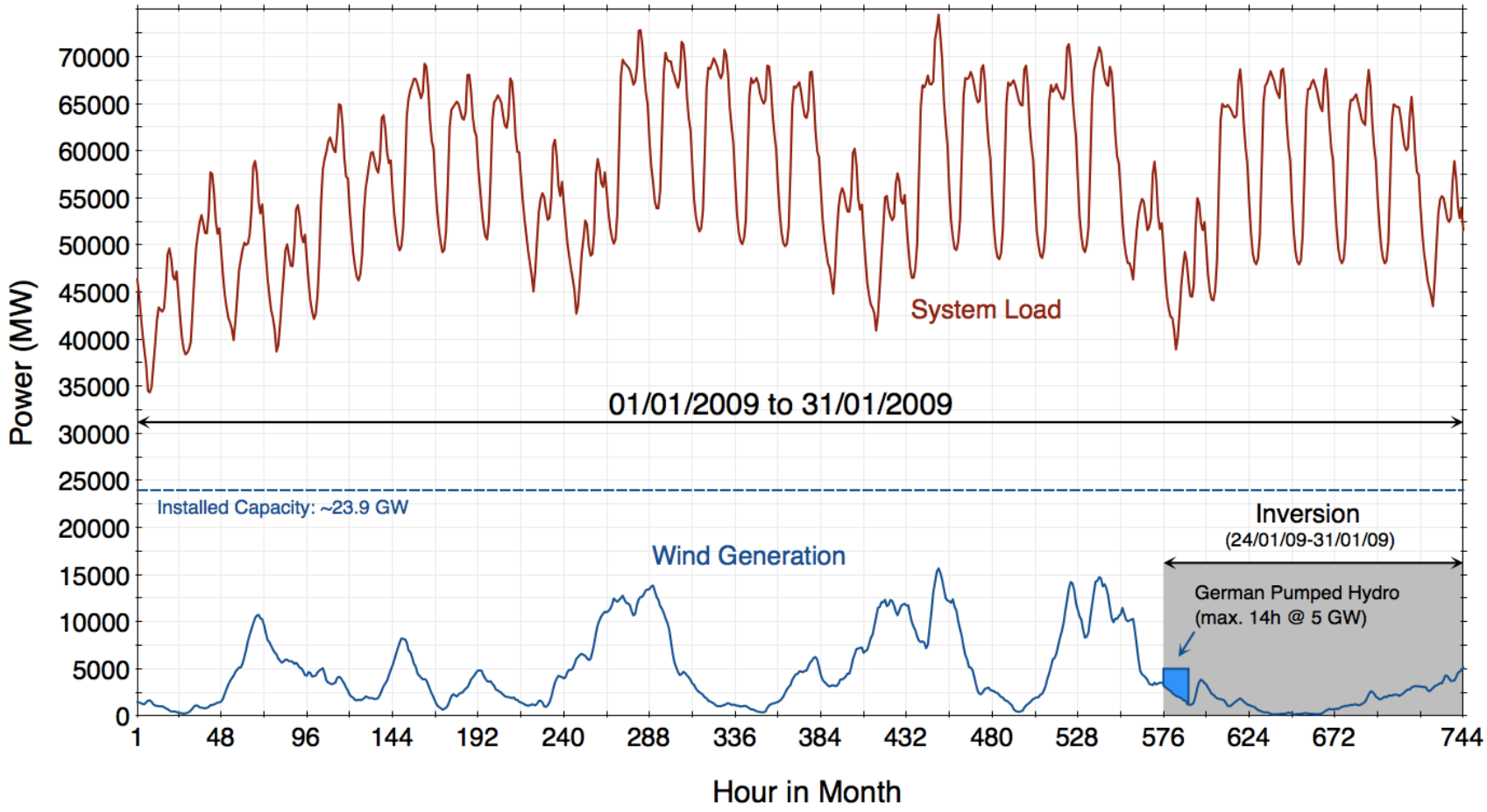
Challenge #2: Long Periods of Low Generation



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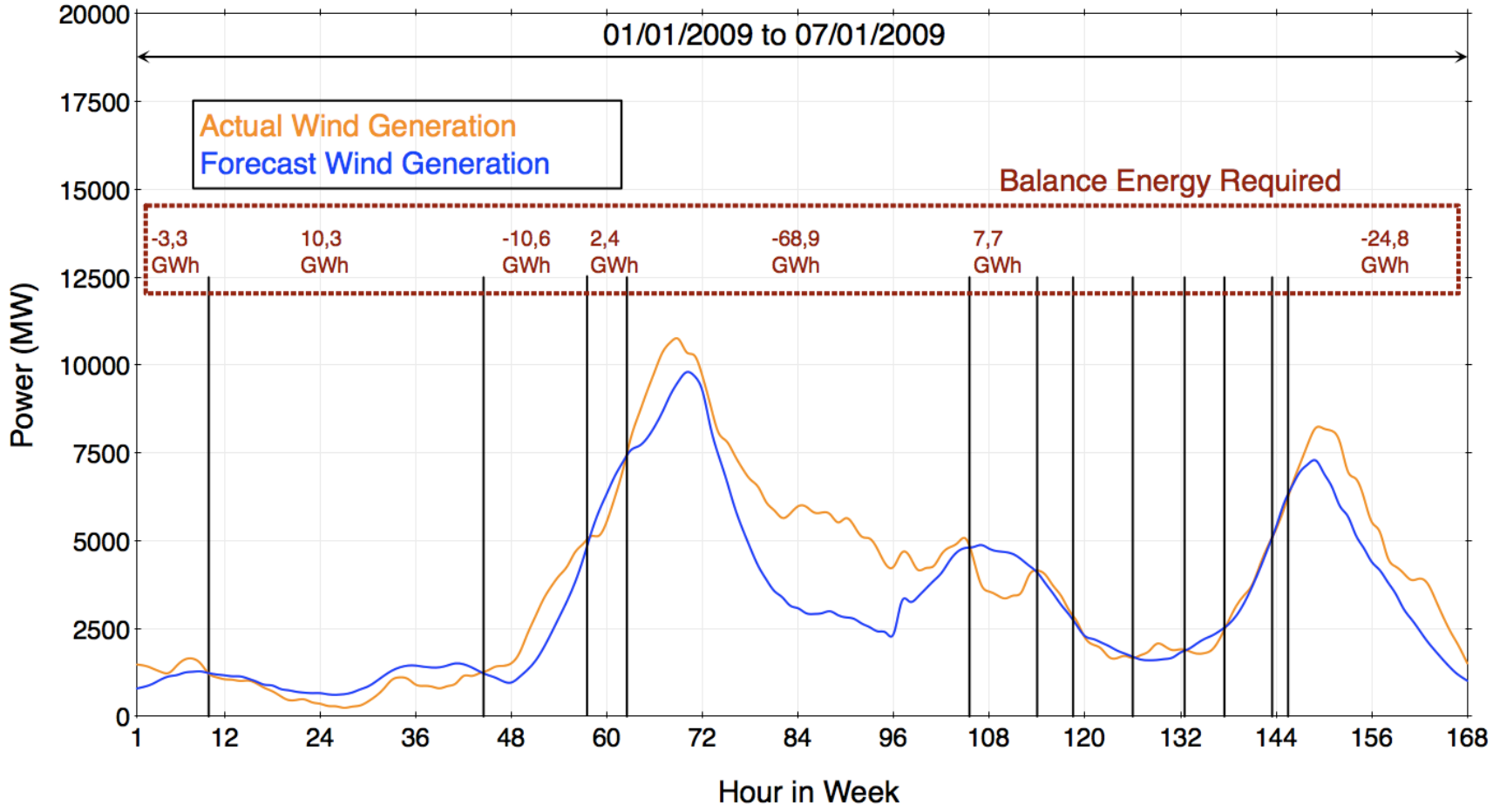
Challenge #3: Forecast Errors



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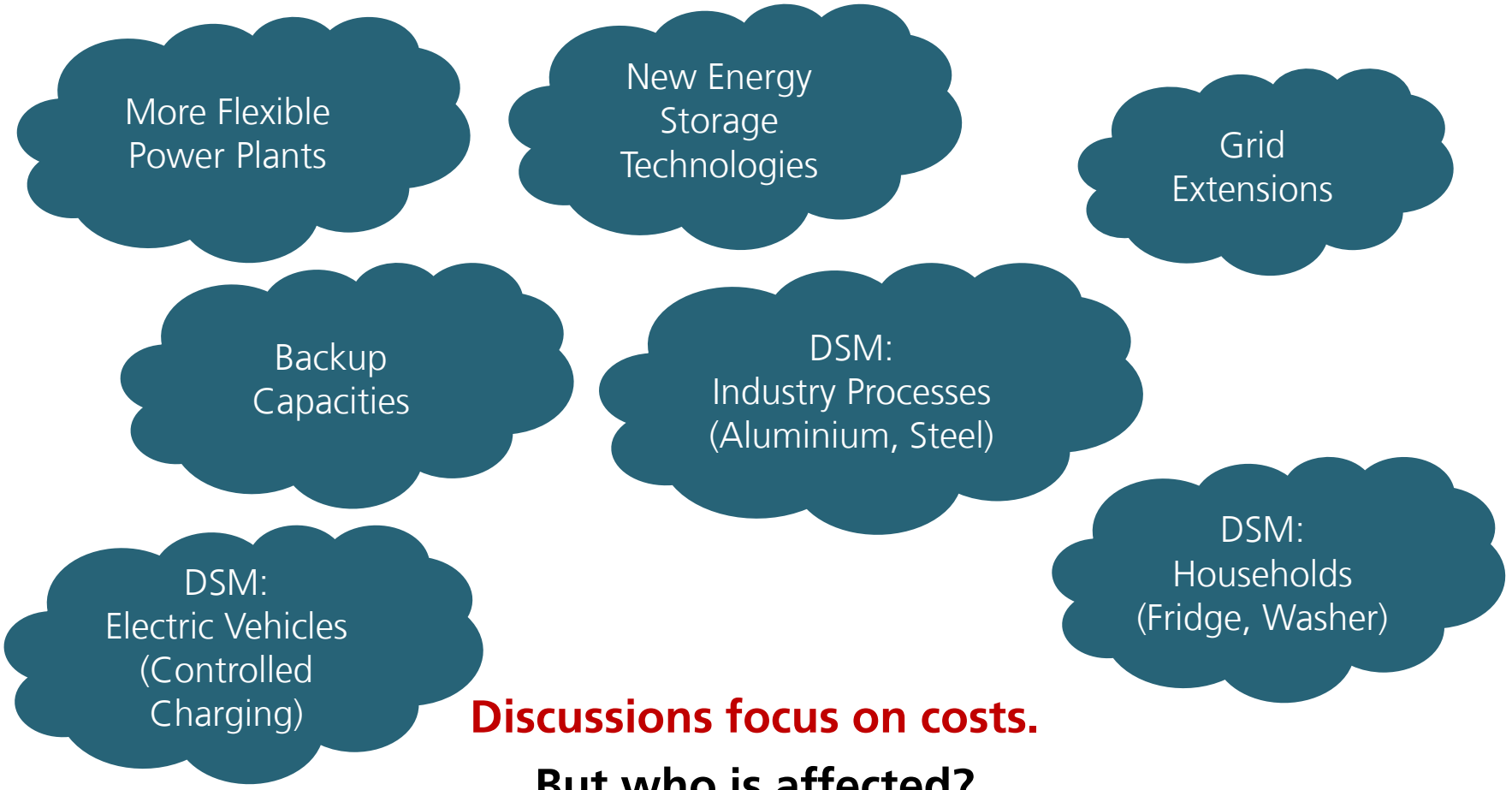
Possible Solutions



Discussions focus on costs.

But who is affected?

Who should invest?

Should there be incentives?

Who is affected?

- Regarding challenge #1:
  - Grid operator is in charge of resolving grid congestion
  - Extensions to the transmission grid will be needed

- Regarding challenge #2 and #3:
  - It depends greatly on the regulatory framework!
  - Right now:
    - Fixed feed-in tariff system, i.e. plant owner is not affected

    → Provide a secure investment environment for renewable energy technologies (and it has worked!)

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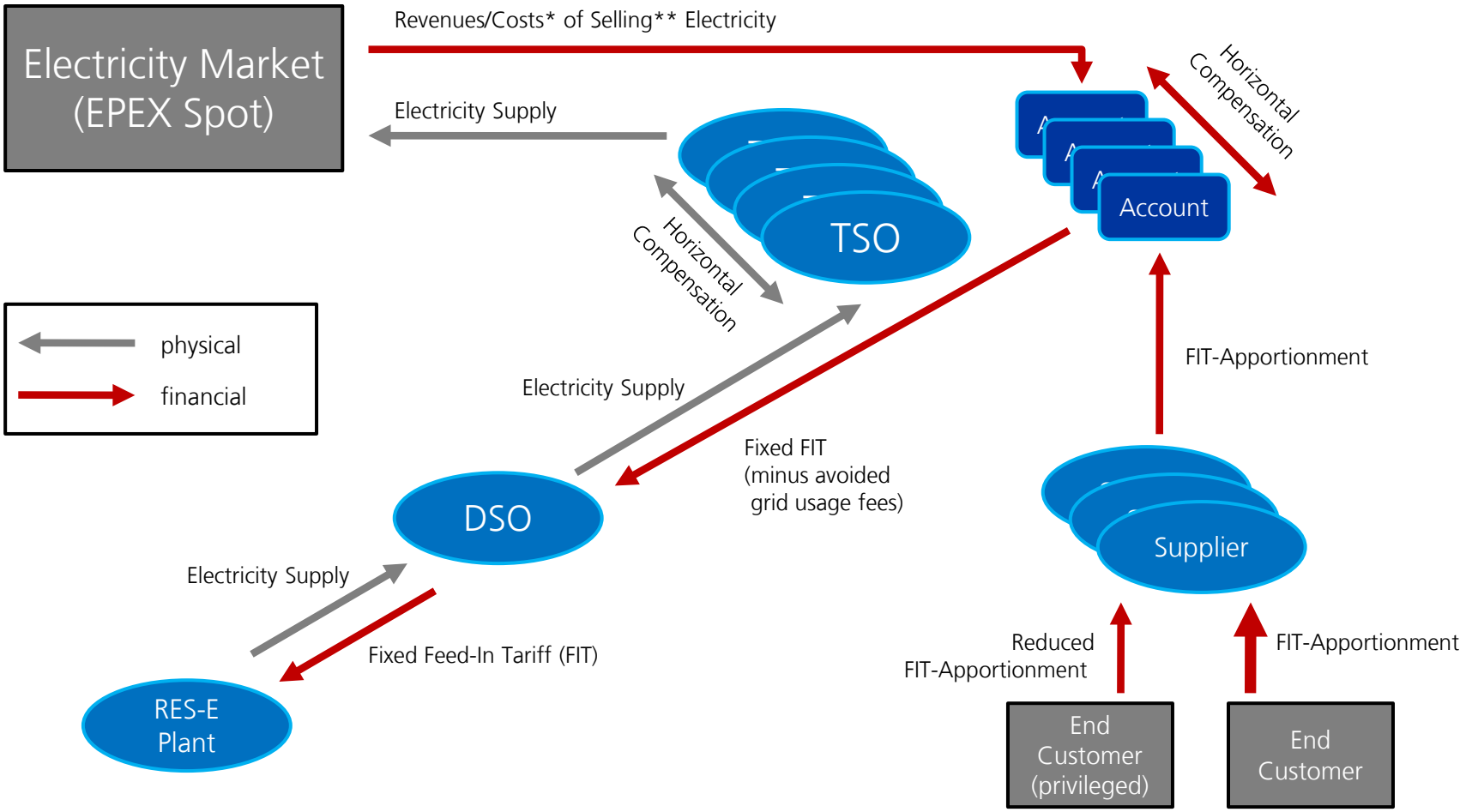
Current Regulatory Framework in DE: Integration of Renewables



* Costs arise due to negative power prices
** TSO has to accept any price (price-unlimited bid, -3000 €/MWh)

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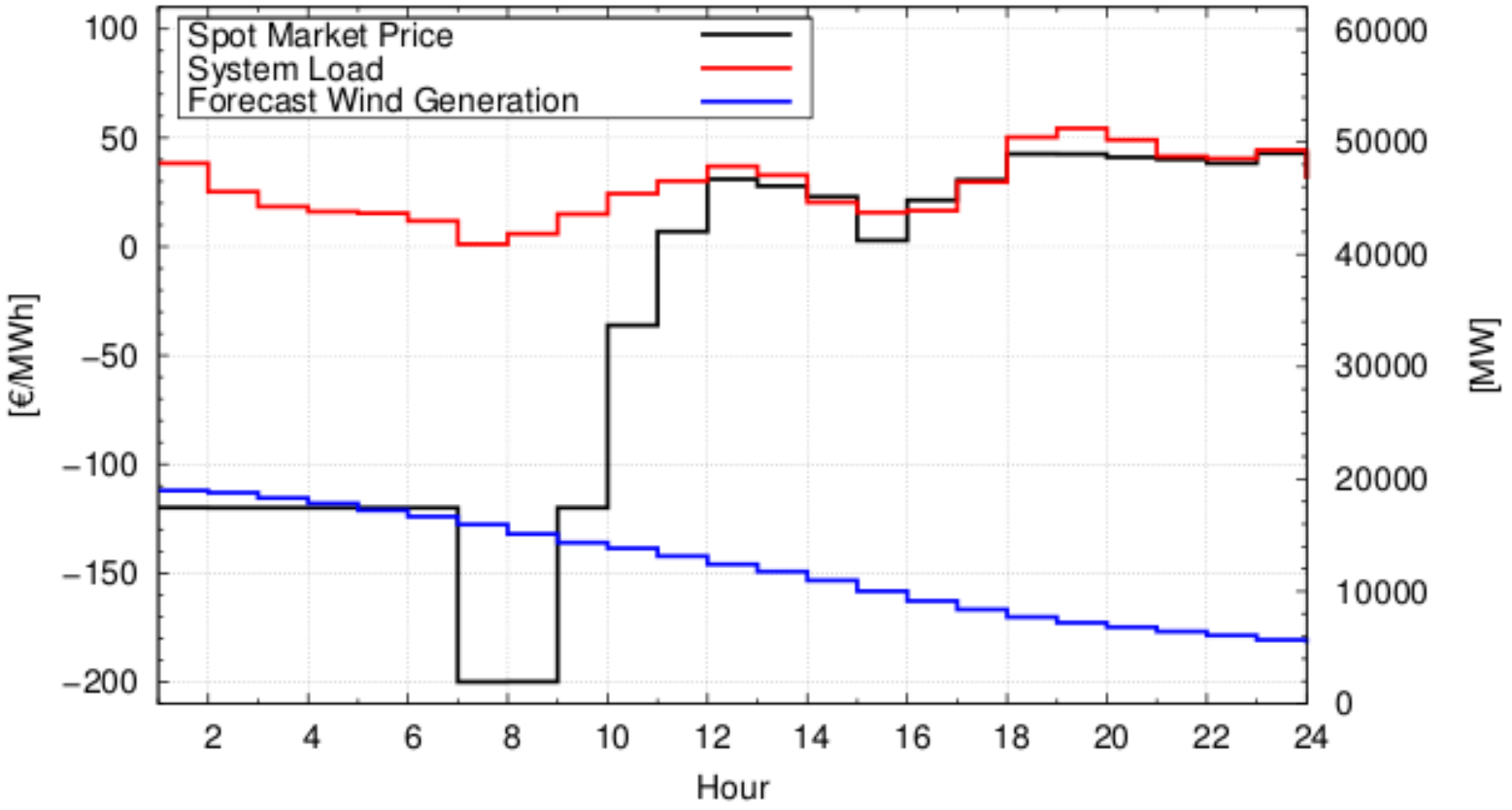
Negative Spot Market Prices Situation on 26/12/2009



F. Genoese, M. Genoese, and M. Wietschel, "Occurrence of negative prices on the German spot market for electricity and their influence on balancing power markets," in 7th International Conference on the European Energy Market (EEM), 2010.

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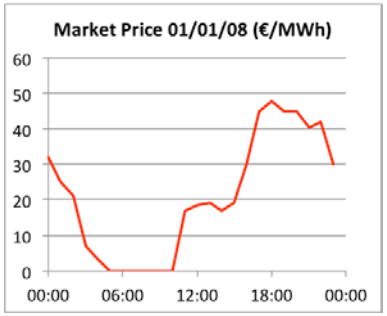
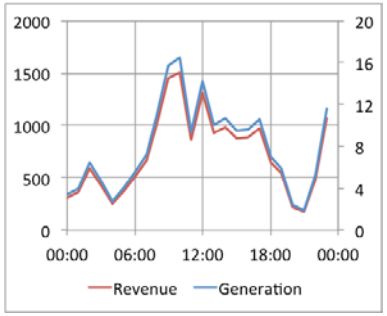
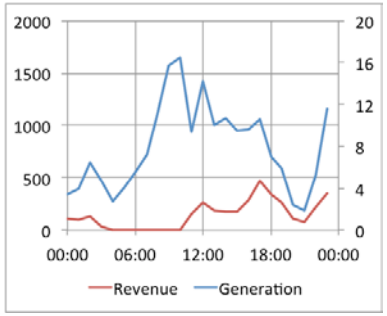
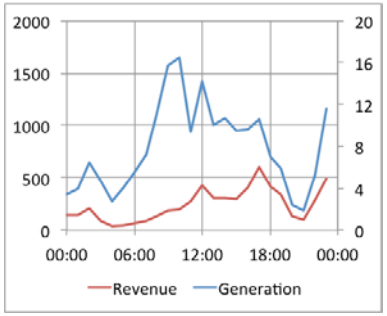
Market Integration of Renewables: Direct Trading with Market Premium

	A: Fixed Feed-In Tariff	**B: Direct Trading** (no market premium)	**C: Direct Trading** (with market premium)
Market Trader	Grid Operator (GO)	Plant Owner (PO)	Plant Owner (PO)
Revenues	Fixed payment by GO (independent of time of the day)	PO directly sells electricity to markets; revenues depend on market price	Combination of A & B: • (lower) fixed tariff • earnings from direct trading









Renewable Energy Sources Act (2012): 1.2-1.6 ct/kWh market premium

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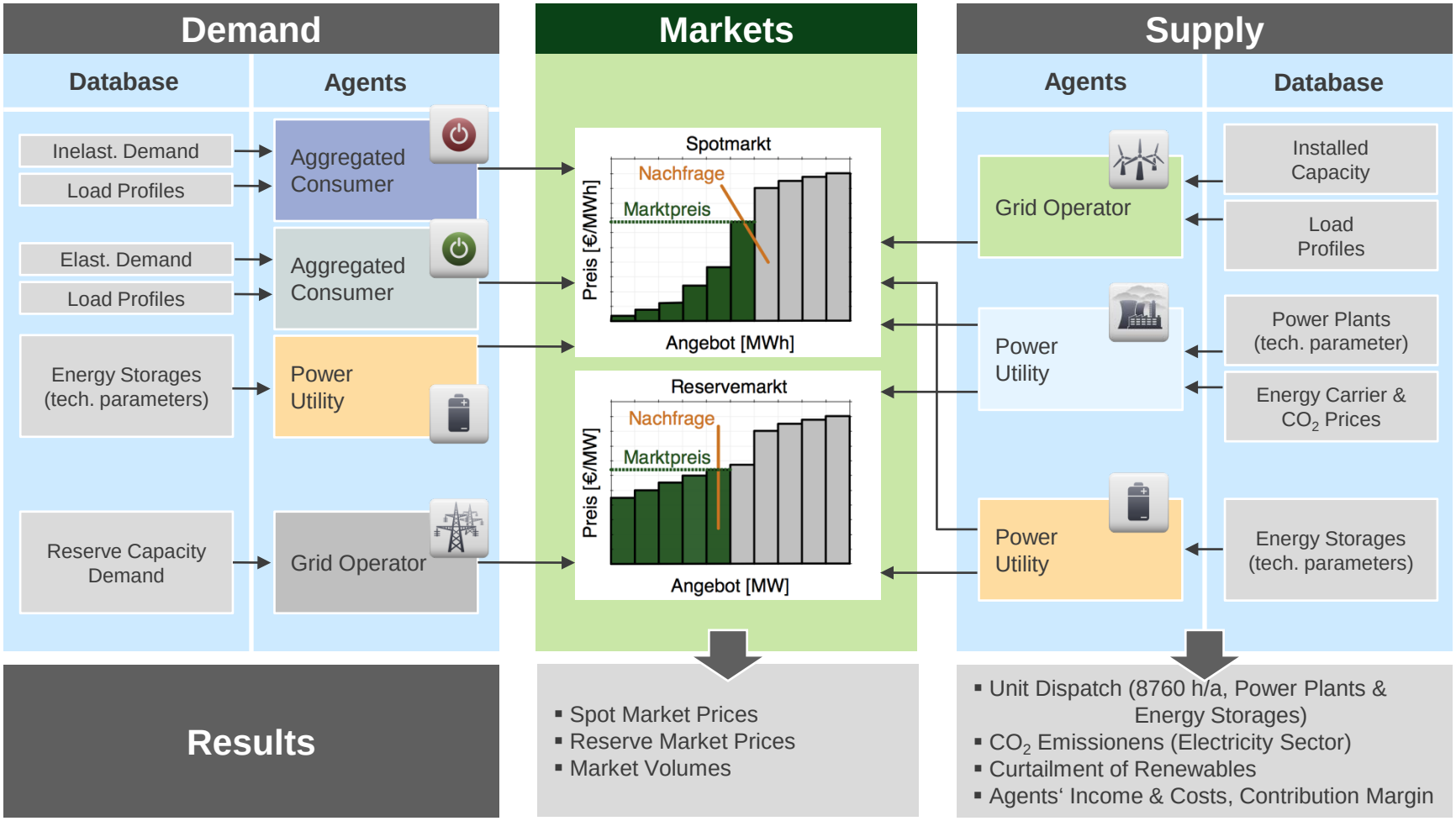
PowerACE
Agent-Based Electricity Market Model



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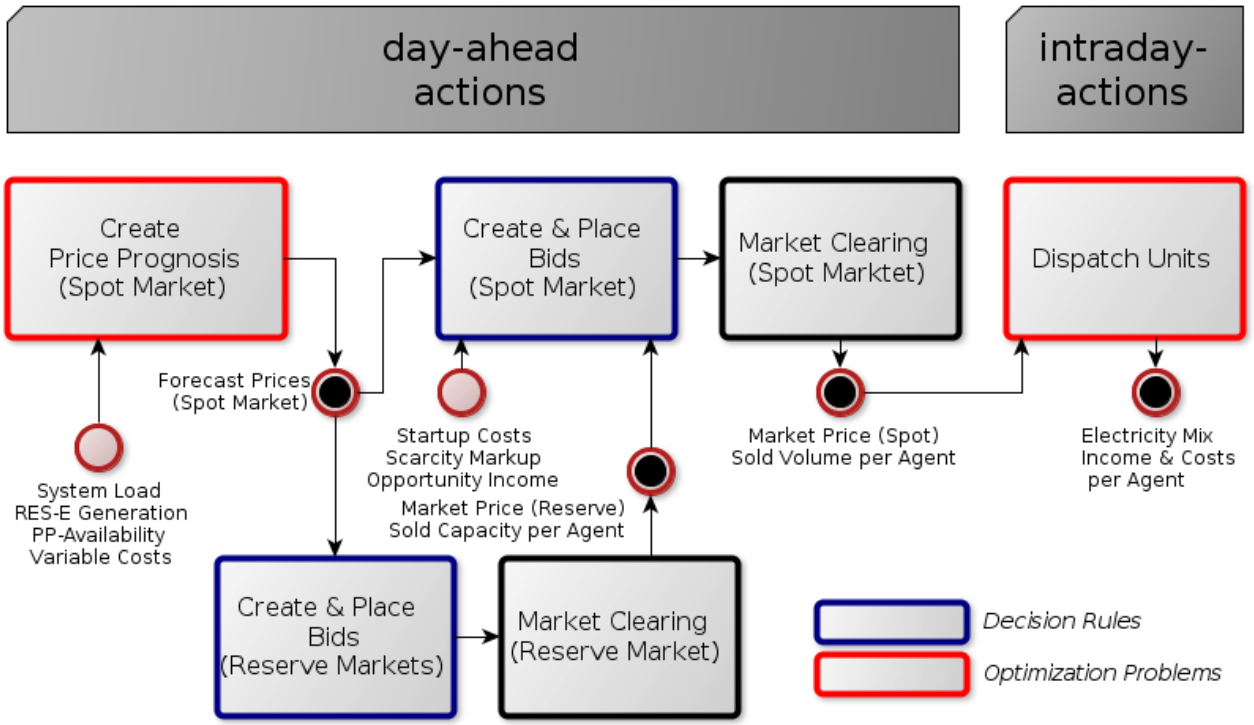
PowerACE
Simulation & Optimization Model



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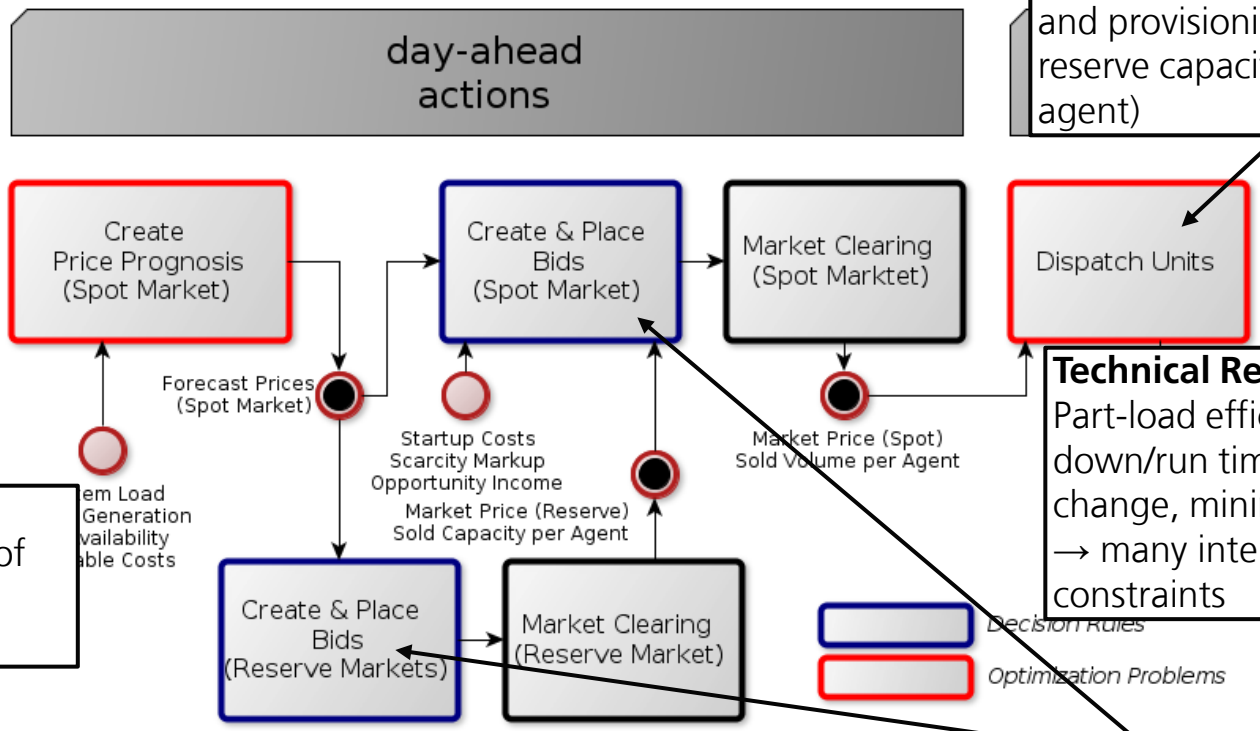
PowerACE
Simulation & Optimization Model

Optimization Step:
Minimize total costs of producing the sold electricity and provisioning the sold reserve capacity (for each agent)



Optimization Step:
Minimize total costs of meeting demand & reserve requirements

Technical Restrictions:
Part-load efficiency, minimum down/run times, limited load change, minimum load
→ many intertemporal constraints

Complexity of the Optimization Problem (MILP)

- 5 variables per thermal unit and hour (2/5 are binary)
- 8 variables per storage unit and hour (2 /8 are binary)
- 500 Thermal Units, 30 Storage Units

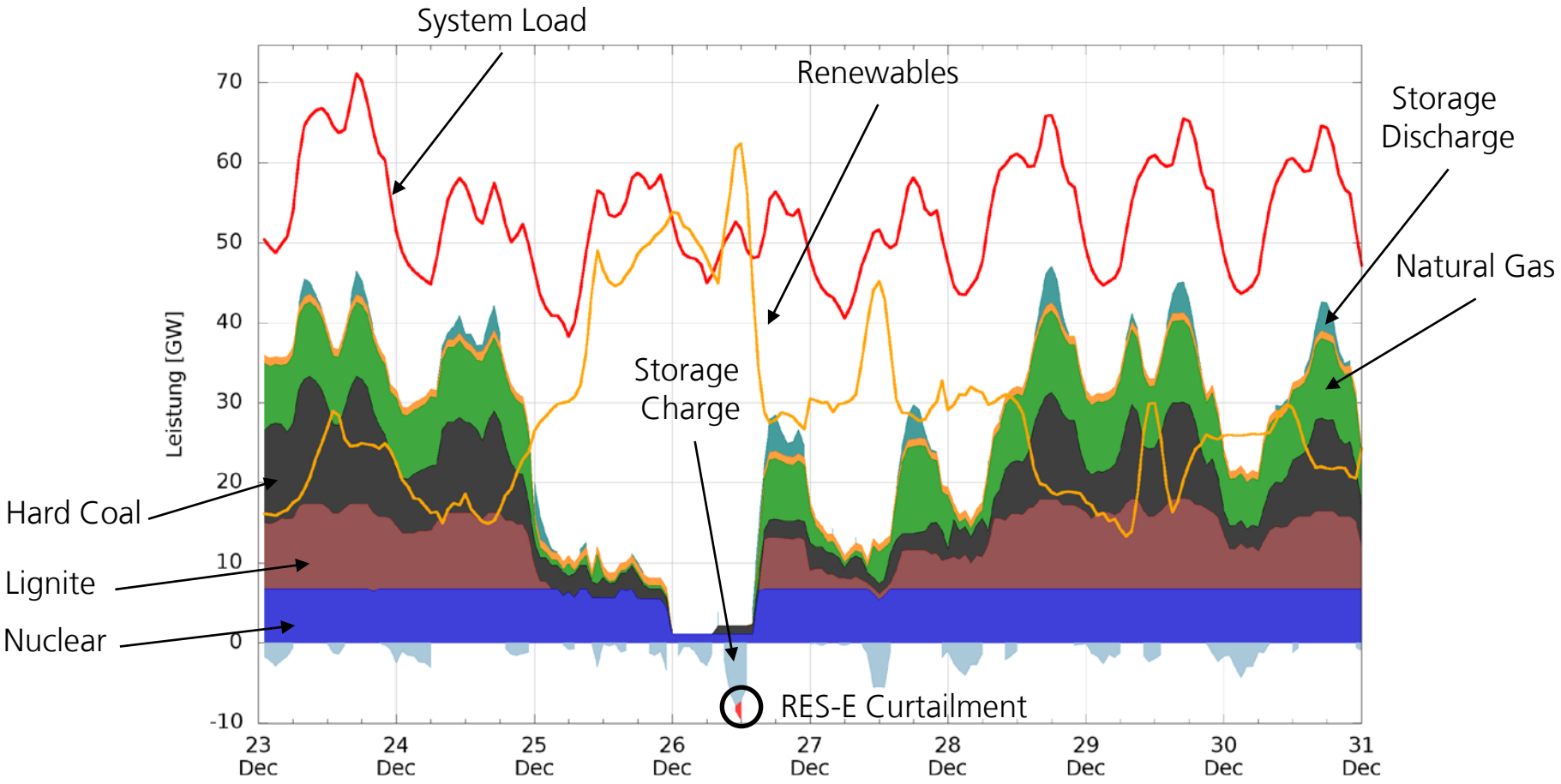
Simulation Step:
Factor in opportunity income (e.g. avoided shut-down costs)

PowerACE

- Simulation program written in Java (approx. 12,000 LOC)
- Optimization problems are solved with Gurobi, interface: JavaILP library
- Bottom-up model
  - detailed technical parameters of thermal units, storage units (especially flexibility)
  - detailed renewable load profiles for different technologies
  - high time resolution: 8760 h/a
- Agents
  - 5 major German utilities (EnBW, RWE, E.on, VE, Steag), 2 agents for local utilities & industry's own production capacities
  - Grid operator, aggregated agents for consumption
- Flexible design, adding new agents (e.g. wind park owner) is easy
- Agent-based simulation approach to model incomplete information, different decision rules, negative prices, …

F. Genoese, M. Genoese, and M. Wietschel, "Medium-term Flexibility Options in a Power Plant Portfolio – Energy Storage Units vs. Thermal Units," in 9th International Conference on the European Energy Market (EEM), 2012.

Typical Result
Unit Dispatch 23/12/2020-31/12/2020



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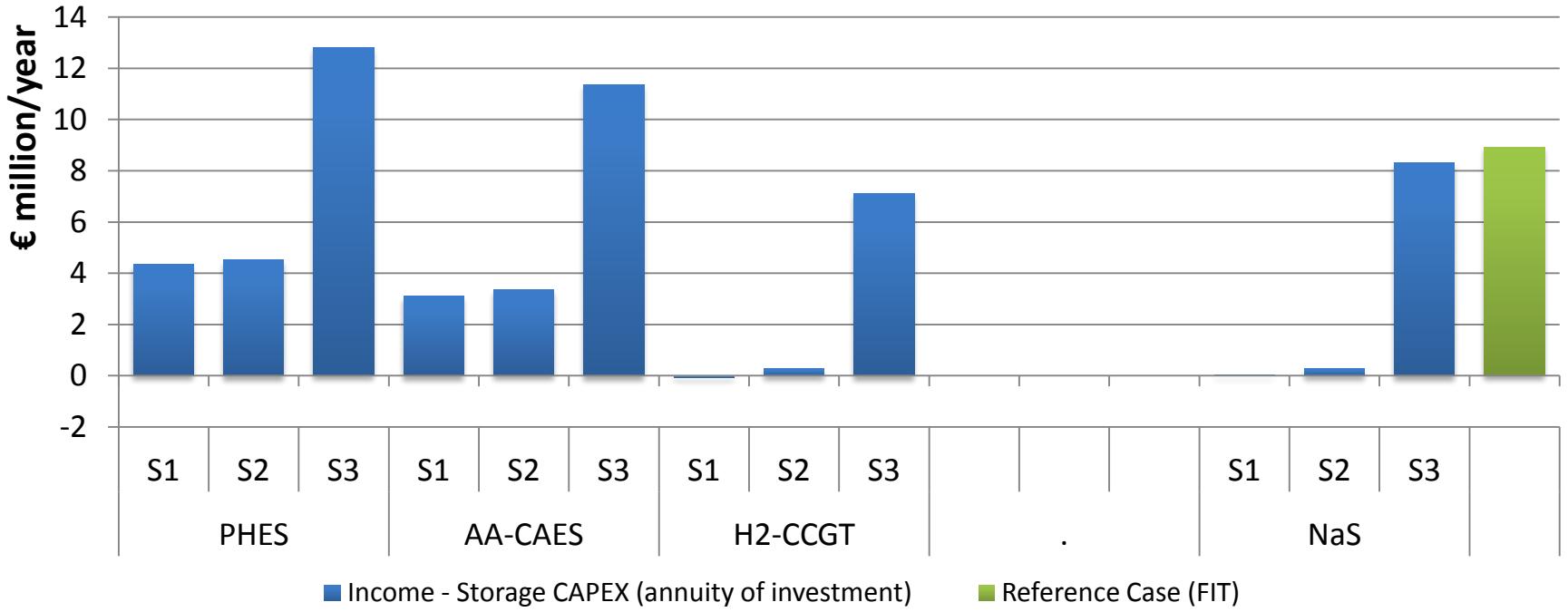
Modelling Activity
Testing Regulatory Changes

- Research project for a technology developer
- Main research questions:
  - Is there a market for new energy storage technologies in 2020?
  - Which are the most promising technologies?
  - How will the recent regulatory changes affect this market?

Scenario	Main Assumptions (2020)
S1	o 30% RES-E share o moderate reduction of electricity demand (-5.6% cp. to 2008) o moderate increase of energy carrier prices (e.g. gas: 25 €/MWh)
S2 (WEO-450)	o 40% RES-E share o significant reduction of electricity demand (-7.9% cp. to 2008) o moderate energy carrier but high CO_2 prices (e.g. CO_2: 38 €/t)
S3	o 43% RES-E share o significant reduction of electricity demand o significant increase in both energy carrier and CO_2 prices (gas: 42 €/MWh)

Modeling Results (2020)
Wind Park, Direct Trading & Market Premium

- 50 MW wind park in NE Germany
- 20 MW / 250 MWh storage unit, technologies: pumped hydro (PHES), compressed air (AA-CAES), hydrogen (H2-CCGT), redox-flow (RFB), sodium-sulfur (NaS)
- Storage unit is used to balance forecast errors & shift production to hours with higher spot market prices
- Reference case: wind park owner chooses FIT (in 2020: ~ 7,9 ct/kWh)



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Summary (1)

- Fixed feed-in tariffs have ensured a steady development of electricity generation from renewable energy sources in Germany

- Main future challenges:
  - Regional imbalance of supply and demand
  - Long periods of low generation
  - Forecast errors

- Solutions exist or can be developed but current regulatory framework doesn't favor development/investments
  - Right now, grid operator has to handle both grid and market integration of renewables
  - There is no incentive for plant owners to produce when electricity is needed
  - Market premium as a method to maintain feed-in tariffs while improving market integration – but adjusting its level is tricky!

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Summary (2)

- Modeling approach to test regulation changes (e.g. market premium)
  - agent-based simulation with integrated optimization methods
  - bottom-up electricity market model
  - detailed representation of conventional (thermal) generation, storage units and renewable load profiles (on-/off-shore wind, photovoltaics, hydro)
  - hourly time resolution

- Modeling results show:
  - Market premium as of 01/2012 will only induce a demand for new energy storage technologies if energy carrier prices rise significantly
  - Compressed Air Energy Storage is a promising new storage technology

- Outlook:
  - Model extensions to evaluate/benchmark other options (esp. various DSM solutions)

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