TECHNISCHE UNIVERSITÄT DRESDEN

Stochasticity in Electricity Markets with a Simplified Network

Infraday, Berlin

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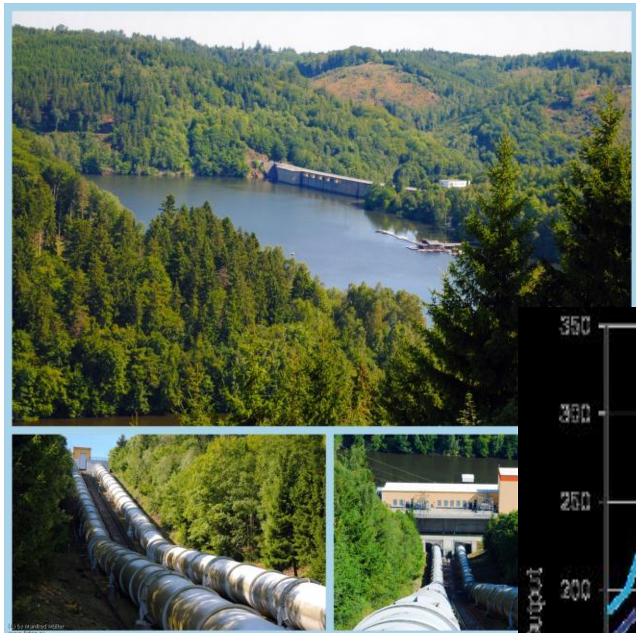
Chair of Energy Economics and Public Sector Management

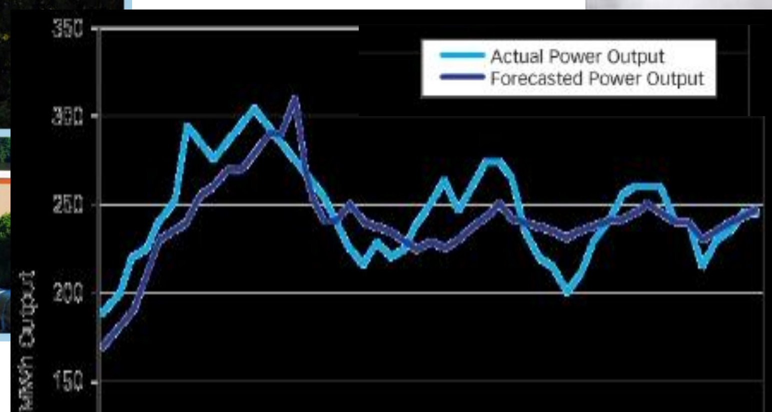
Agenda

1. Motivation
2. Modeling Approach
3. Results
4. Conclusions


20-20-20
RES
80, 100% … 2050

Renewable Intermittency





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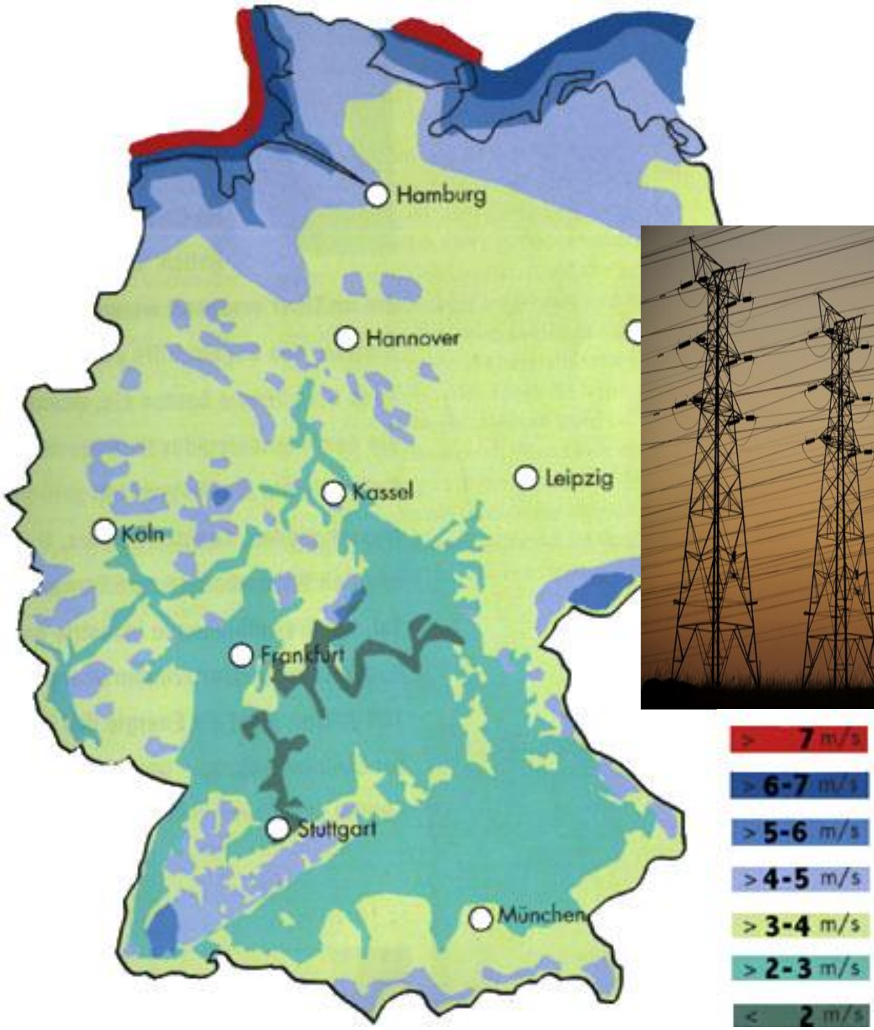
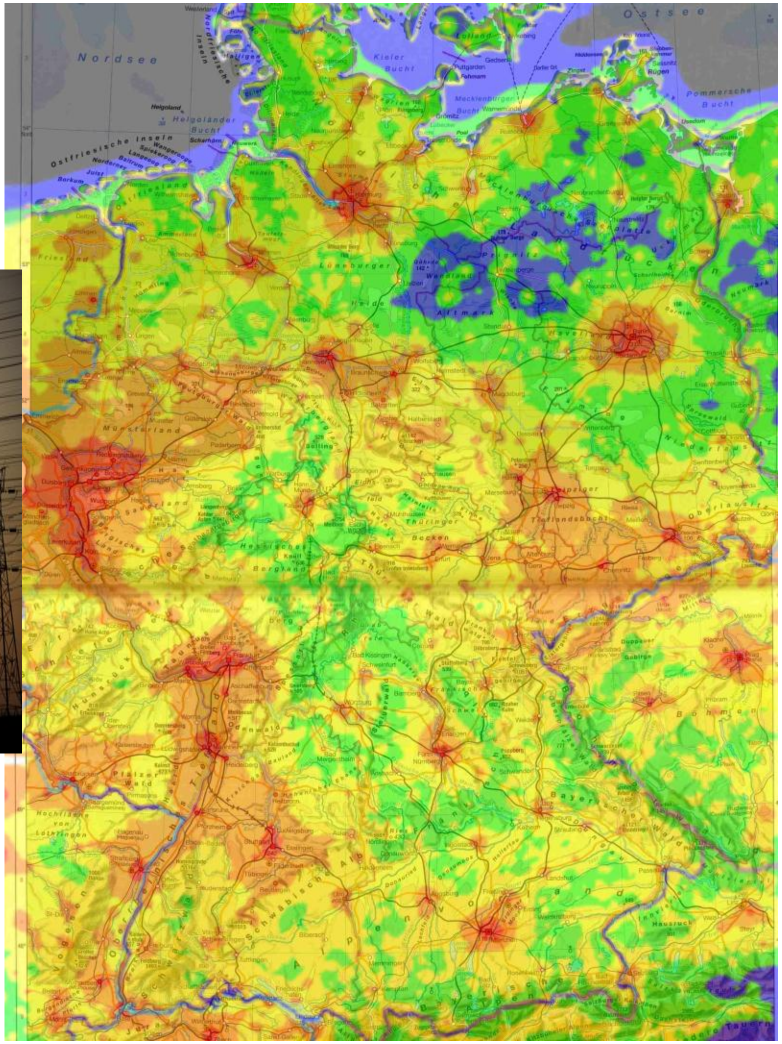
Locational Aspects





Questions

What are the impacts renewable intermittency?

What are the effects of locations (network restrictions)?

What happens if the effects interact?

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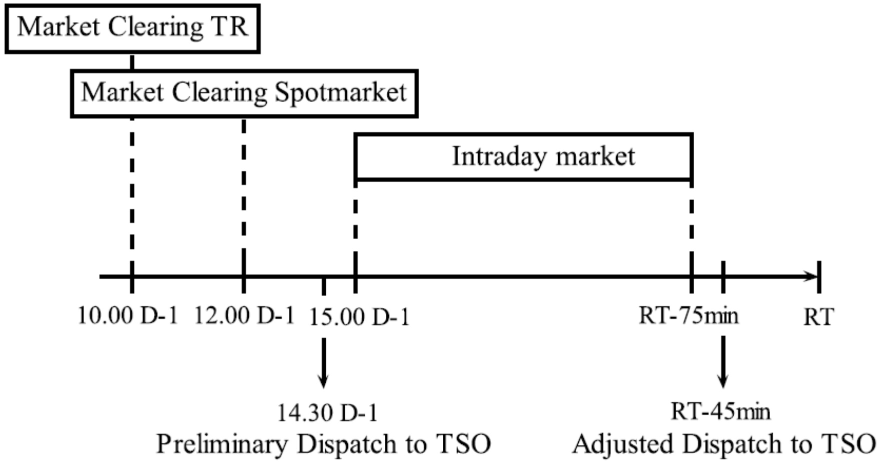
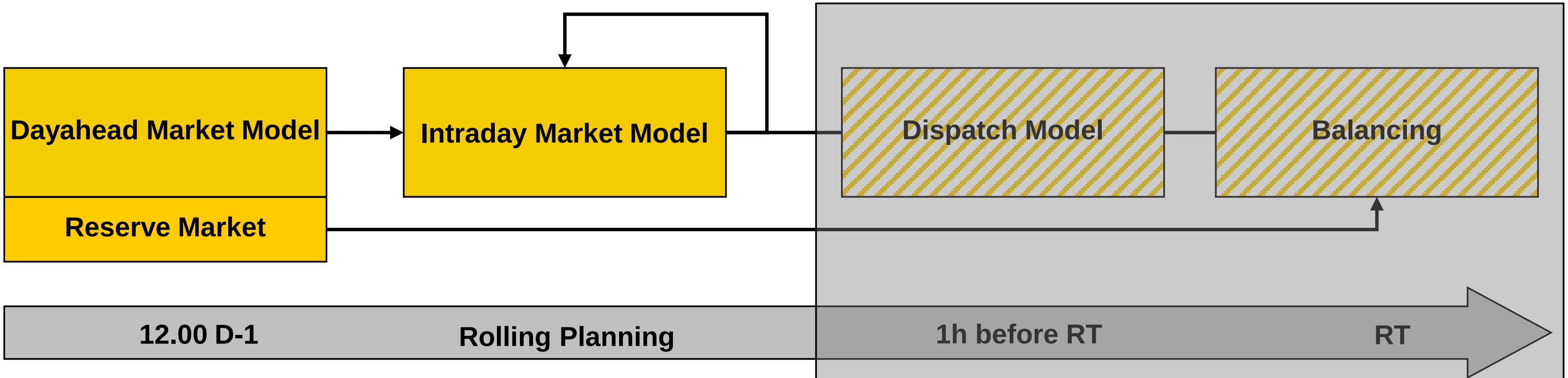
Daily German Electricity Markets

- **12.00: Dayahead market (Spotmarket)**
  - **Central auction at EEX**
  - **Clearing for 24h of following day**
- **14.30: Preliminary dispatch timetable**
  - **§ 5 (1) StromNZV**
- **15:00: Start of intraday market**
  - **Bilateral or standardized (EEX)**
  - **Closure of market RT-75min**
- **RT-45min: Final dispatch timetables**
  - **§ 5 (2) StromNZV**
  - **Management of network constraints**
- **RT: Balancing of unexpected deviations**



Modelling Approach



12.00 D-1

- 24h
- UC & dispatch of power plants

- Initial wind forecast for delivery day

Rolling Planning

- Time variable (24h)
- UC & dispatch given restrictions of dayahead and previous intraday market

- Arrival of new wind forecasts

1h before RT

- Redispatch

- Arrival of new wind forecasts

RT

- Hourly
- Dispatch of reserve capacity

- Realization of wind generation

Dayahead Market Model

Given: **wind forecast, (past power plant plans)**

Decide about: **plant status, generation, reserve provision, storage use**

min (Generation Cost + Startup Cost)

subject to:

Generation	=	Demand
Reserve Capacity	=	Reserve Demand
Generation	<=	Installed Capacity
Generation	>=	Minimum Generation (if online)
Offline Time	>=	Minimum Offline Time
Online Time	>=	Minimum Online Time

+ Storage restrictions, Wind Shedding

Intraday Market Model

Given: **new wind forecast, current plant status, reserve capacities**

Decide about: **plant status, generation, reserve provision, storage use**

min (Generation Cost + Startup Cost)

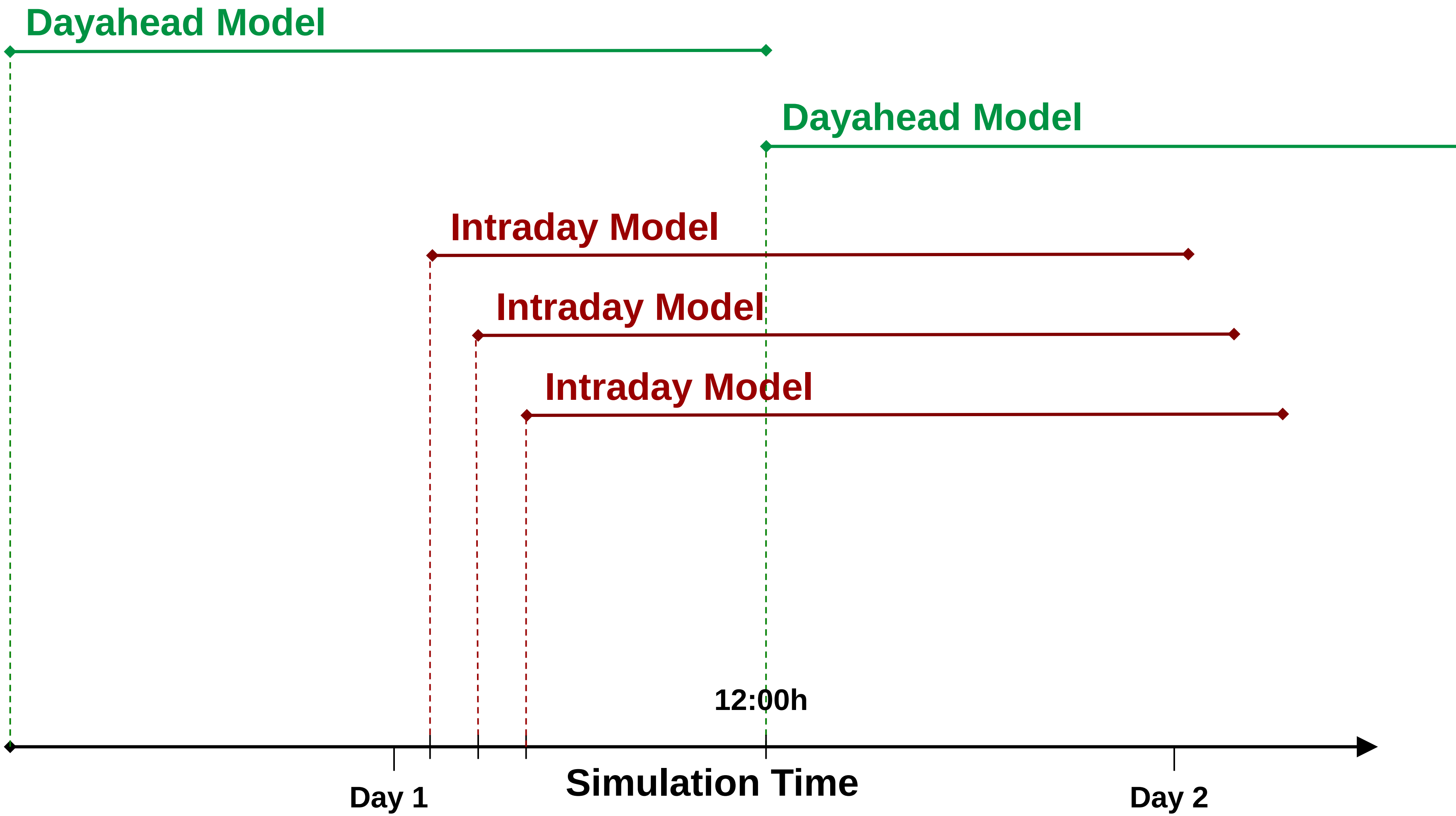
subject to:

Generation	=	Demand
Generation	<=	Installed Capacity (net of reserve)
Generation	>=	Minimum Generation (net of reserve)
Offline Time	>=	Minimum Offline Time
Online Time	>=	Minimum Online Time

+ Storage restrictions, Wind Shedding

+ Running requirements given by previous decisions (reserve, minimum times)

Rolling Planning



Intraday model run in hourly steps

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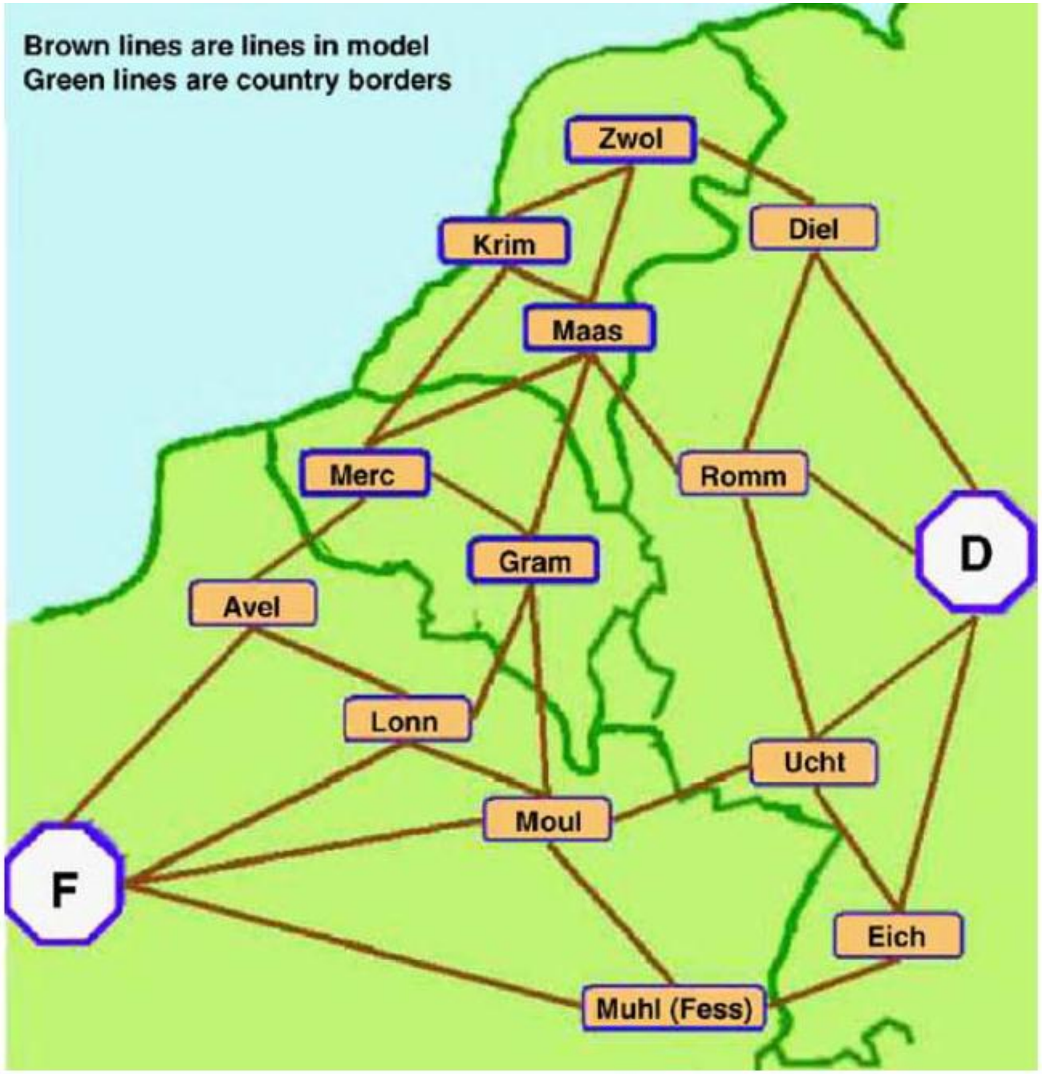
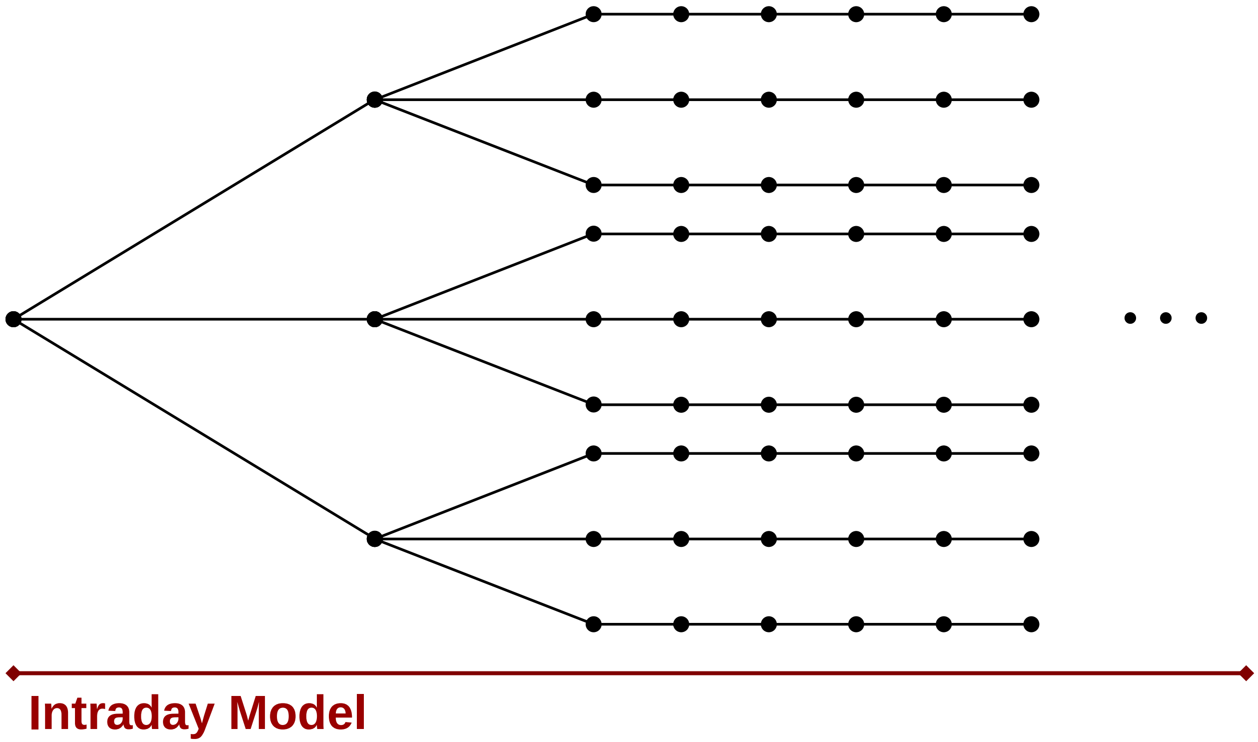
Introducing Network Constraints

- DC loadflow model
- Network constraints in
  Dayahead
  Intraday
  model
- Node and overall demand market clearing condition
- Wind input uniformly distributed over the grid
- Demand population distributed over the grid



Stochastic Programming Approach

- **Stochastic intraday model deciding about the plant status and generation given future uncertainty of wind**



- **Simple stochastic: (up, average, down) with (+1%, 0, -1%) deviation per time period (implies perfect correlation of wind sites)**

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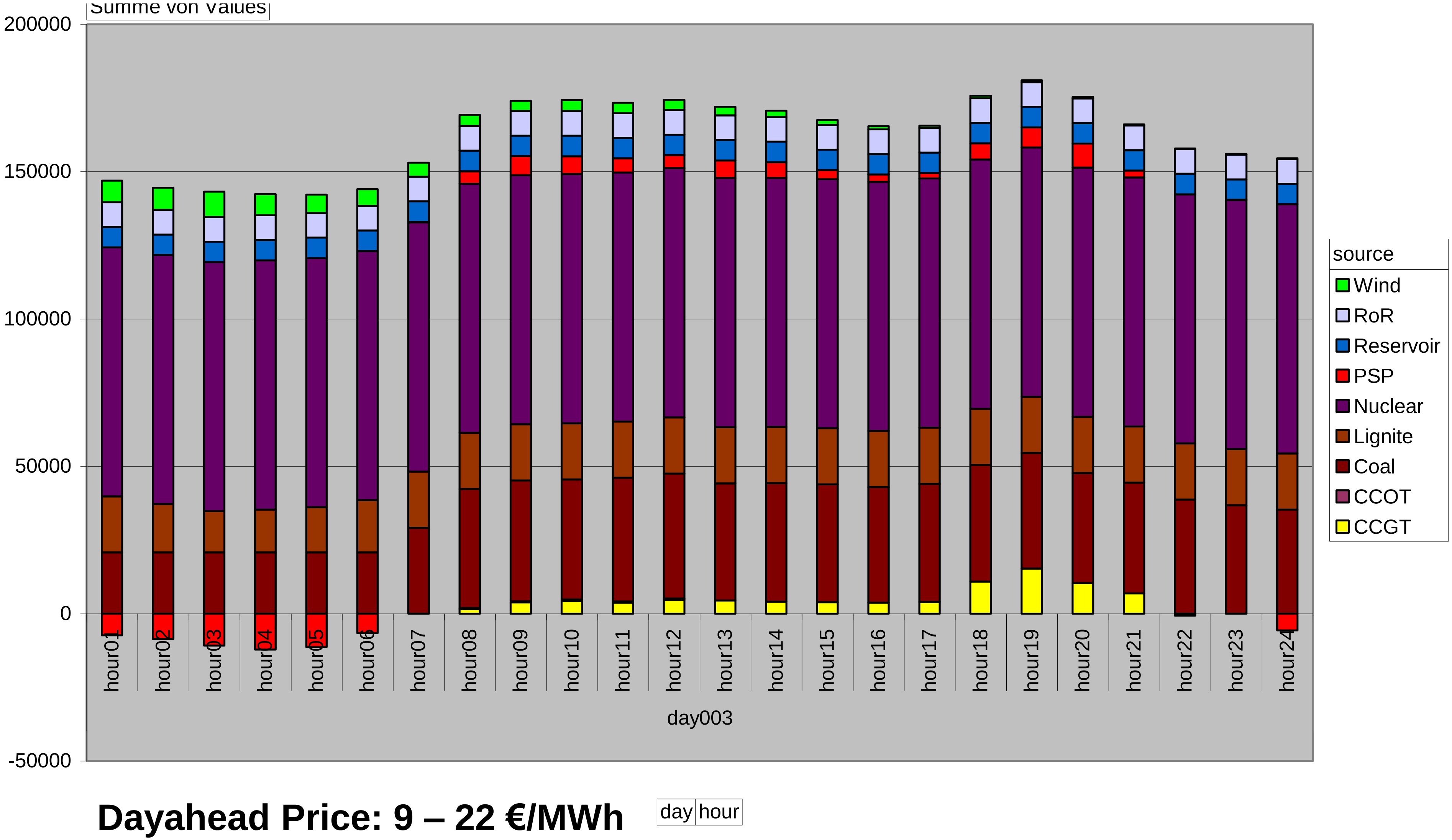
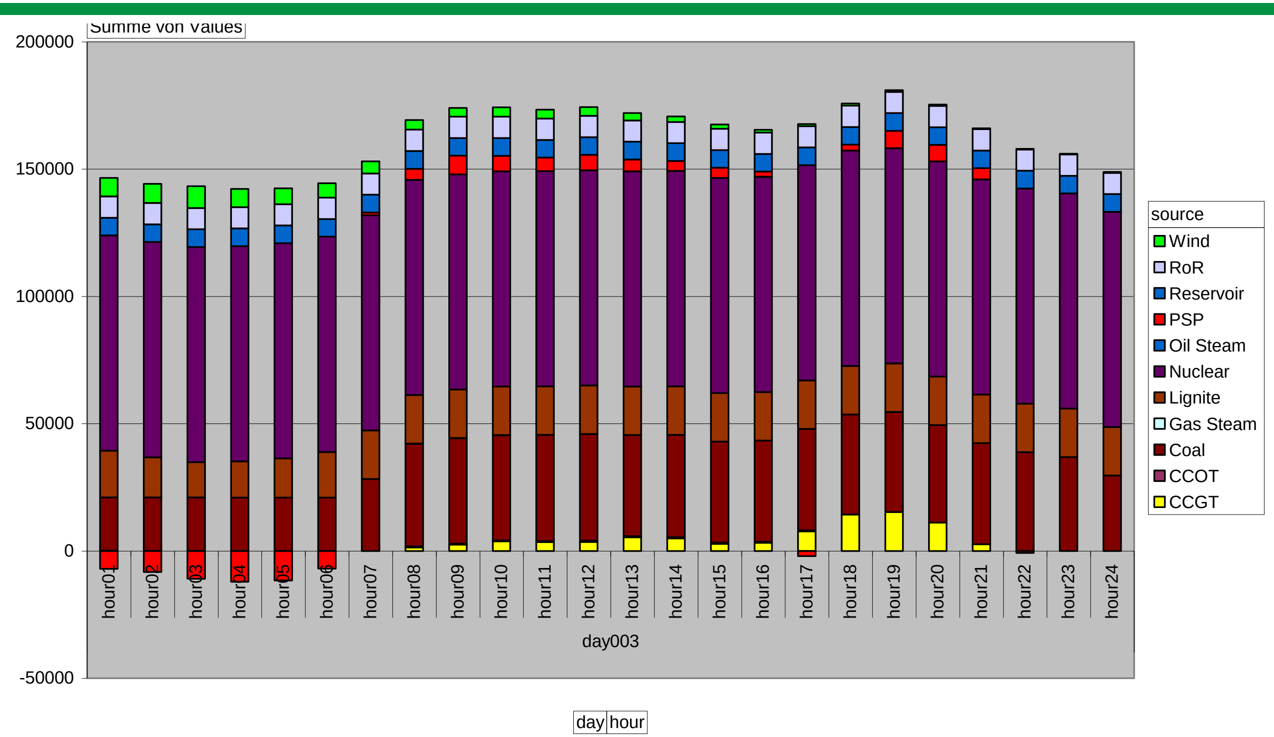
Keep it simple: No Grid… No Stochastic Programming



Dayahead Price: 9 – 22 €/MWh

Solve time for one week: 0.15 h = 9 min

Stochastic Programming… No Grid Restrictions



Dayahead Price: 21 – 47 €/MWh

More flexible units in the market

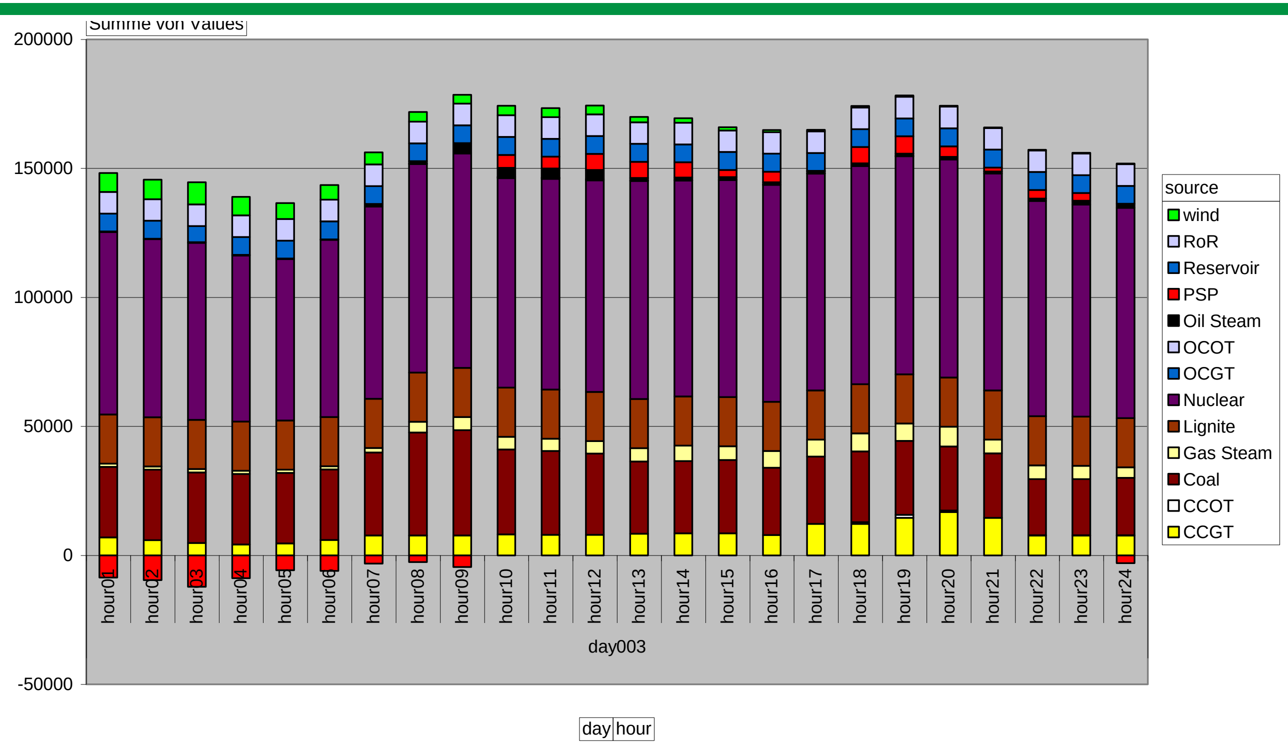
Different use of storage facilities

More reactions in intraday market

$\Leftarrow$ **Balancing uncertainty**

Solve time for one week: 40 h

Grid Restrictions… No Stochastic Programming



Dayahead Price: 9 – 22 €/MWh

More flexible units in the market

Different use of storage facilities

More reactions in intraday market

⇐ **Locational aspects**

Solve time for one week: 0.5 h

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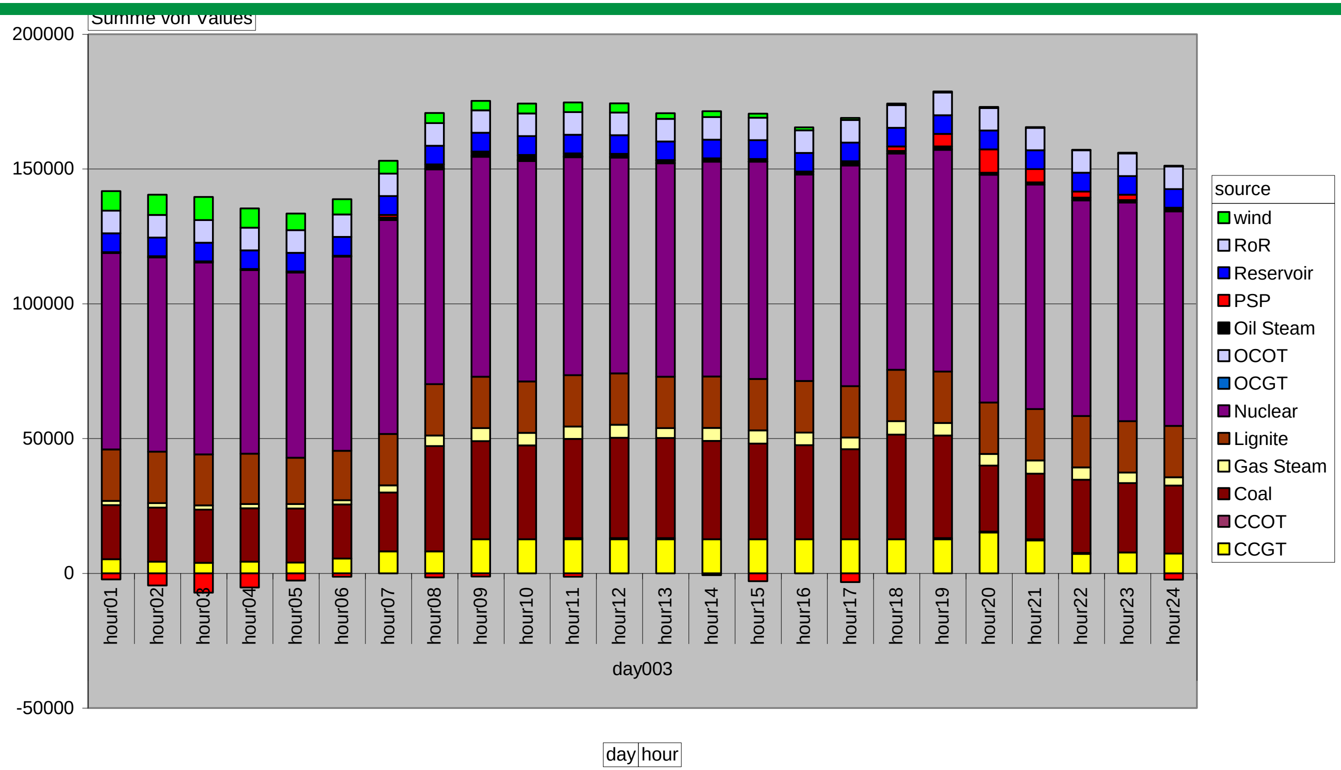
Stochastic Programming and Grid Restrictions



Dayahead Price: -9 – 256 €/MWh

More flexible units in the market

Different use of storage facilities

More reactions in intraday market

$\Leftarrow$

Balancing Uncertainty

&

Locational aspects

Solve time for one week: 50 h

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Conclusion

- **Stochasticity causes**
  - **significant price impacts**
  - **flexible units online**

- **Locational aspects (network restrictions) cause diversification of the generation portfolio**

- **Combining stochasticity and locational aspects yields high volatility of prices and diversified generation portfolios**

- **Storage important to balance uncertainty and for grid stability**

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Further Research …

- Stochasticity causes a high computational burden. Is there a worth doing stochastic programming?

- What's about combined heat and power (CHP/KWK), demand side management, price reactions … ?

- What are the restrictions coming imposed by future market decisions? How market participants act on this market?

- When and how network/congestion information come into market?

- What's about redispatch and reserve (demand)?

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Structure of the German Electricity Market

	Futures market		Day-ahead market		Intraday market		Reserve market
Trading	Standardized	Bilateral	Auction	Bilateral	Standardized	Bilateral	Tendering
Type	financial	physical	physical	physical	physical	physical	physical
Products	Futures Options	Forwards	Hour contracts Baseload contracts Peakload contracts		Hour contracts		PR: no time slices SR: 3 time slices* MR: 6 time slices**
Contractual partner	EEX	others	EEX	others	EEX	others	TSOs
Participation	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary; Pre-qualification necessary
Clearing interval	Continuous	Continuous	Daily	Continuous	Continuous	Continuous	Monthly (PR,SR) Daily (MR)
Gate closure			12.00 a.m. D-1				10.00 a.m. D-1 (MR)
Pricing		Bargaining	Uniform	Bargaining		Bargaining	PR: Capacity price SR/MR: Capacity/Energy price

* Monday– Friday: peak/offpeak period; Weekend and general holiday: base period.
** 0.00– 3.59; 4.00– 7.59; 8.00– 11.59; 12.00– 15.59; 16.00– 19.59; 20.00– 23.59.

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Market Integration of RES in Germany

- **Wind generators are neither responsible for balancing nor responsible to bring generated energy to market**

- **TSOs are obliged to bring renewable generation efficiently to the day-ahead or intraday market (§ 64(3) EEG, § 2(2) AusglMechV)**

- **Wind generators receive defined feed-in tariff**

- **Deficits between received revenues and paid feed-in tariffs are finally paid by consumers**

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