

Impacts of Intra-day Rescheduling of Unit Commitment and Cross Border Exchange on Operational Costs in European Power Systems

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Content

- Market design and wind power
- Cases
- Wilmar model
- Results

MARKET DESIGN

PAST

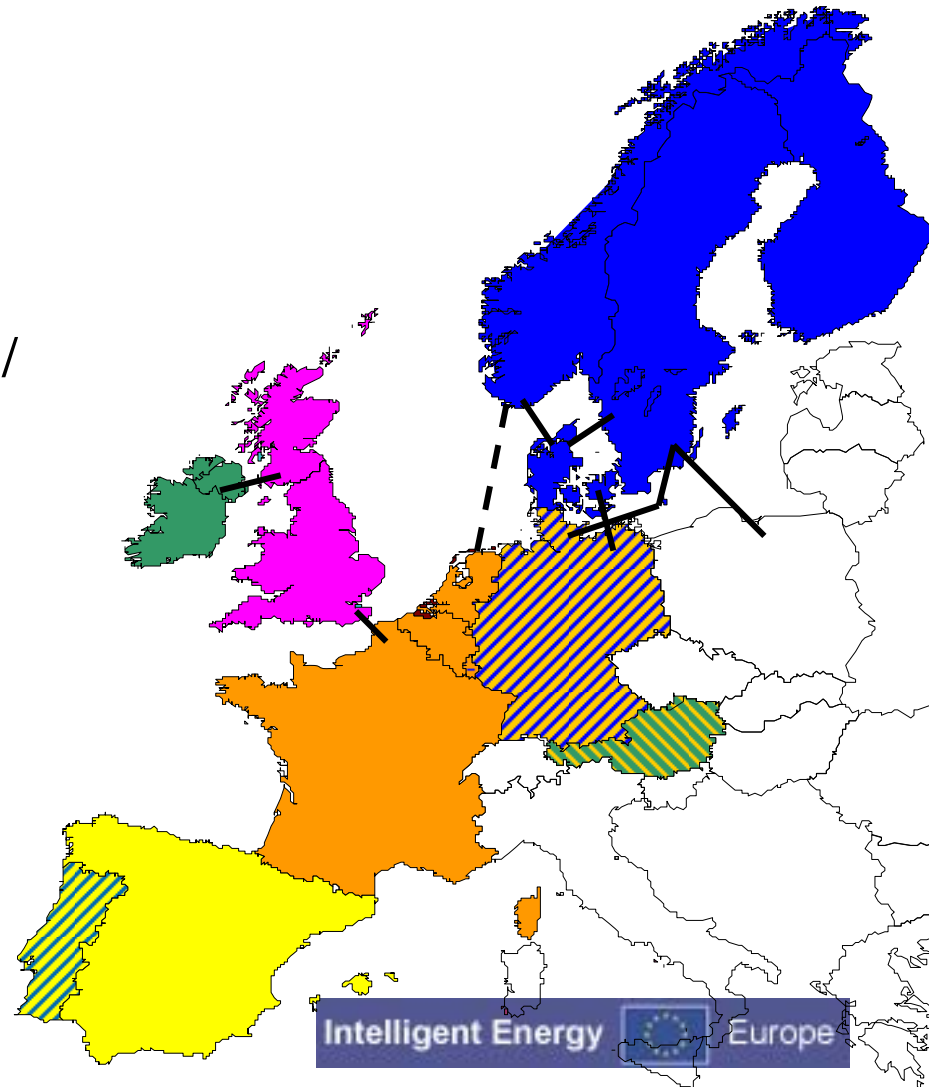
- Vertically integrated monopolies

PRESENT

- Unbundling: TSO vs. producers / suppliers
- Competition
- National – regional markets

FUTURE

- European integration
- Regional markets



Market design and wind power

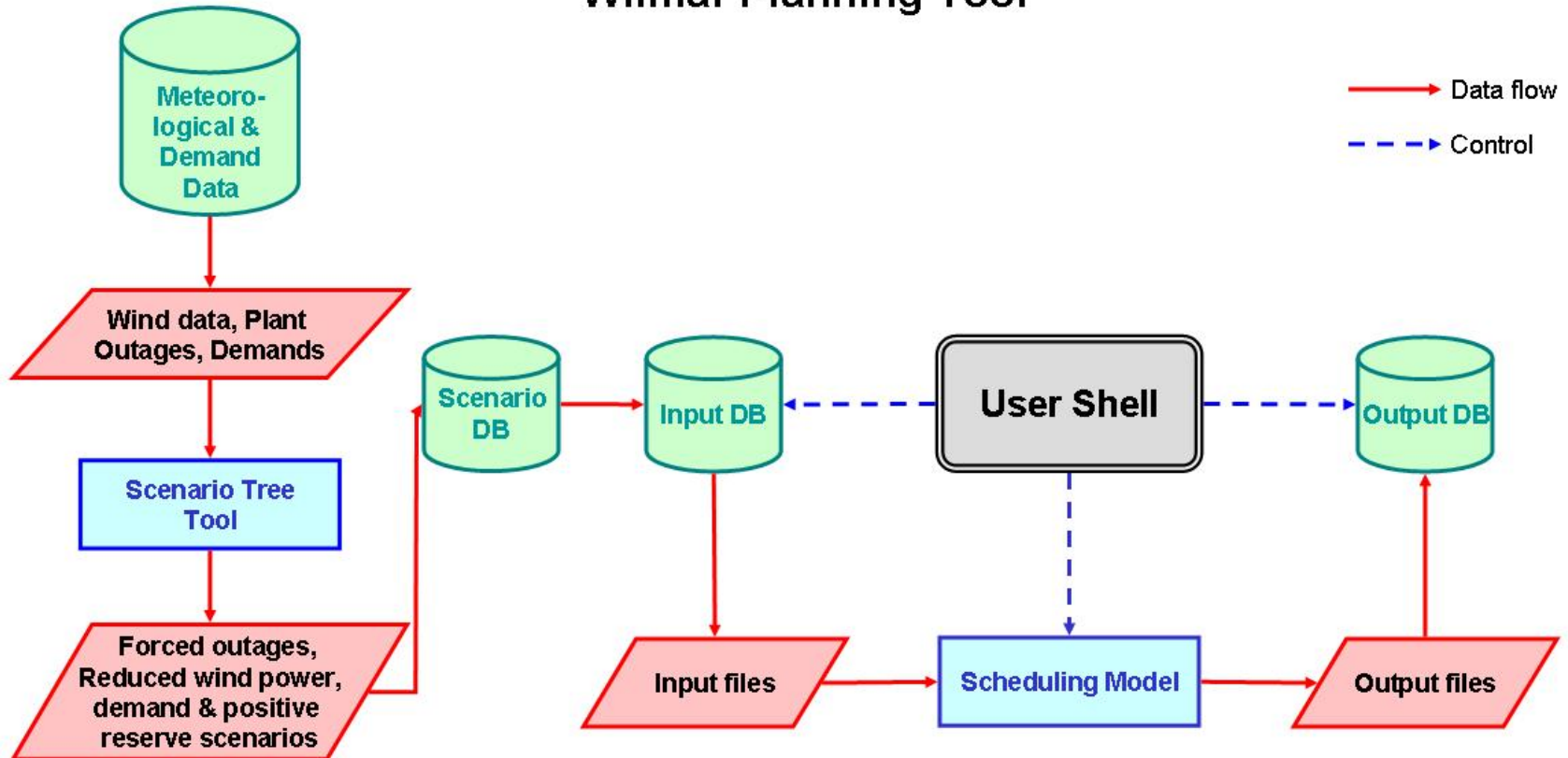
- Wind power adds variable and partly predictable power production:
 - Create higher demand for flexibility in the power system
- Market design should encourage the usage of available flexibility:
 - In cross-border exchange of power and reserves
 - In rescheduling of units

Wilmar Planning tool – Basic idea

- Improve operational decisions in power systems (unit commitment and dispatch of units) by using not only:
 - The expected value of wind power and load forecasts
 - But also accuracy of forecast, i.e. the distribution of forecast errors
- Approach:
 - Development of hourly system-wide stochastic optimisation model with stochastic input parameters
 - Covering both day-ahead scheduling and rescheduling due to updated forecasts
 - Rolling planning to take updated forecasts into account
- Consequence: Model makes unit commitment and dispatch decisions being robust towards forecast errors

Components of Wilmar Planning Tool

Wilmar Planning Tool



Scheduling model

- Stochastic, mixed integer, linear optimisation model
- Stochastic input in the form of a scenario tree
- Stochastic input:
 - Wind power production forecasts (dispatch)
 - Electricity demand forecasts (dispatch)
 - Forecasts of demands for replacement reserves (unit commitment)
- Replacement reserve: demand for positive reserves that replaces spinning reserves (activation times above 5 minutes):
 - Demand dependant on forecast horizon (forecast horizons from 1 hour to 36 hours ahead)
 - Demand dependant on wind power and load forecasts
 - For a one hour forecast horizon replacement reserves can be understood as positive minute reserve

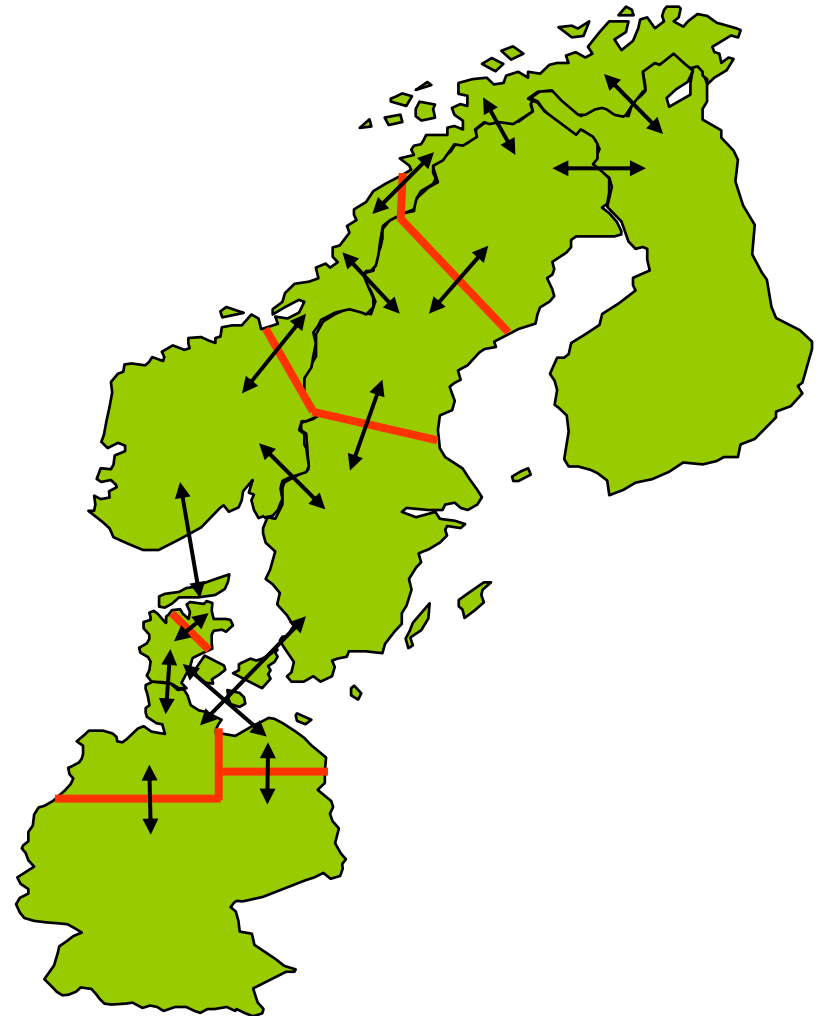
Scheduling model

- Optimisation over all outcomes represented by the scenario tree taking both demands for electricity and demand for spinning and replacement reserves into account
- Minimisation of expected costs. Expectation taken over branches in scenario tree
- **Unit restrictions:** minimum up time, minimum down time, start-up time, minimum stable operation level, piece-wise linear fuel consumption curve, restriction on ability to provide spinning reserve
- Model representation of:
 - Thermal units: condensing, combined heat and power
 - Heat boilers, heat pumps, heat storages
 - Electricity storage
 - Plug-in electric vehicles
 - Transmission grid

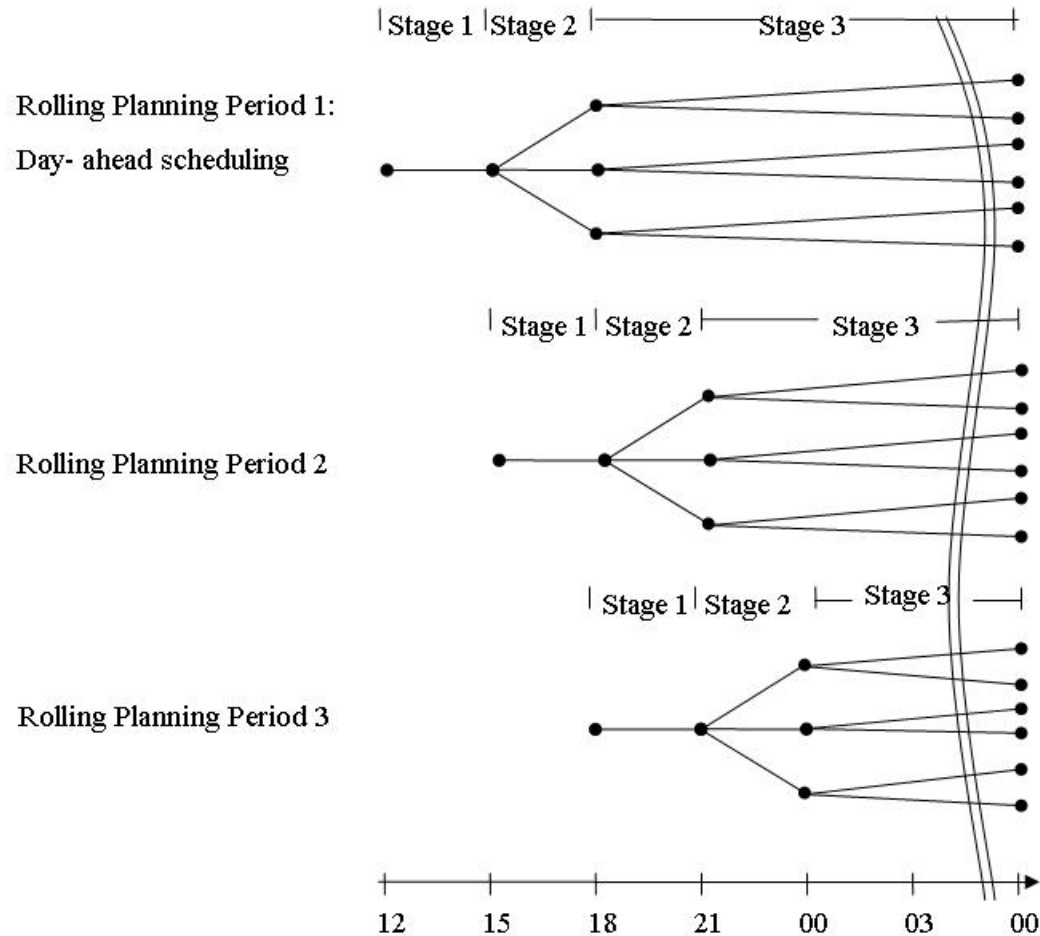
Scheduling model

Subdivision of the modelled area into model regions to consider:

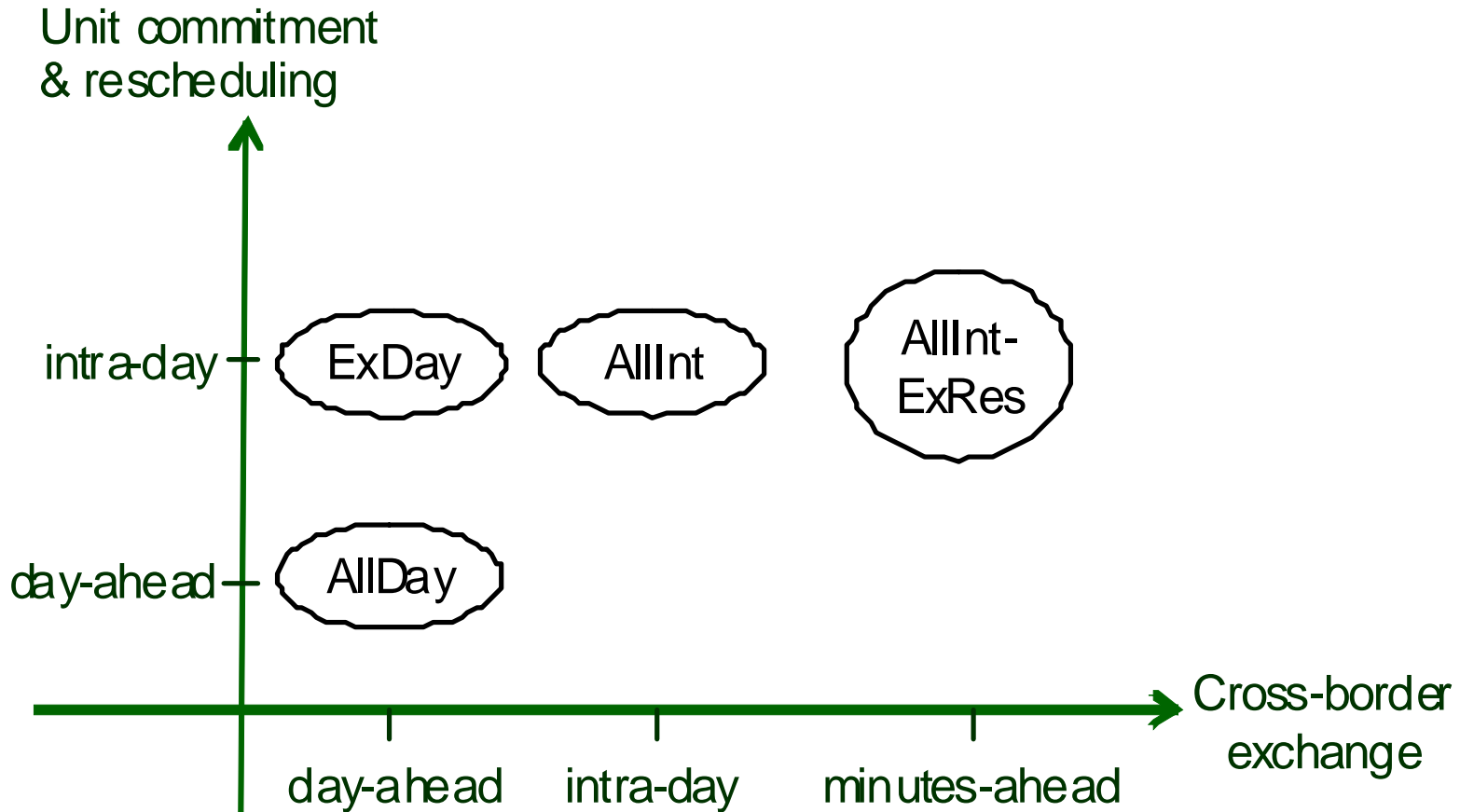
- Spatial concentration of the installed wind power
- Spatial distribution of the electrical demand
- Bottlenecks in the transmission grid



Rolling planning: rescheduling due to updated forecasts



Overview market rule cases



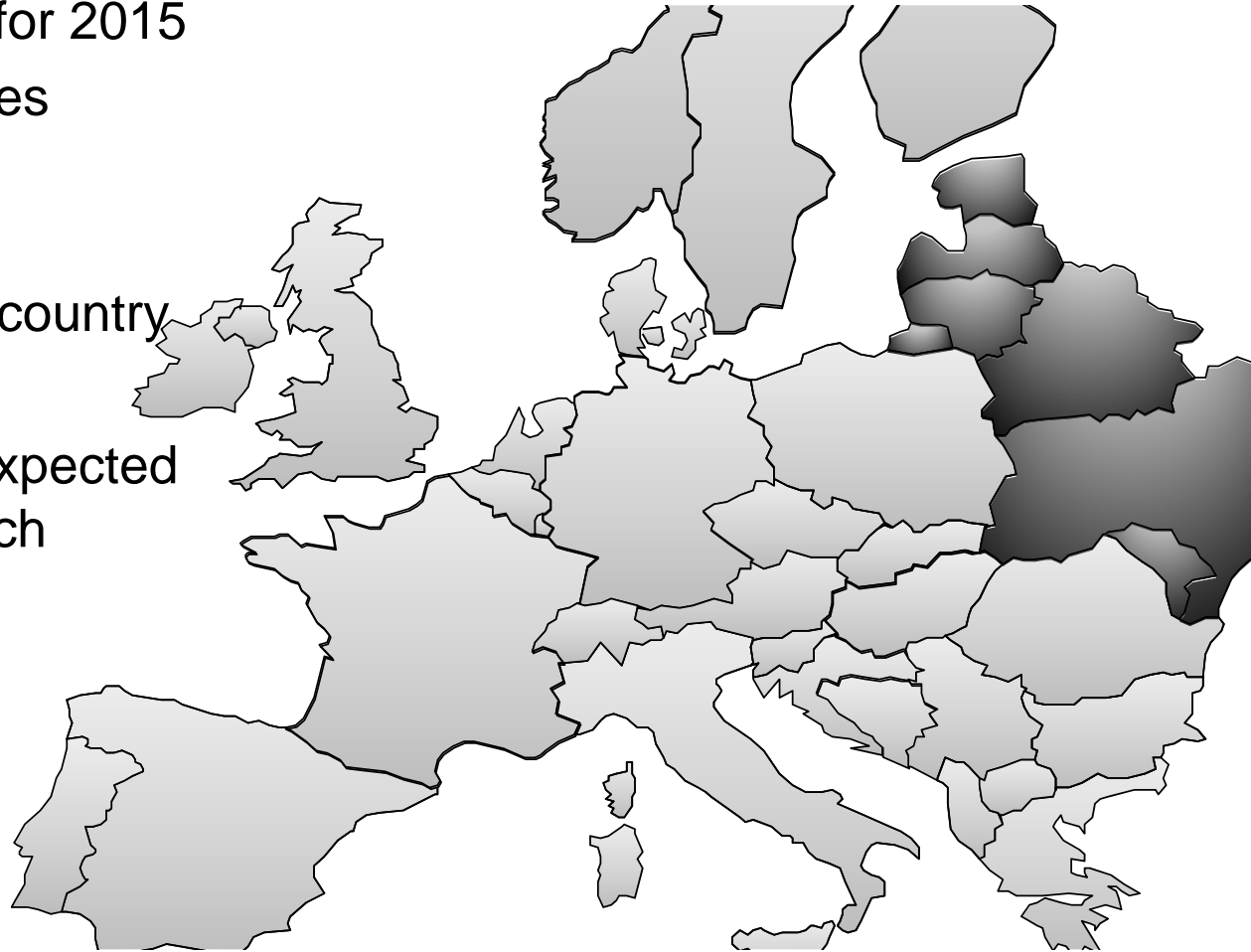
Overview cases

- **AllDay:** Unit commitment for slow units and power exchange over borders determined day-ahead (12-36 hours ahead) and not rescheduled intra-day.
- **ExDay:** Like AllDay except for unit commitment for slow units now being rescheduled intra-day. Cross-border exchange is still allowed day-ahead only.
- **AllInt:** Like ExDay but power exchange allowed to be rescheduled intra-day.
- **AllIntExRes:** Like AllInt but exchange of replacement reserves across borders allowed, i.e. part of the demand for replacement reserves can be provided by a neighbouring country by reserving part of the cross-border transfer capacity for this purpose.

Slow units: units with a start-up time above 1 hour

Cases

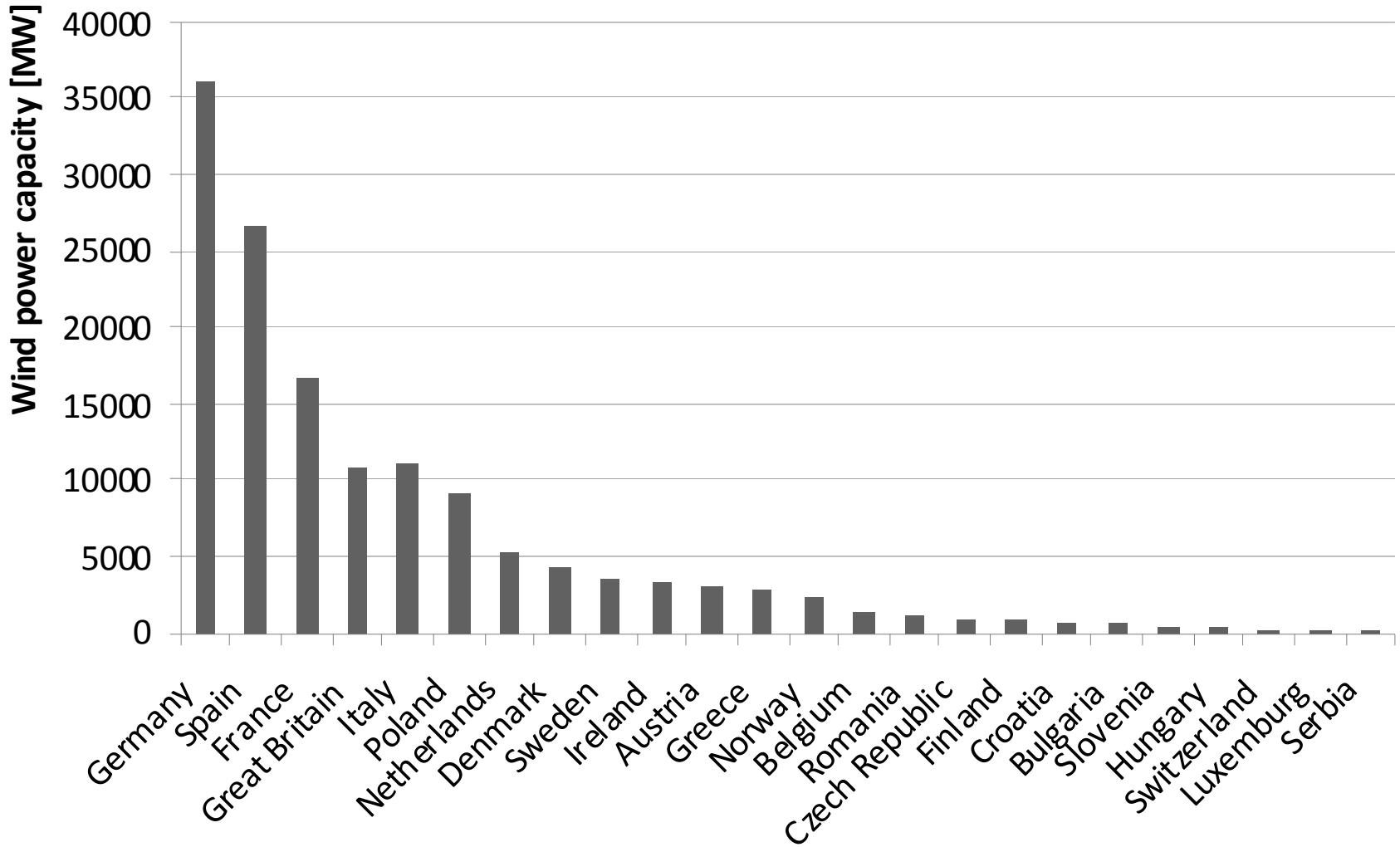
- 4 market rule cases for 2015
- 31 European countries included in model
- Hourly resolution
- Only one region per country
- Only one forecast (expected wind and load) in each planning loop



Data input

Data on	Source	Resolution
Fuel & CO ₂ prices	IEA	Yearly
Load profiles	ENTSO-E	Hourly
Annual load	ENTSO-E	Yearly
Wind power generation	Tradewind project/	Hourly
RES-E deployment (excl. wind power)	Green-X	Yearly
Hydro inflow	Marketskraft / national statistics	Hourly / yearly
Reservoir levels	Marketskraft / national statistics	Seasonal
Conventional power plants	Platts database/ own research	Single plant
Technical parameters	Academic literature	Single plant
Heat load	National statistics	Hourly

Installed wind power capacity (source Tradewind)

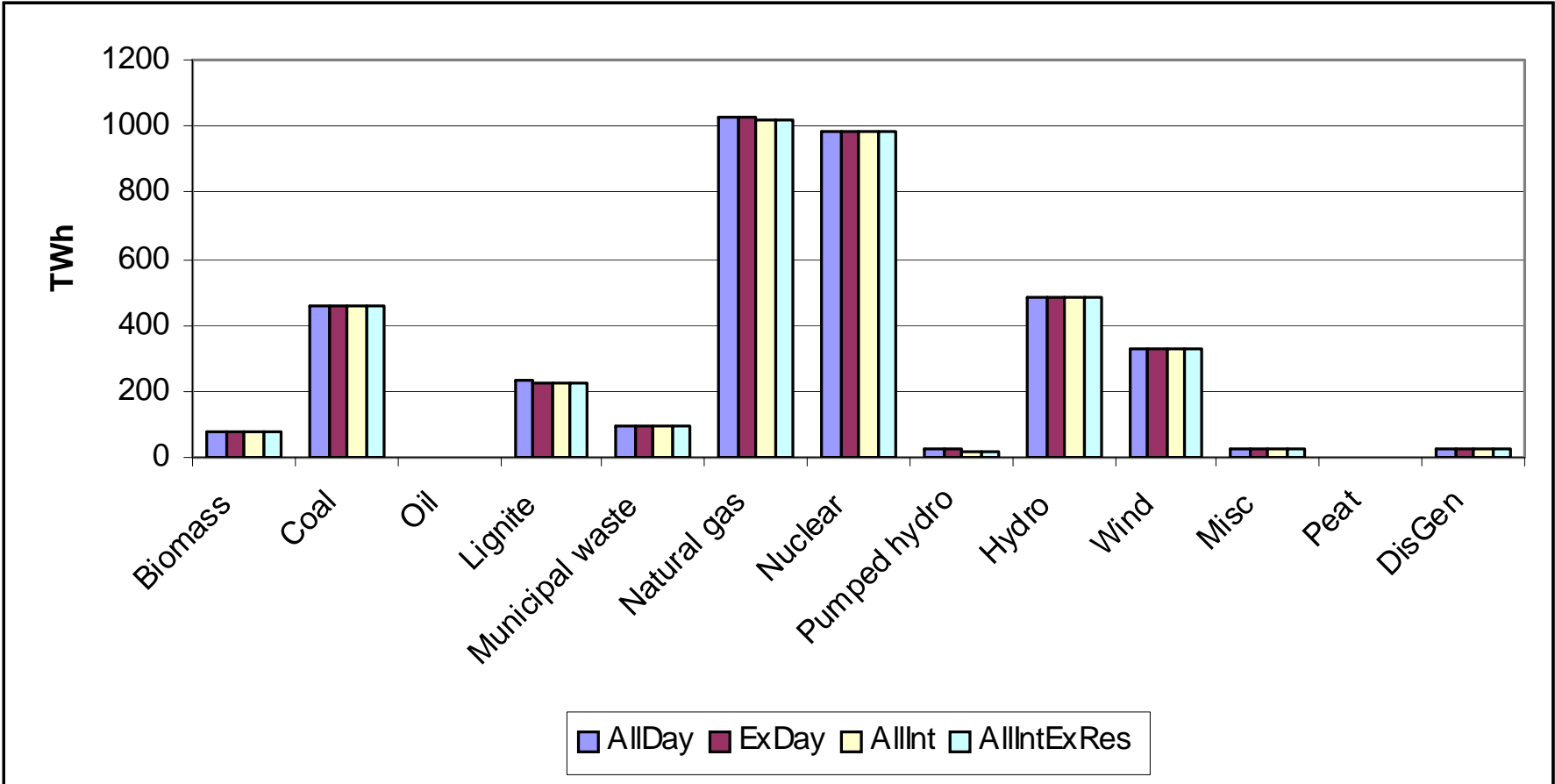




Data input

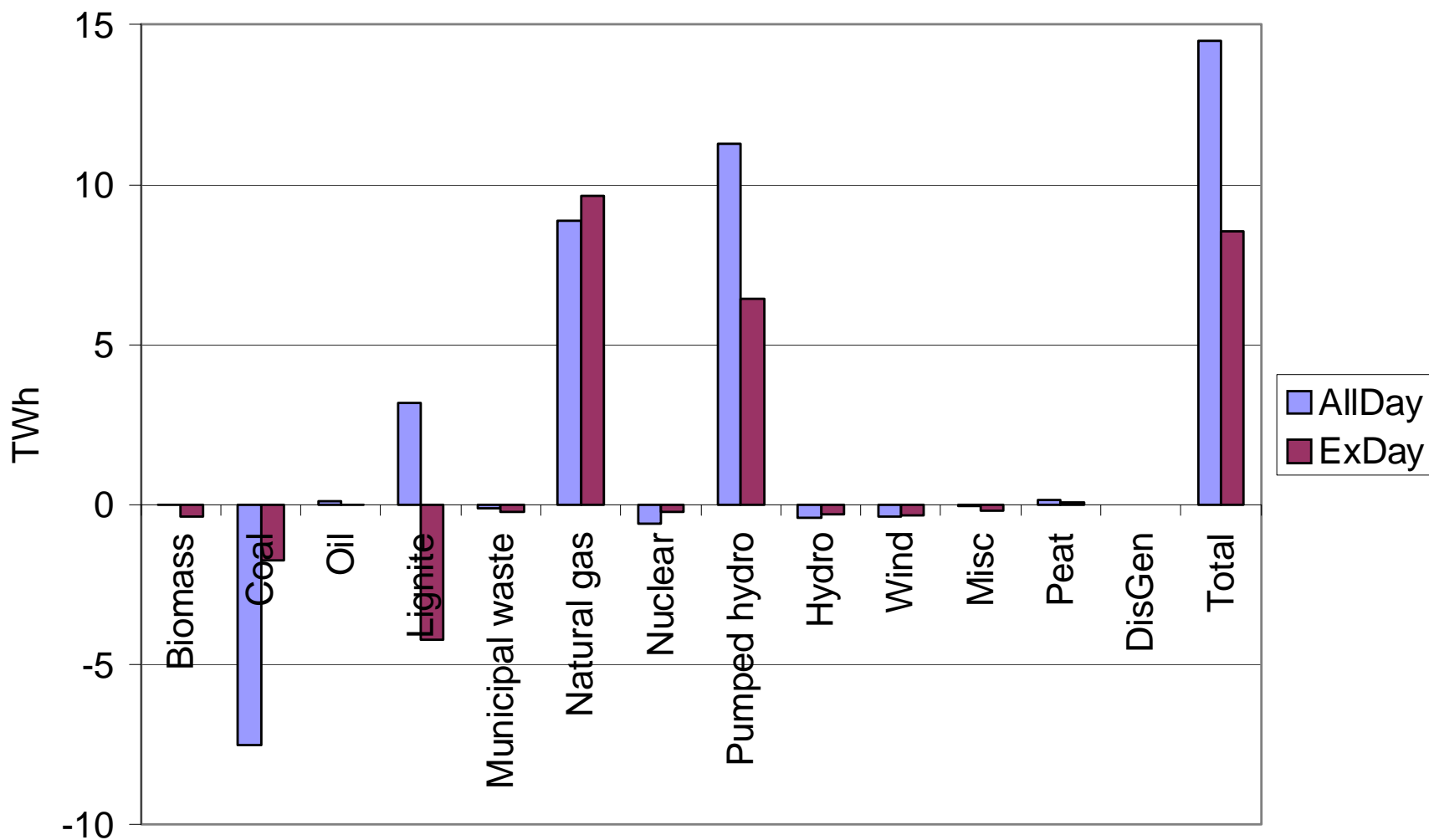
- Renewable capacities excluding wind derived with the Green-X tool based on database combining promotion policies for renewables and potentials of renewables in Europe
- Price of tradable CO₂ emission certificates: 46 EUR/tons CO₂

Yearly electricity production distributed on fuels in 2015

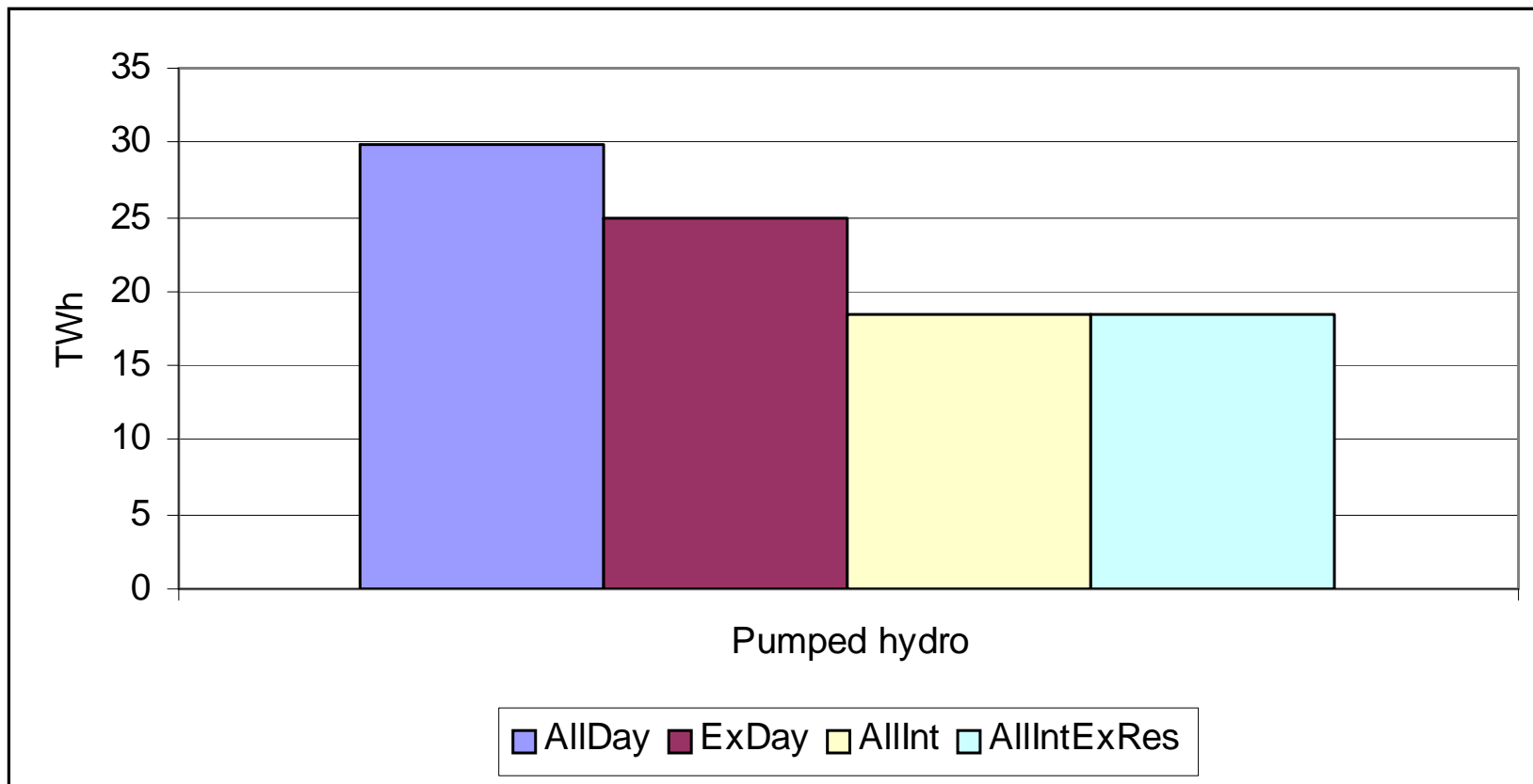


Wind power production 8.7% of electricity production in 2015

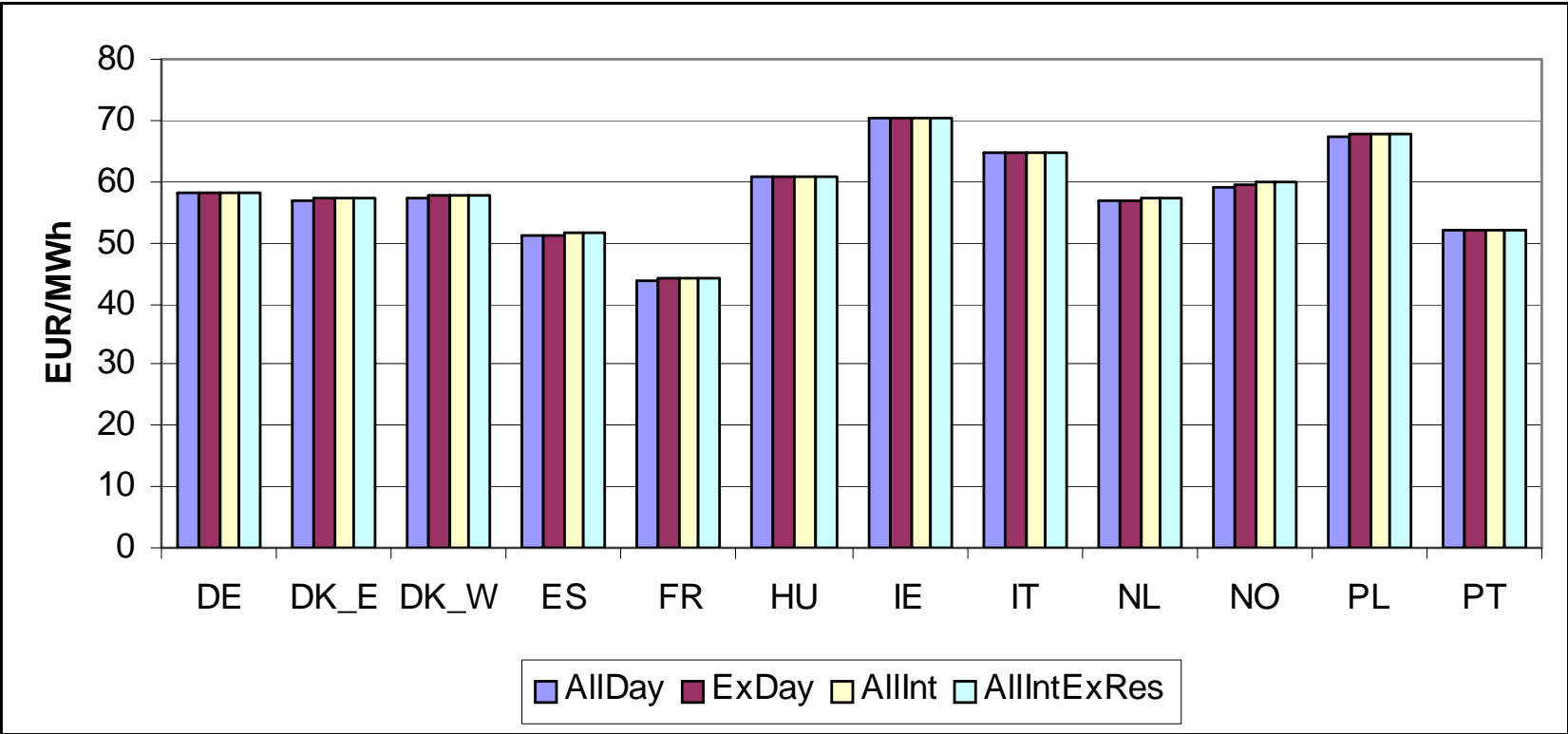
Differences in yearly electricity production relatively to AllInt



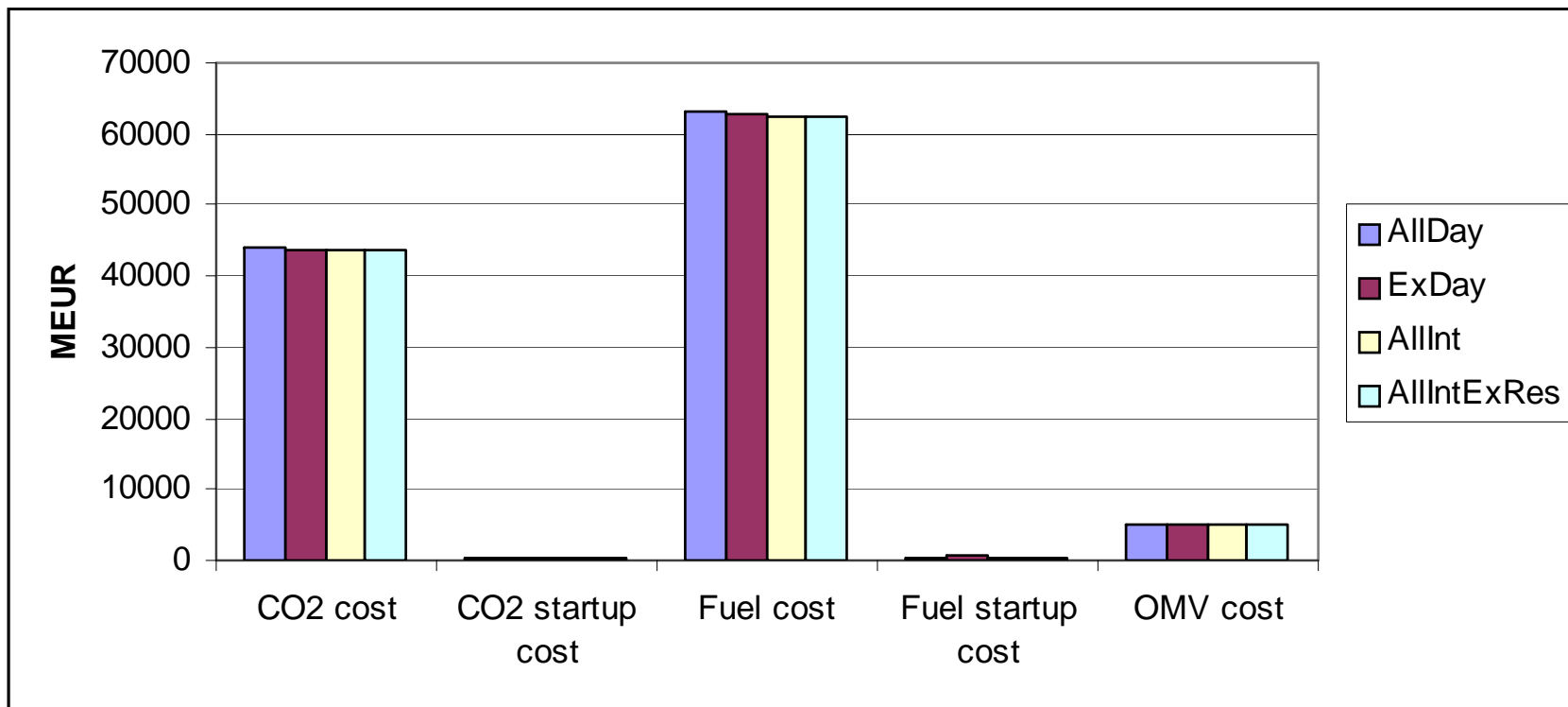
Yearly production from pumped hydro



Yearly average power prices on intra-day market for selected countries

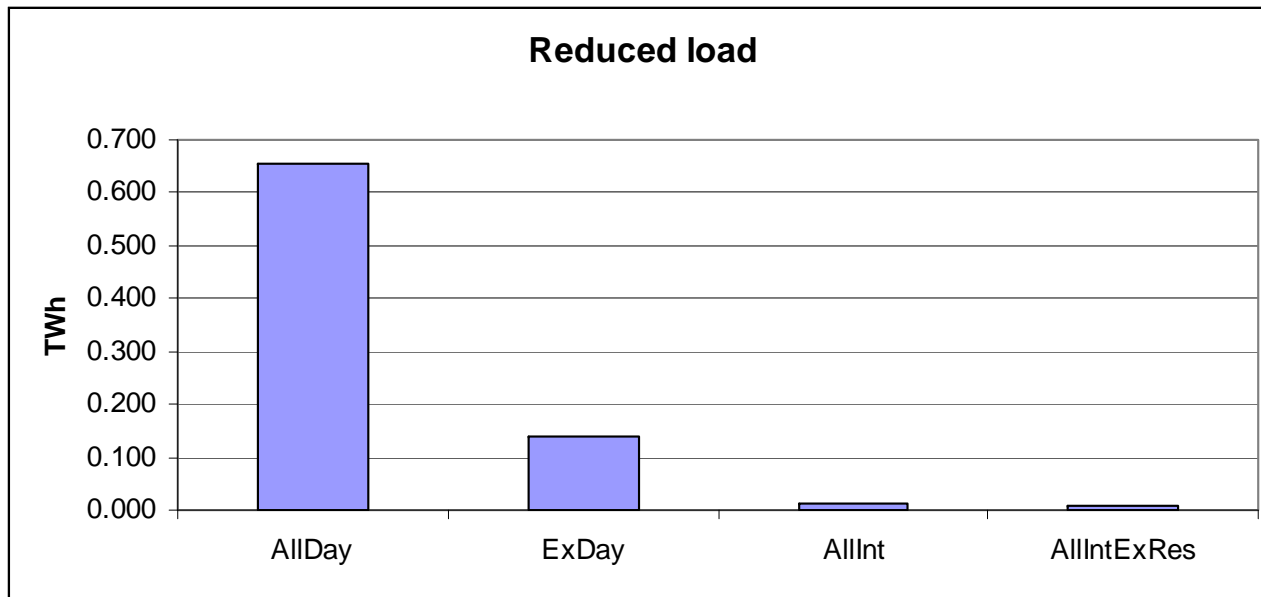


Yearly operational costs 2015 in MEUR



	Total operational cost	Relatively to AllInt	Difference relatively to AllInt
AllDay	114026	1.010	1159
ExDay	113659	1.007	791
AllInt	112867	1.000	0
AllIntExRes	112867	1.000	-1

Value of lost load and not meeting reserves 2015



Total yearly load
3648 TWh

VOLL (Value of lost load) set to 3000 EUR/MWh

Costs of not meeting reserve targets set to 300 EUR/MWh

	Reduced load [TWh]	Demand for positive minute reserves not met [TWh]	Value reduced load [MEUR]	Value minute reserve not met [MEUR]
AllDay	0.657	0.052	1970	15
ExDay	0.139	0.239	418	72
AllInt	0.010	0.014	31	4
AllIntExRes	0.010	0.014	30	4

Conclusions

TIME AND SPACE DIMENSION

- Intra-day rescheduling of unit commitment of slow units:
 - reduces lost load
 - operational costs savings excluding value of lost load: 391 MEUR/y
- Intra-day rescheduling of cross-border exchange
 - operational costs savings: 791 MEUR/y
- Total system costs savings due to intra-day rescheduling 1159 MEUR/y (1% of costs)
- Cross-border exchange of reserves:
 - no operational cost savings
 - yields savings in investment rather than system cost

Recommendations

FLEXIBILITY OF POWER PLANTS

- slower power plants to participate in intra-day rescheduling
- *slow* meaning start-up time > 1h

INTERNATIONAL DIMENSION

- allow intra-day rescheduling of interconnectors
- establish cross-border intra-day markets
- pursue the regional markets initiative

RESERVE POWER EXCHANGE

- yields savings in investment rather than system cost
- investigate trade off between national investments and international exchange

Recommendations

CONGESTION MANAGEMENT

- replace explicit auctioning with implicit auctioning of interconnectors