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All island grid study - Results concerning system operation

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All Island Grid Study – Results concerning system operation

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Content presentation

- Purpose
- Assumptions
- Tool
- Results
- Conclusions

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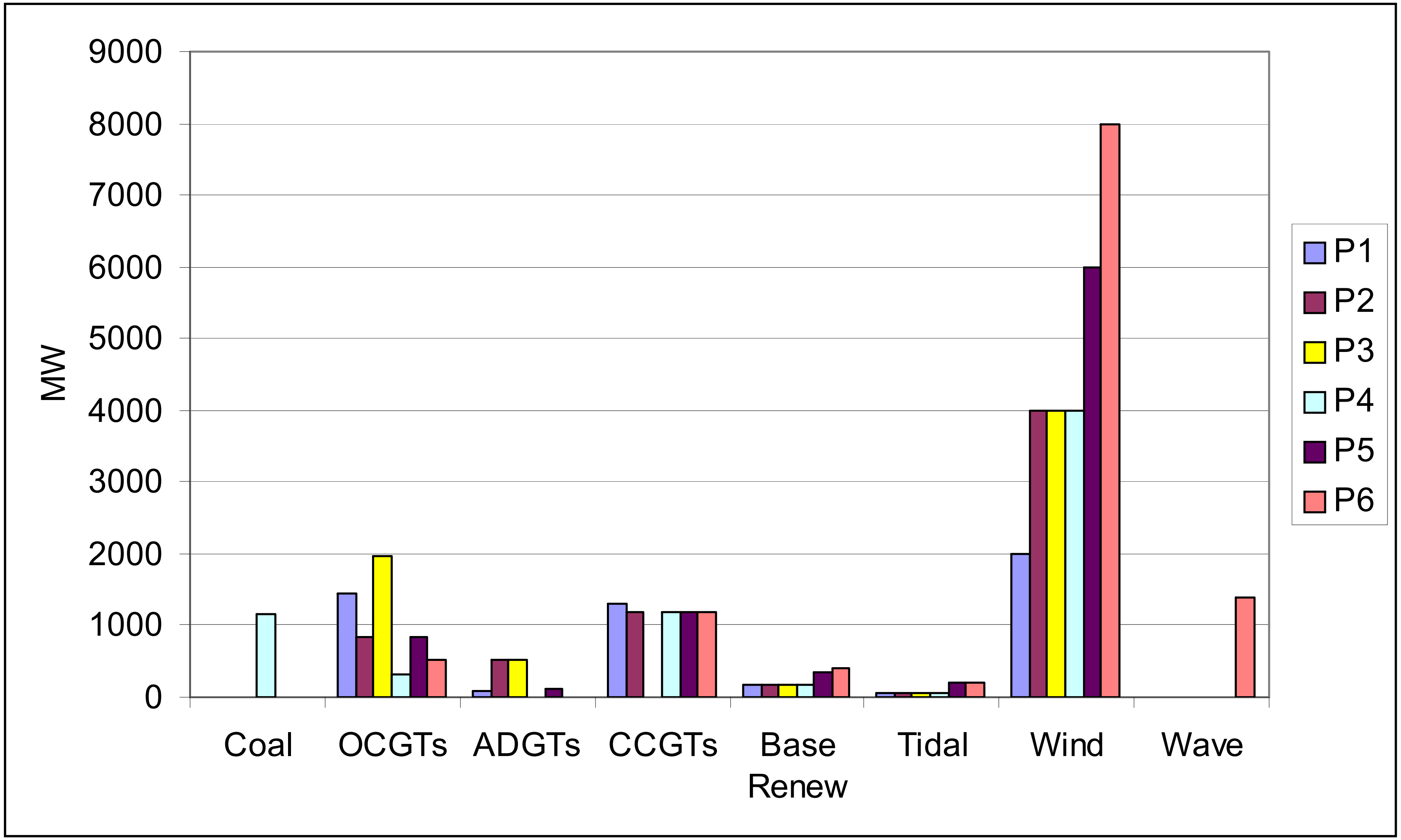
Purpose

- All Island Grid Study – Work stream 2B: Wind variability management studies
- Impacts of renewable generation on All-Island power system:
  - Variability and predictability of renewable generation
  - Costs and benefits of absorbing various levels of renewable generation
  - Emissions and costs of existing units
  - Most suitable mix of complementary conventional plants
  - Detailed model of system operation

Assumptions

- No consideration of the grid structure and load flow issues in the All Island system
- Six portfolios investigated: determined using investment model (WS2A)
- 1000 MW transmission capacity to Great Britain
- Reduced representation of the power system in Great Britain:
  - Eight aggregated power plant classes
  - Wind power production time series equal to Irish wind power production time series shifted one hour in time
  - Usage interconnector determined day-ahead and not changed intra-day

Overview portfolios – Installed capacities of new plants



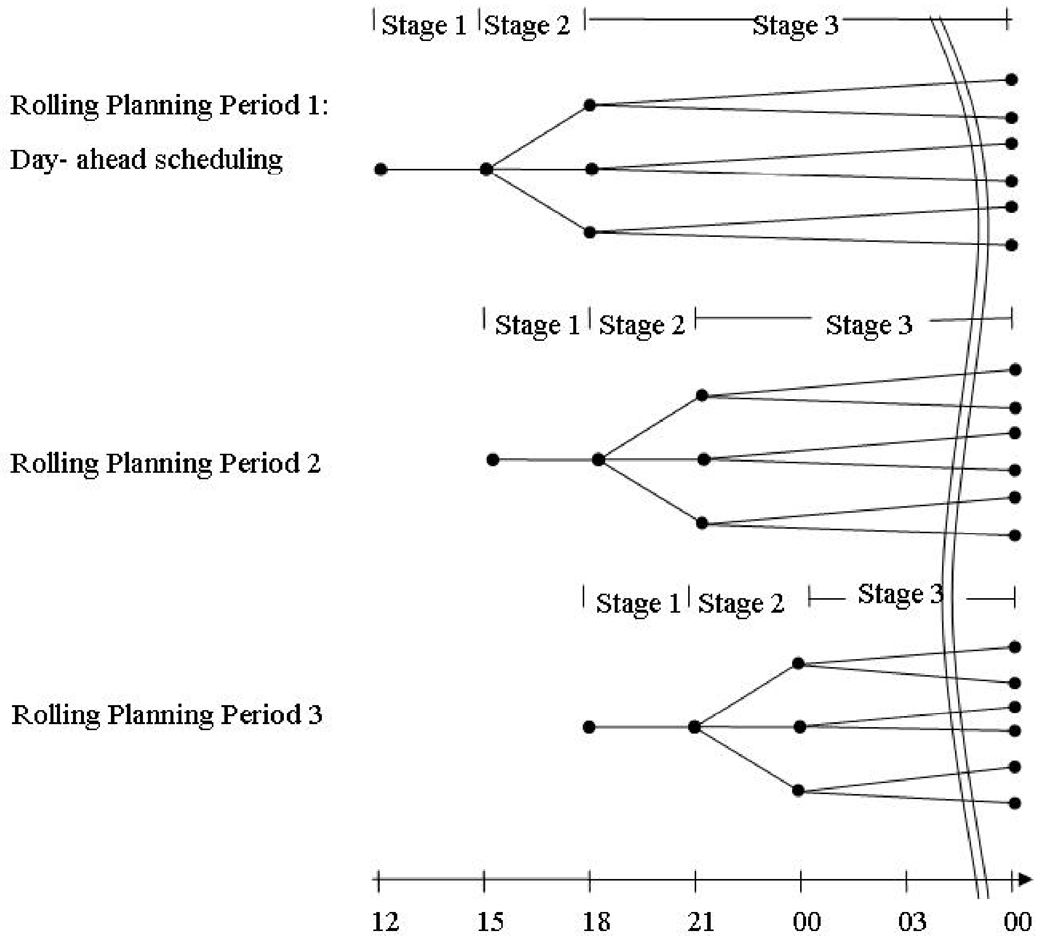
Scheduling model

- 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 5 minutes to 36 hours ahead)
  - Demand dependant on wind power and load forecasts

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

Rolling planning in scheduling model



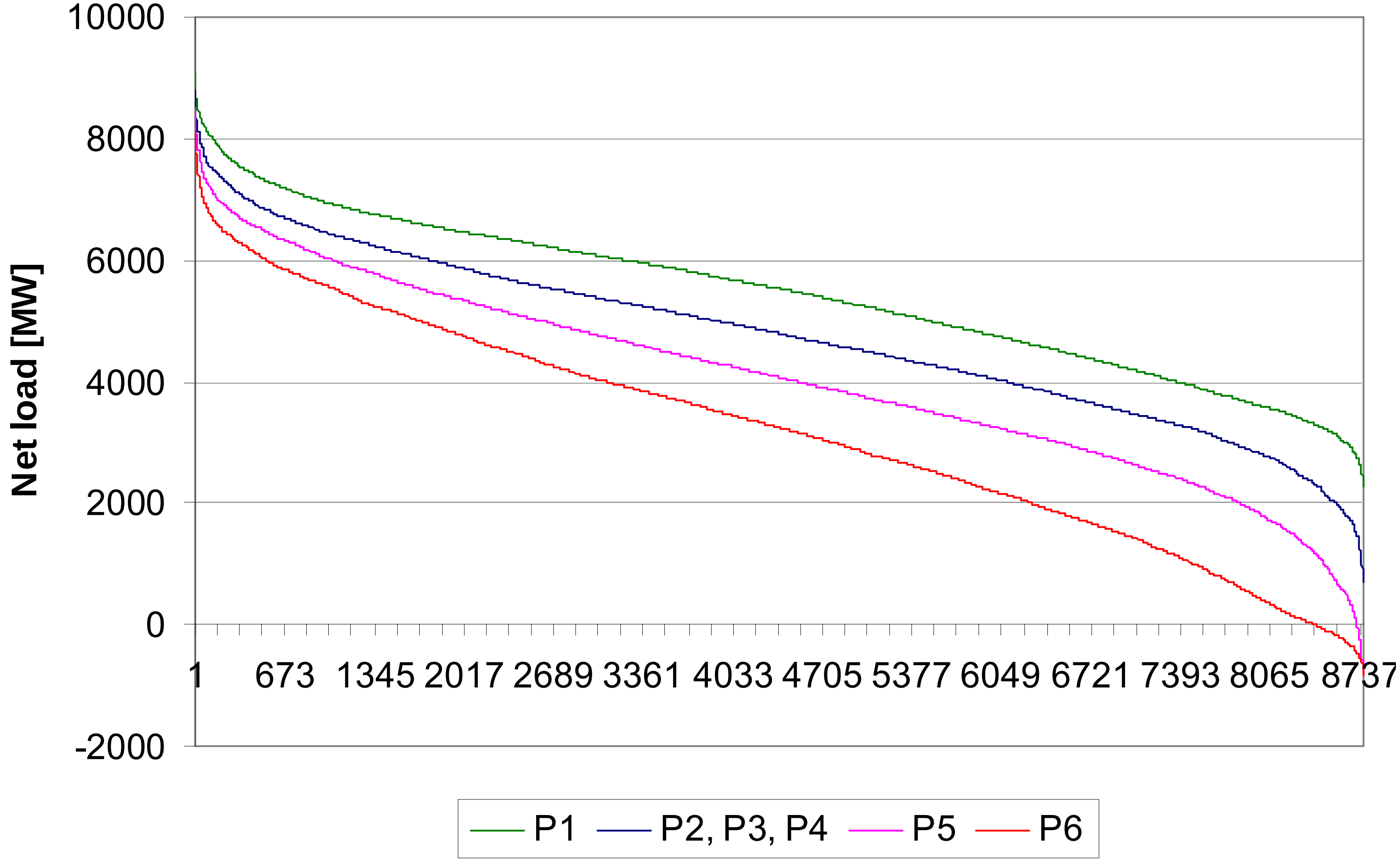
Scheduling model

- Output from SM:
  - In general: levels of each variable and marginals (shadow prices) of each equation.
  - Realised hourly unit commitment and dispatch of each unit
  - Realised distribution of each reserve power category on units
  - Hourly power exchange with Great Britain
  - Hourly emissions of CO_2 from each unit
  - Total system-wide operational costs: fuel, start-up, variable operation and maintenance, costs connected with consuming CO_2 emission permits

Scenario Tree Tool

- Probabilistic approach
- Generates scenario trees
- Generate time series for forced outages of power plants
- Estimate Loss of load expectation (LOLE) of generation portfolio
- On the basis of:
  - Historical hourly time series of wind power production (or wind speed) and electricity demand
  - Wind production forecast accuracies and load forecast accuracies for different forecast horizons
  - Forced outage rate and mean time to repair of power plants
  - Scenarios of installed wind power capacity and yearly electricity demands
  - Assumption about what quantile of total forecast error distribution to be covered by reserves

Net load – realised load minus realised wind power production



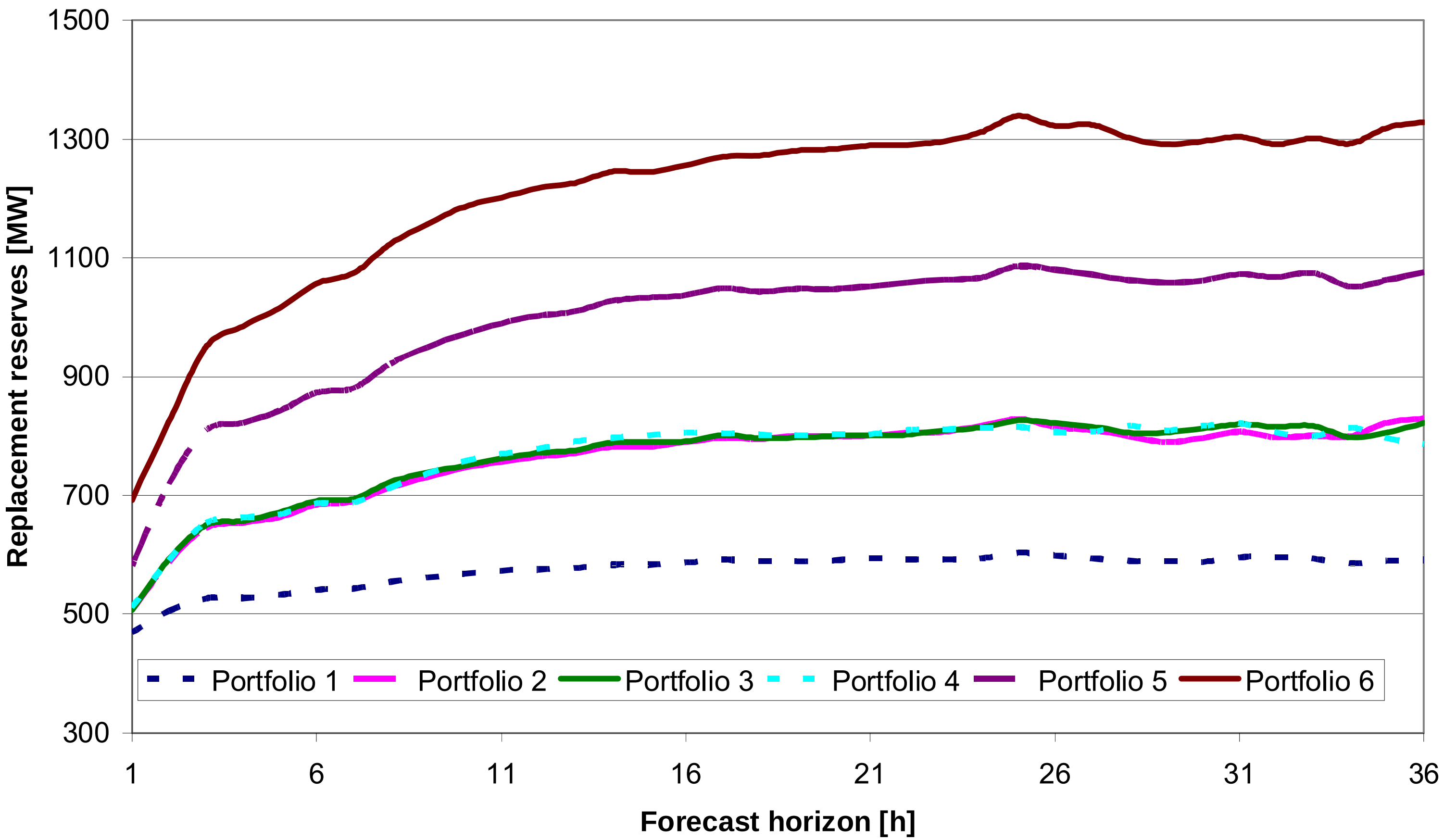
Negative net load: export to GB, pumped hydro, wind curtailment

Δ net load: change in net load from one hour to the next

	P1 [MW]	P2, P3, P4 [MW]	P5 [MW]	P6 [MW]
Maximum	1600	1822	2572	3732
Minimum	-1619	-2383	-3366	-4473
Positive Mean	338	361	392	412
Negative Mean	-289	-315	-346	-373
Standard deviation	417	447	489	529
90% percentile	538	572	610	647
10% percentile	-486	-518	-561	-602

Most hours: Δ net load below 1000 MW (at least in 8192 hours out of 8760 hours in portfolio P6)

Average demand replacement reserves



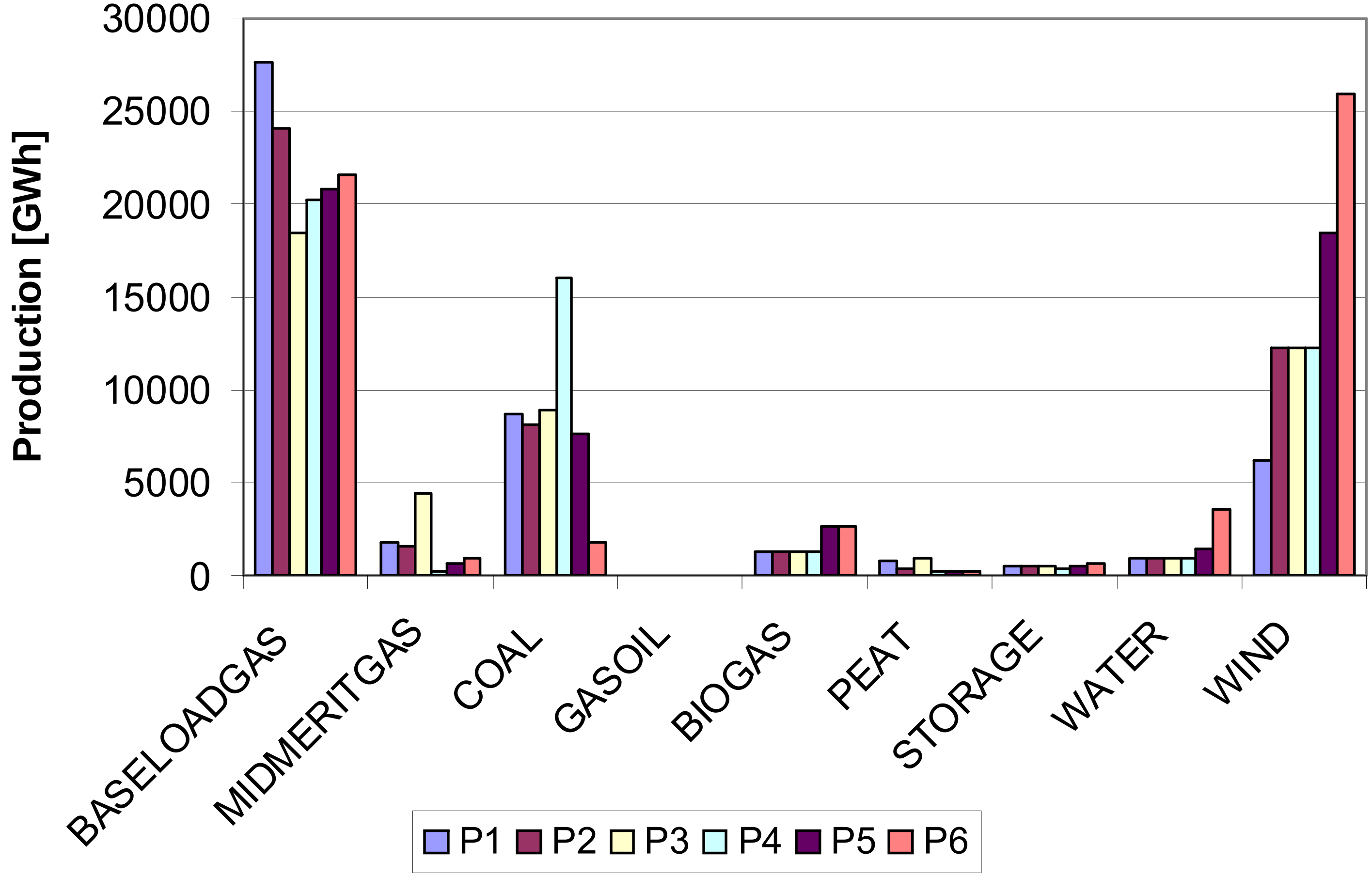
Provision of replacement reserves

- Replacement reserve:
  - Nearly 100% from offline units (OCGTs)
  - Supply often higher than demand -> costs of providing replacement reserve often zero

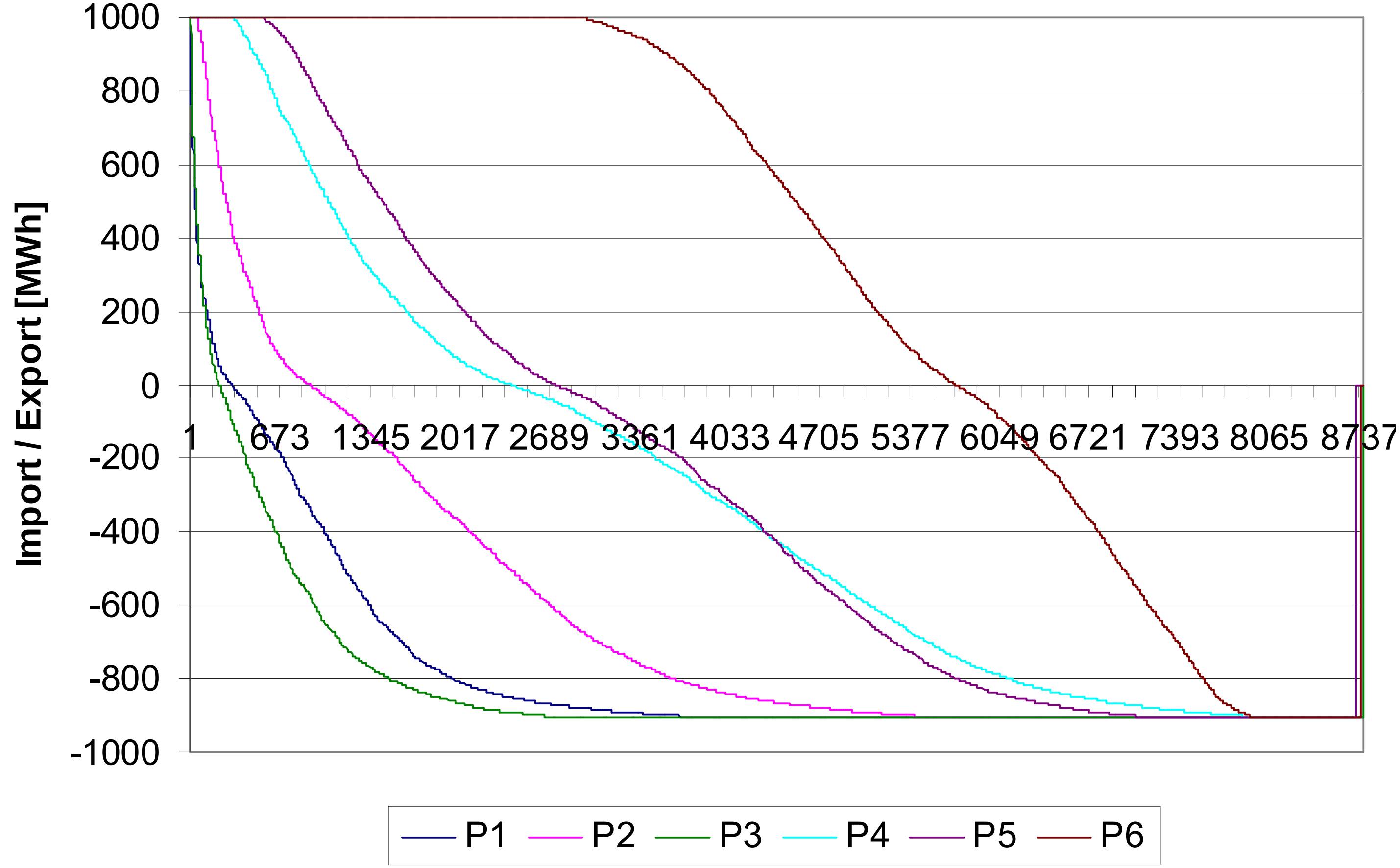
Provision of positive spinning reserve

- Pumped hydro storage (70 MW when pumping)
- Old coal units:
  - In P1-P5 due to high part-load efficiencies
  - Not in P6 due to high CO_2 price
- ADGTs: high part-load efficiencies, used especially in P3 due to lack of base load units
- Provision from wind power: increases with increased share of wind power (1322 hours in P6)

Yearly production distributed according to fuel type



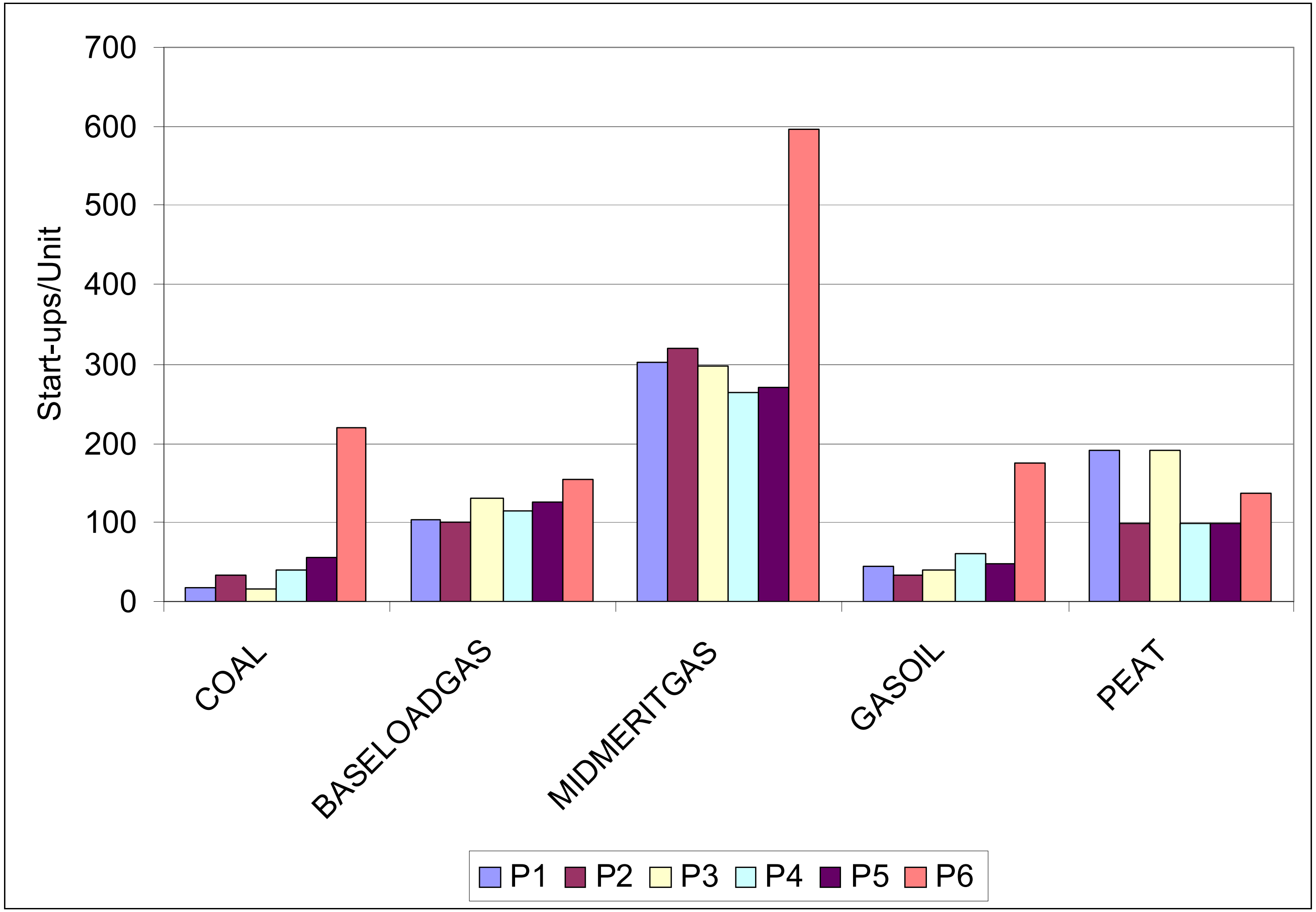
Duration curve power exchange with Great Britain



Dispatch thermal plants in P1 to P5

- Coal and new CCGTs:
  - Low number of start-ups (below 100 per year)
  - High capacity factors (0.6-0.9)
  - Start-ups increase and capacity factors decrease with increasing wind
- OCGTs: low capacity factors (0.1), around 300 start-ups per year

Average yearly number of start-ups per unit for each fuel type



Reliability

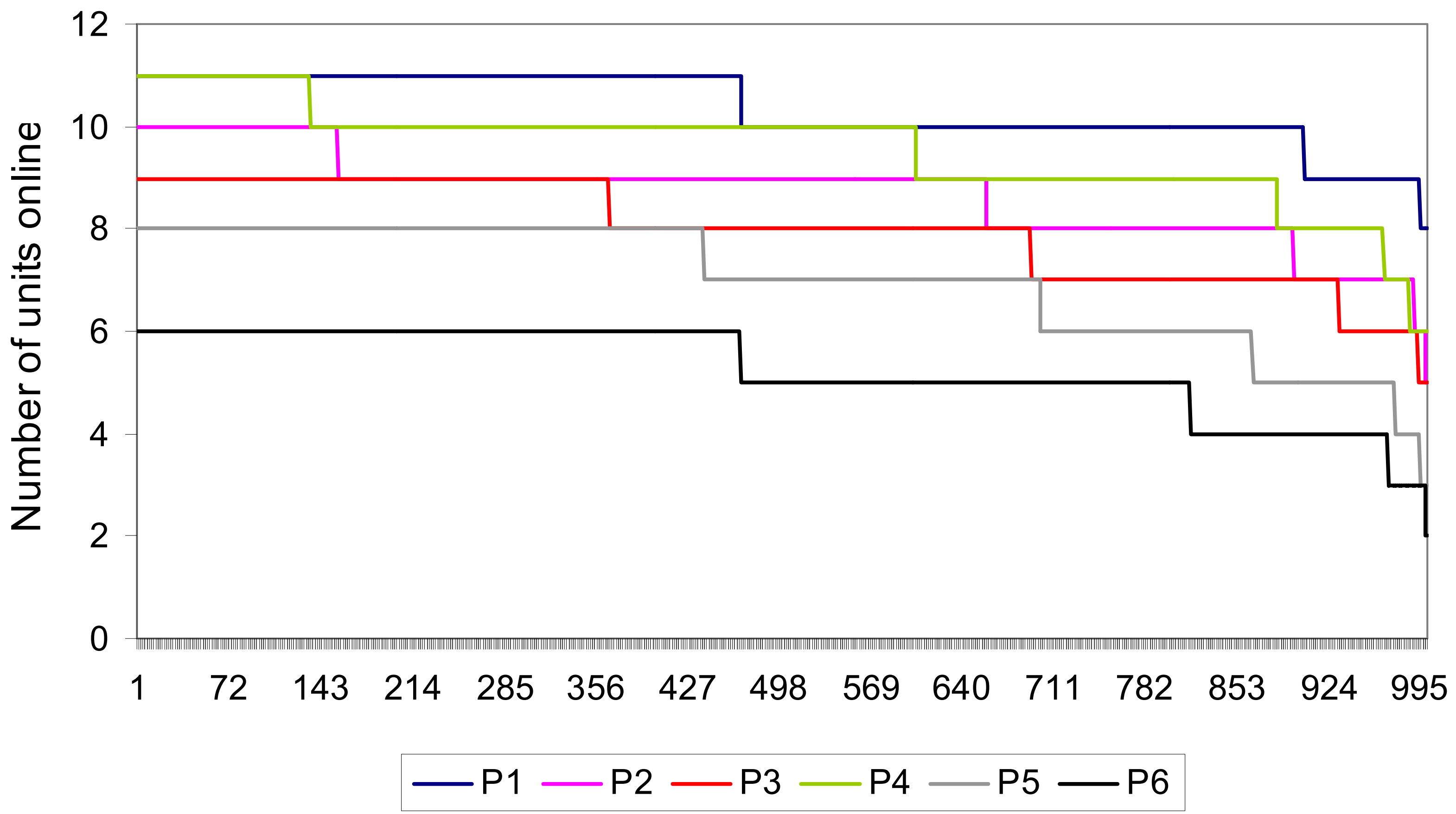
Portfolio	Hours where load is not met	Hours where demand spinning reserve is not met	Hours where demand for replacement reserve is not met due to lack of capacity
P1	0	4	96
P2	3	6	101
P3	0	1	98
P4	1	5	115
P5	0	3	88
P6	23	77	544

P6: reliability problems due to usage interconnector determined day-ahead

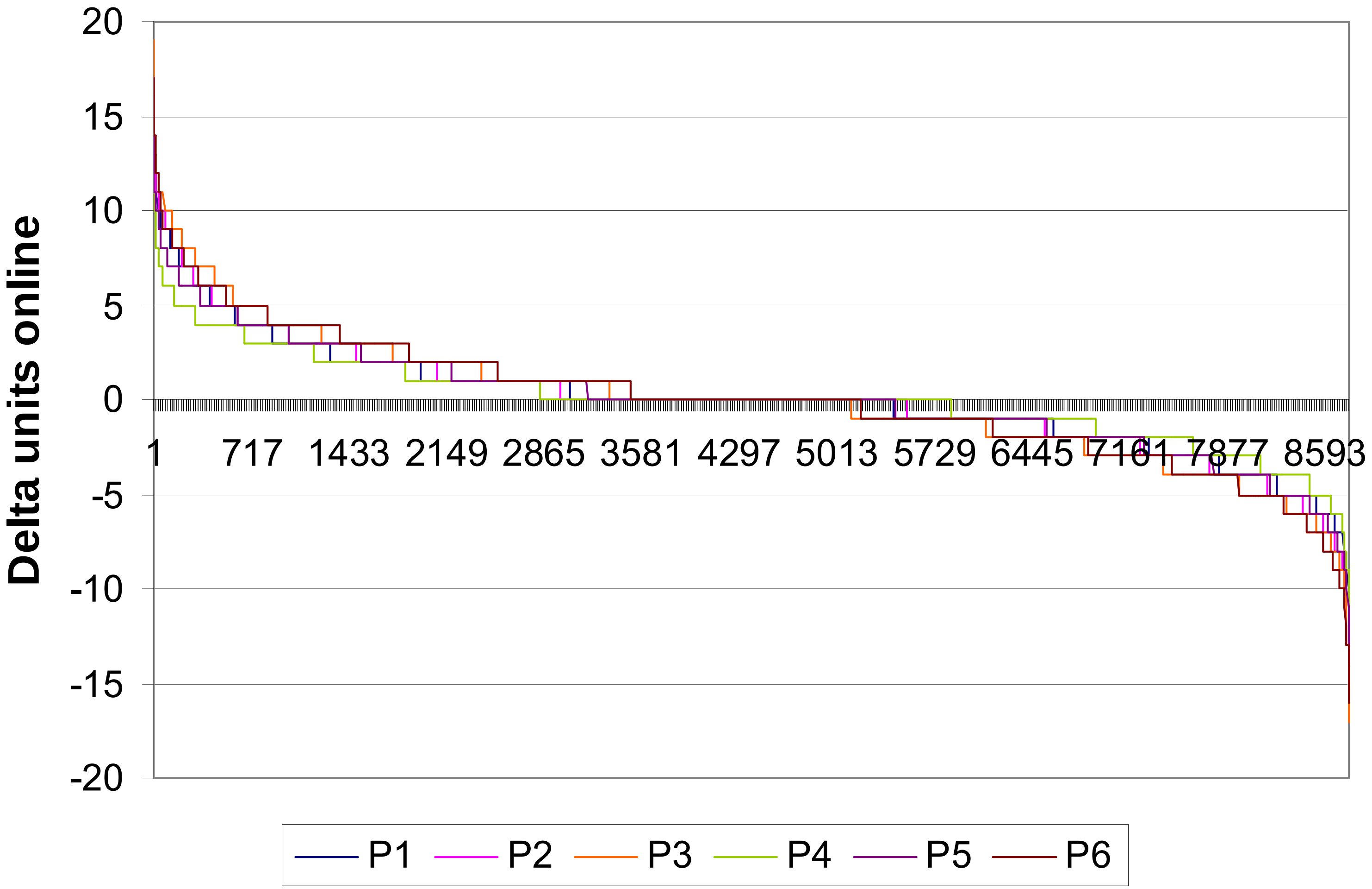
Wind curtailment

	P1	P2	P3	P4	P5	P6
Provision of spinning reserves [TWh]	0	0	0.01	0	0.07	0.10
Other reasons than provison of spinning reserve [TWh]	0	0	0	0	0.02	0.48
Total curtailment as percentage of wind power production	0	0	0	0	0.5	2.3

Number of units online in the 1000 hours with the lowest number of units online for each portfolio.



Units brought online/offline from one hour to the next



Value of improved wind power and load forecasts

	P1	P2	P3	P4	P5	P6
Absolute cost reductions due to perfect forecast [MEuro]	1.2	8.0	4.8	13.6	18.5	65.0
Relative cost reductions due to perfect forecast [%]	0.05	0.4	0.2	0.7	1.2	3.6

- Improved forecasts -> lower demand for reserves -> additional savings related to investments in peak load plants (not included in this study)
- P4 with may base load units has higher costs of partial predictability compared to P3 with many OCGTs

Conclusions

- *Model development:*
  - *Advanced methodology for reserve estimation dependant on forced outages, and uncertainties in wind power production and load forecast implemented*
  - *Wind power able to provide positive spinning reserve*
  - *Stochastic unit commitment and dispatch model using mixed integers*
  - *Rescheduling every third hour taking updated wind power and load forecasts and associated change in demand for reserves into account*

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Conclusions

- *Renewable power production:* From 16 % of yearly electricity demand in portfolio P1 to 59 % in portfolio P6.
- *Increased wind in system:* lower and more variable net load, increased demand for replacement reserves
- *Transmission Great Britain:* Net import decreases as wind increases
- *Conventional unit operation when wind increases:*
  - Only small problems with following variations in net load and provide reserves
  - More start-ups and reduced capacity factors as wind power increases
- *Wind curtailment:* Negligible in P1-P4 and amounts to 0.5 % in P5 and 2.3 % in P6 in terms of percentages of yearly wind power production.
  - Small number of units online in some hours in high wind portfolios: requirements on number of units online will increase wind curtailment

Conclusions

- *Reliability of the All Island power system:*
  - Portfolios rely on the production from wind power and import from Great Britain to cover peak load
  - Portfolio P3 shows the highest overall reliability
- *Impact of improved forecasting:*
  - Cost reductions due to perfect forecasts relatively small in comparison to the total system operation costs of the All Island power system.
  - Absolute sum of the cost reductions is not negligible.
  - Value of perfect forecast increases with increasing wind power capacity installed.
  - Value of perfect forecast higher in P4 (base load plants) compared to P3 (peak load plants)