

Operational Issues for Systems with Significant Wind Penetration

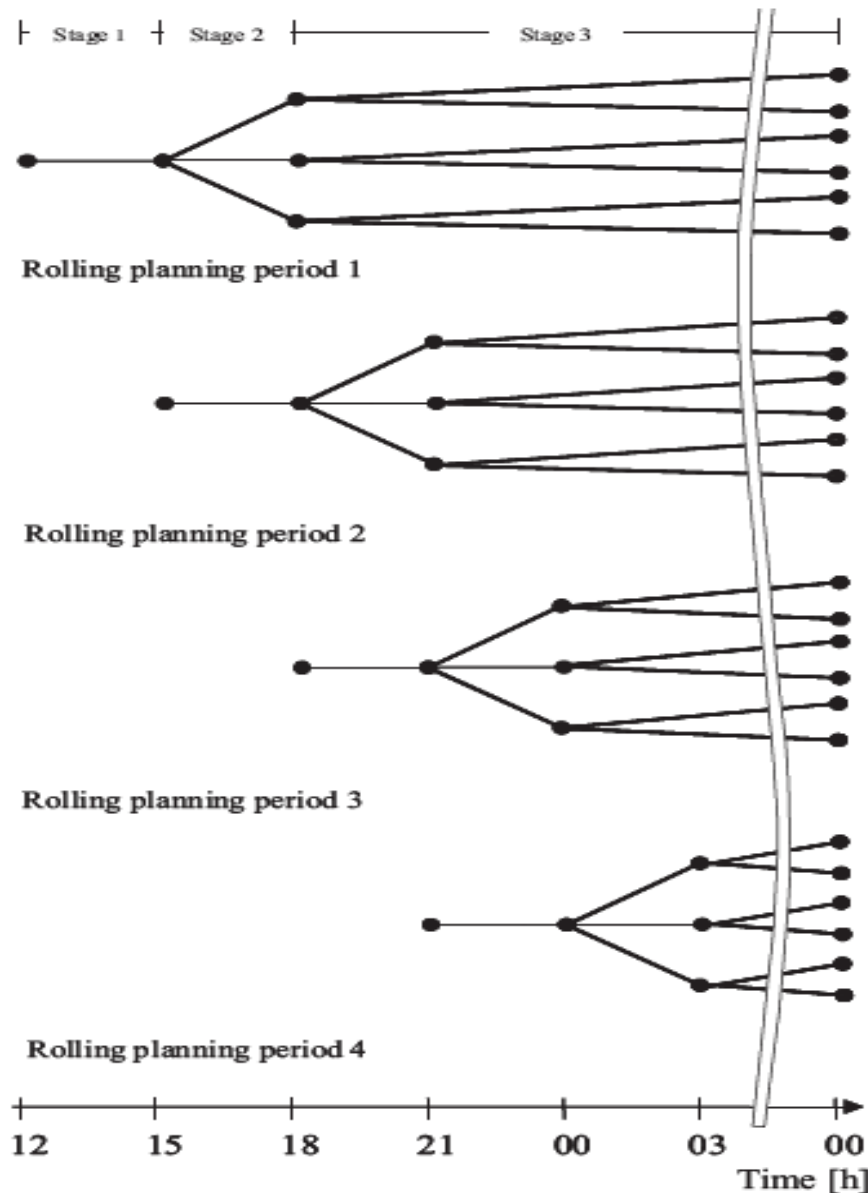
Stochastic Unit Commitment and Impact of Pumped Storage

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ERC Research Seminar, Jan 12 2009

- Introduction to stochastic unit commitment for Systems with large levels of wind power
- Examination of stochastic unit commitment
 - Stochastic versus deterministic scheduling
- Impact of pumped storage in systems with increasing wind penetration

- Schedule plant to meet forecasted demand at lowest cost
- Day ahead/hourly timeframe
- How does a significant amount of installed wind power change this?
 - Adds another stochastic element to problem
 - With small penetration of wind power, units backed off
 - Optimal to use wind forecasting when scheduling the system
- Solution: Stochastic Optimization (WILMAR)



- 2 main parts:
 - Scenario Tree Tool
 - Scheduling Model
- Uses rolling planning to minimise expected costs (fuel, carbon, startup) while meeting load under various constraints

(1) Examination of stochastic UC

- Motivation: Examine differences between stochastic, deterministic and perfect solutions, under operation, performance and cost, to show benefits of stochastic optimisation with large amounts of wind power
 - Stochastic: Wind and load unknown, optimised over multiple values
 - Deterministic: Wind is one time series, forecast incorrect
 - Perfect: Perfect forecast of wind assumed

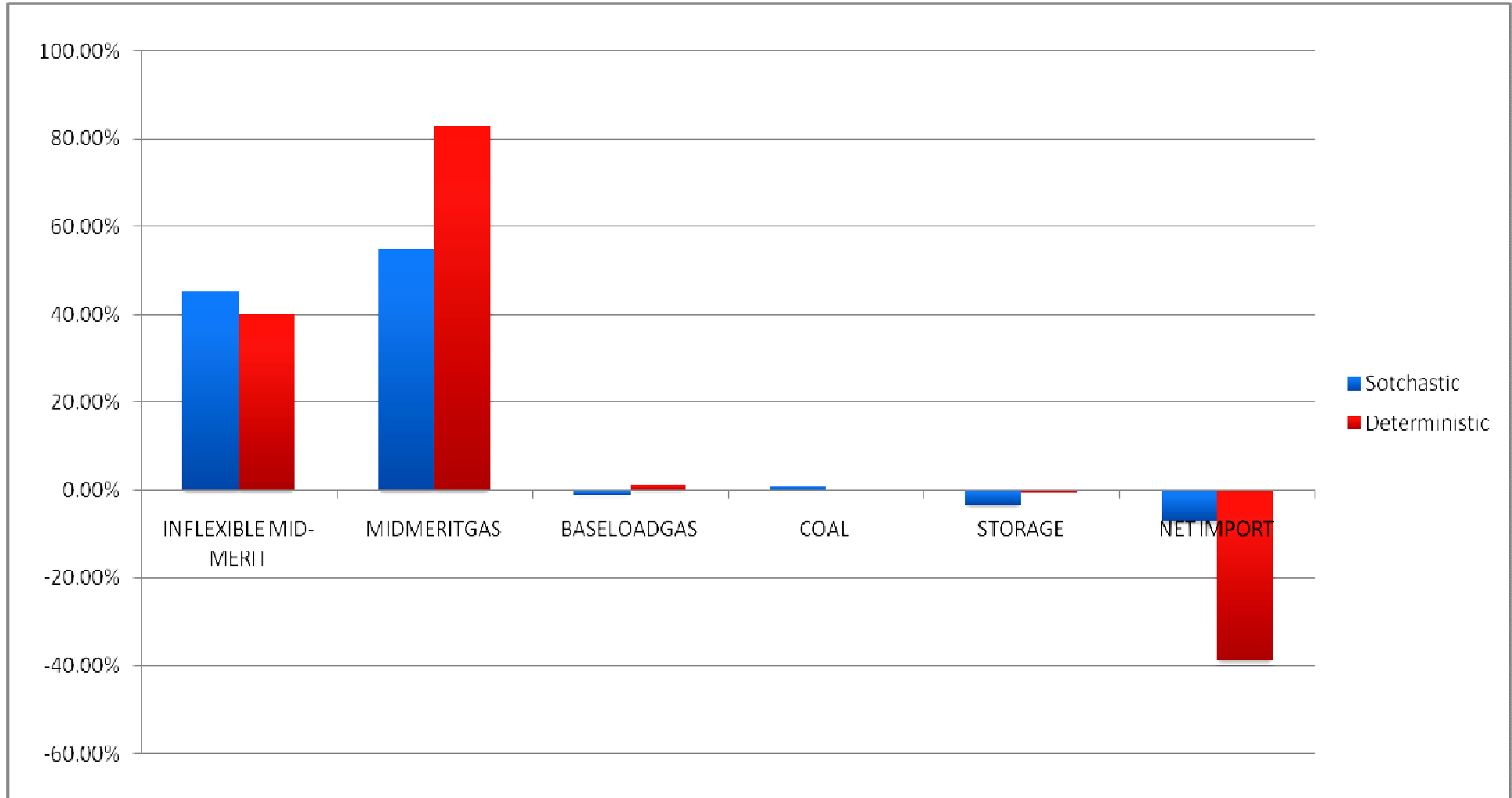
A. Tuohy, P. Meibom, E. Denny & M. O Malley, "Unit Commitment for Systems with Significant Wind Penetration", IEEE. Trans. Power Syst., accepted for publication

- Applied to possible Irish System in 2020
 - Portfolio (5) produced in Grid Study
 - 42% energy by RE (34% by wind)
- 9600 MW peak
- 3500 MW min
- Interconnection to Britain – 1000MW modelled day ahead only
- British units grouped together, deterministic

TYPES OF UNIT IN PLANT PORTFOLIO USED IN STUDY

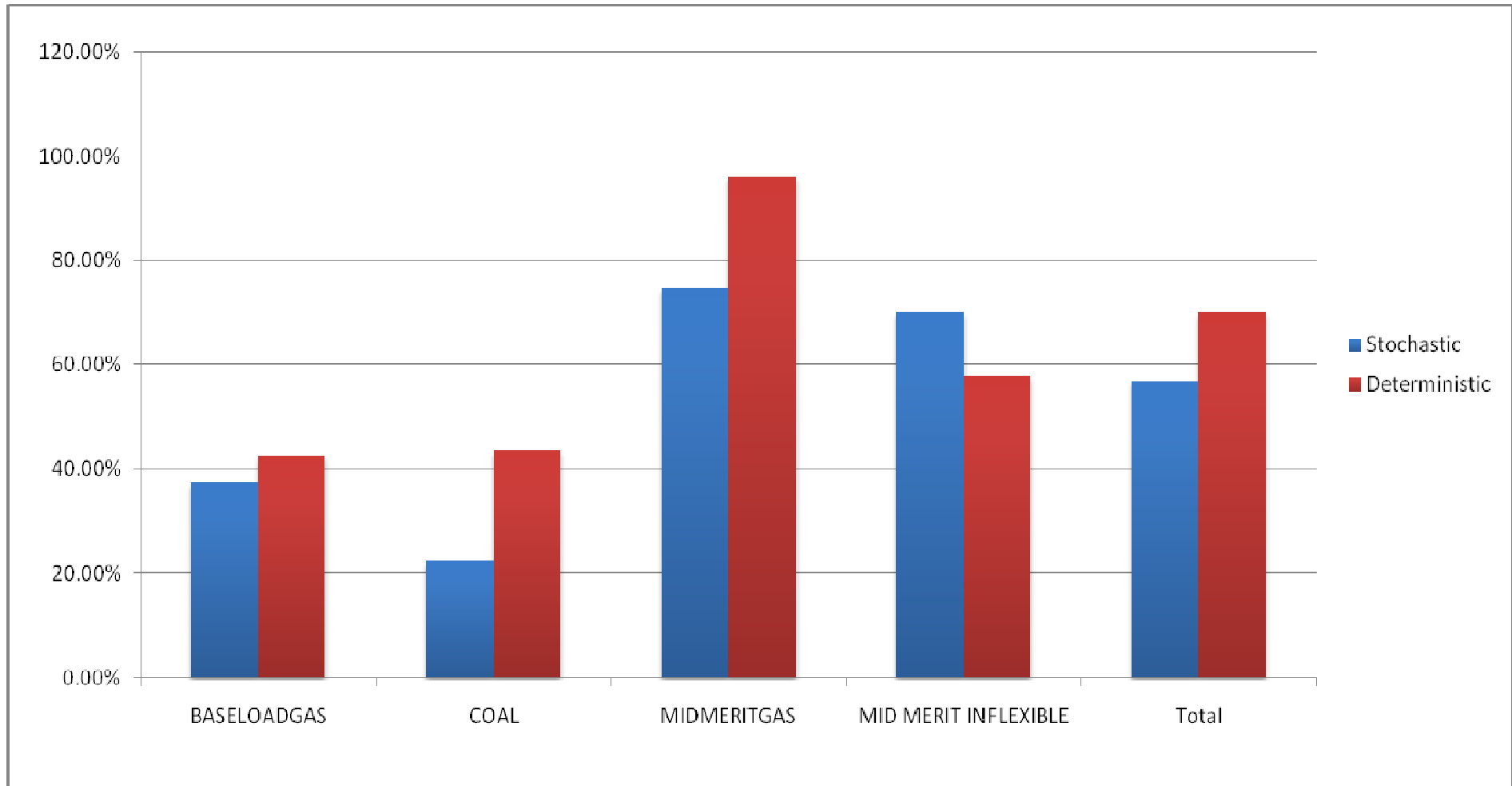
Type of unit	Number	Capacity (MW)	Fuel (€ / GJ)
Coal	5	1257	1.75
Mid-merit Gas	19	1646	6.46
Base-loaded Gas	12	4114	5.91
Inflexible Mid-Merit	3	345	3.71
Base RE	1	360	2.78
Hydro	1	216	-
Pumped Storage	4	292	-
Tidal	-	200	-
Wind Power	-	6000	-

Stochastic vs. deterministic optimization



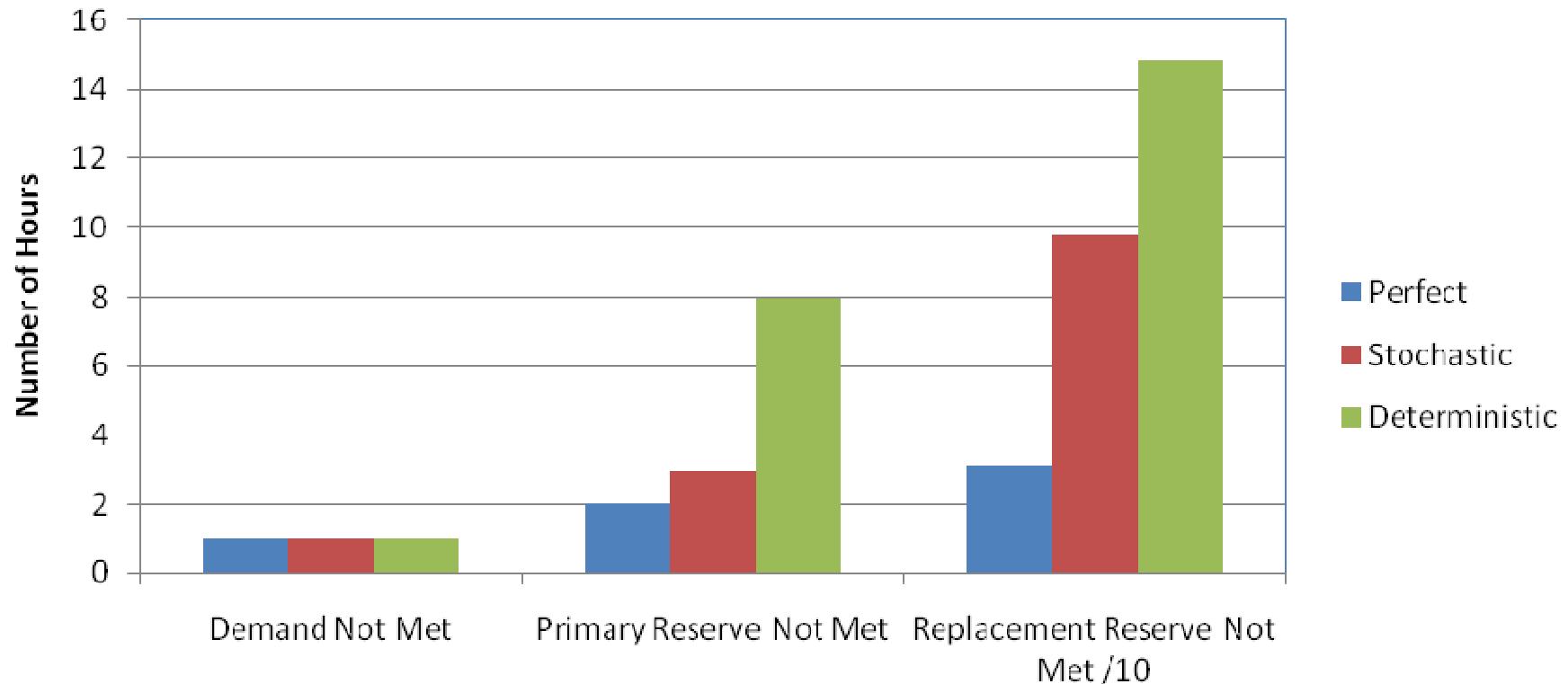
□ Unit Production – change versus perfect forecast

Stochastic vs. deterministic optimization (2)



□ Startups – change versus perfect forecast

Performance of Schedules



□ Not 'reliability', but indicates performance

Total system Costs

Method	Total Expected Cost (M€)	% Change compared to base*
Perfect	13431.33	0.00%
Stochastic	13453.95	1.53%
Deterministic	13457.53	1.77%

* - Base Case is cost of Irish system only in Perfect forecasting – used as British system has no stochastic element - €1477.26M

(2) Impact of pumped storage

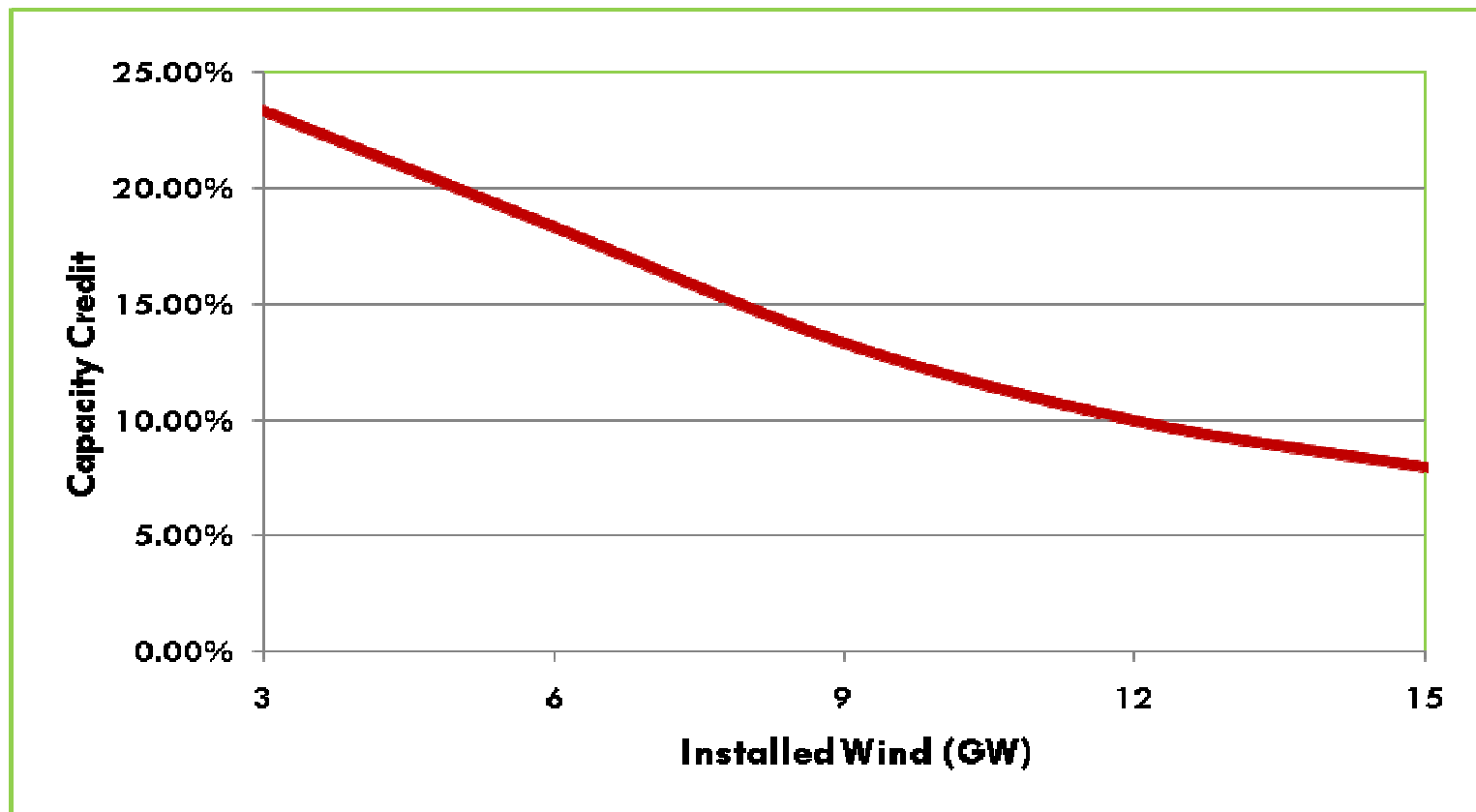
- Examine system with and without pumped storage (incl. Turlough Hill) for increasing levels of wind
- Storage used for system
- Savings need to be large enough to justify additional capital costs

Methodology Applied

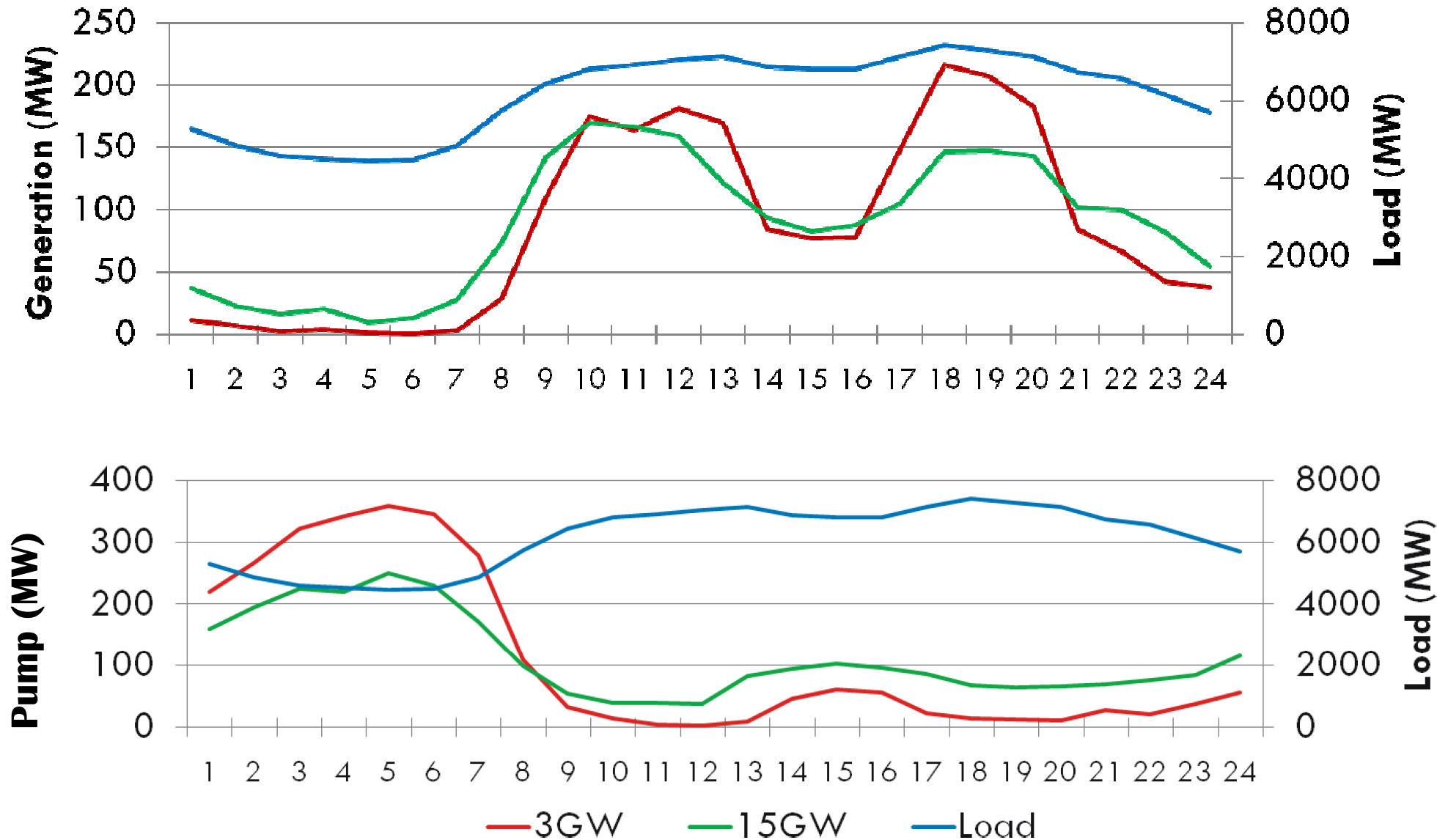
- Using Wilmar model – Portfolio 5 as base system
- Initially examine perfect forecast results
- 3GW – 15GW of wind installed in 2020
- 500MW unit (pump/generate) – 5000MWh store

Adding Wind

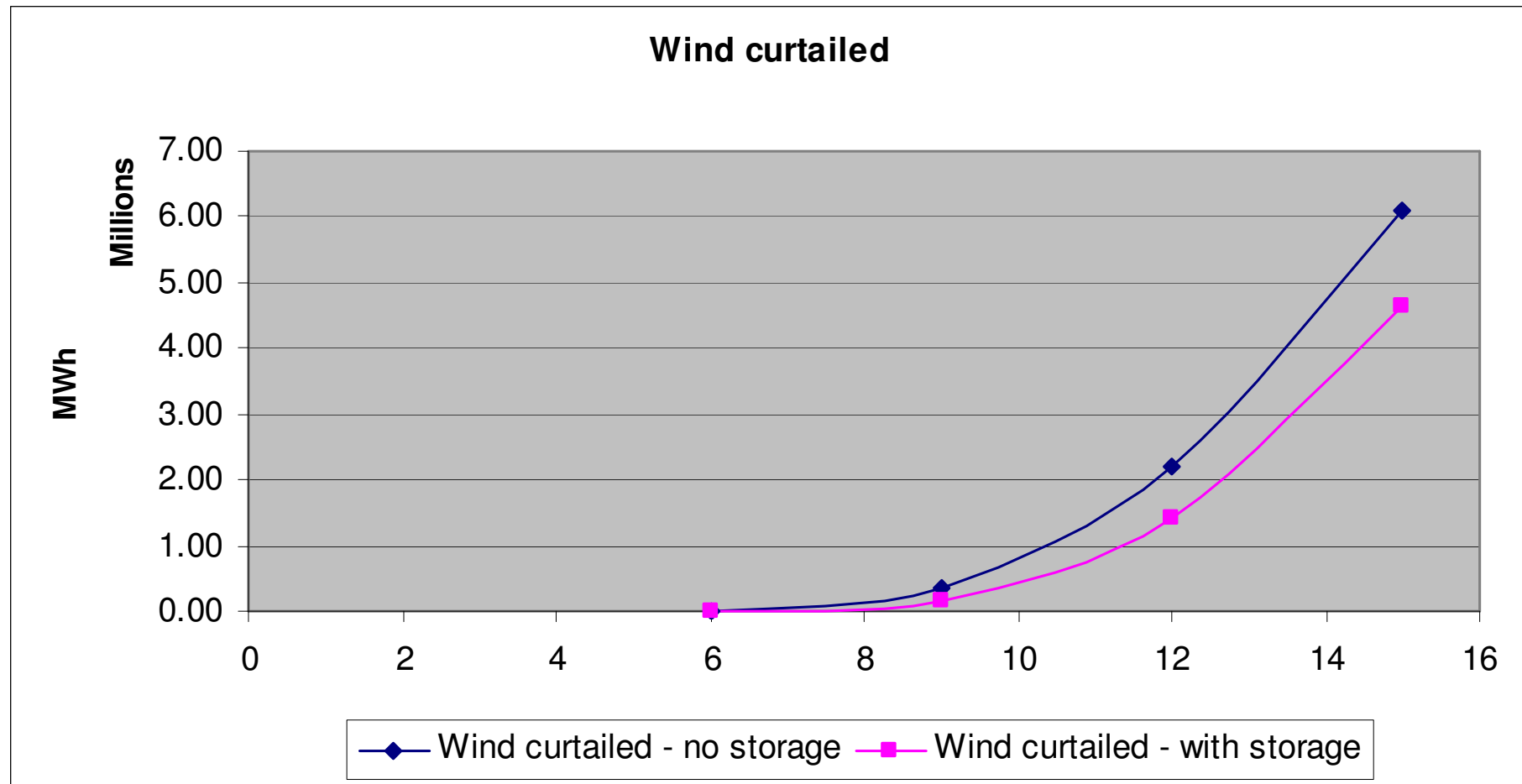
- Units removed – system rerun and hours load and reserve checked to ensure reliability



Results – Operation of Storage

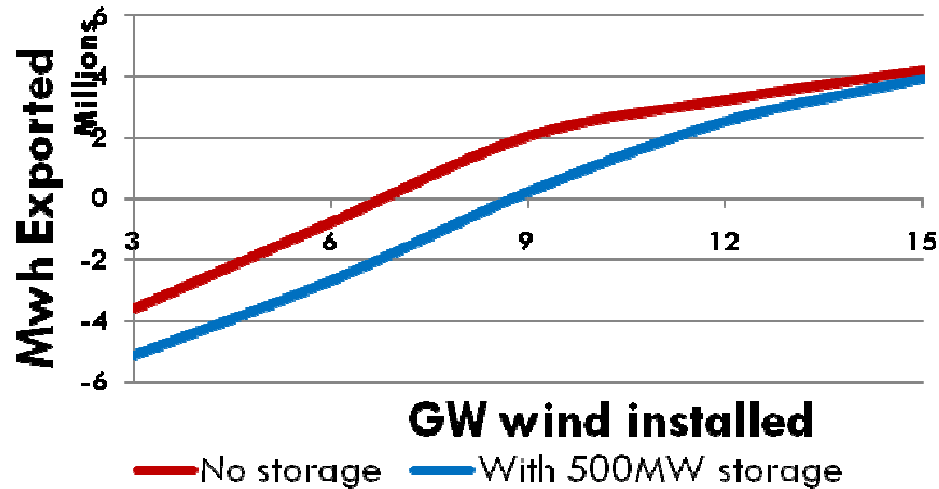


Results – Wind Curtailment



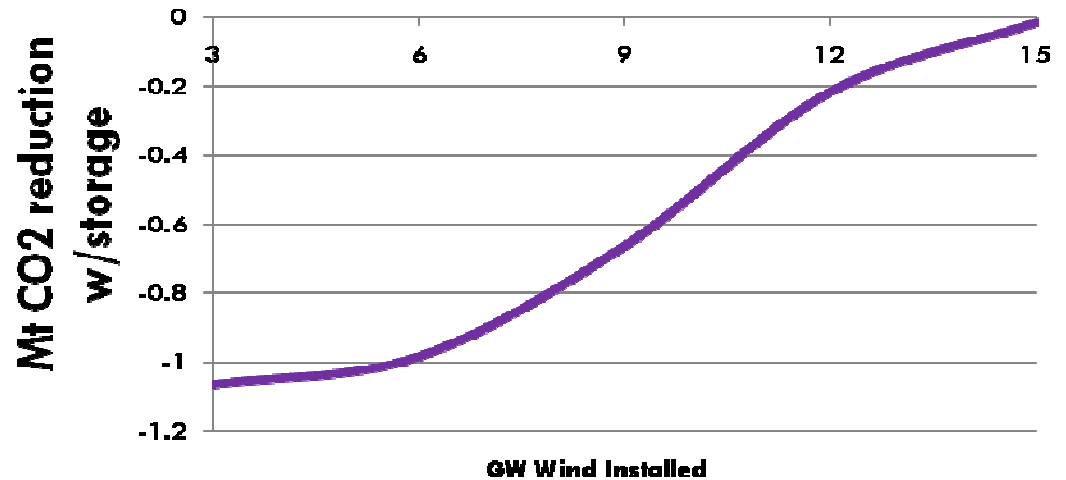
- Now, to meet 60% of energy, only 11.25GW wind, as opposed to 11.65GW is needed

Results – System Operation



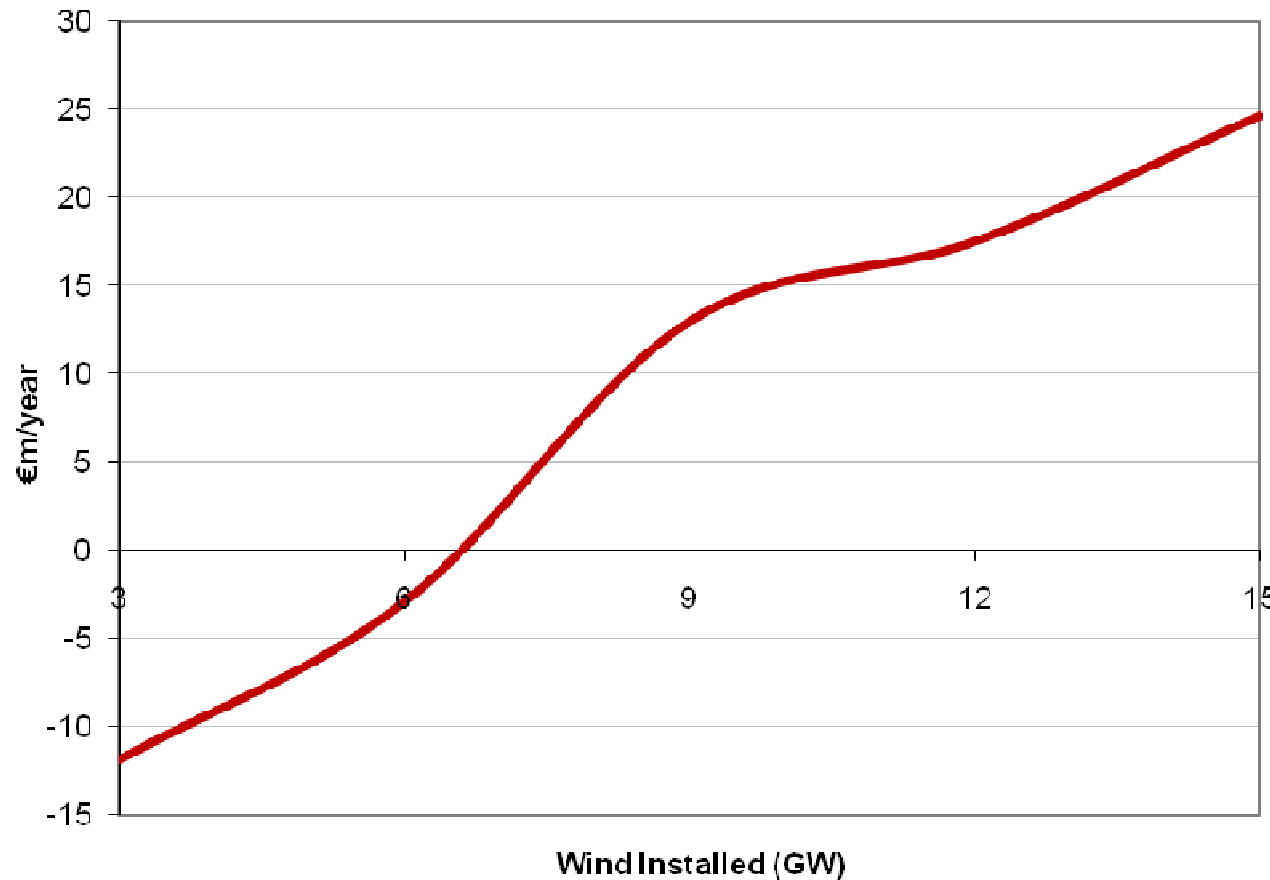
Net export through interconnection reduced with storage

CO₂ saving – actually increases CO₂ (GB & IRL)



Results - Costs

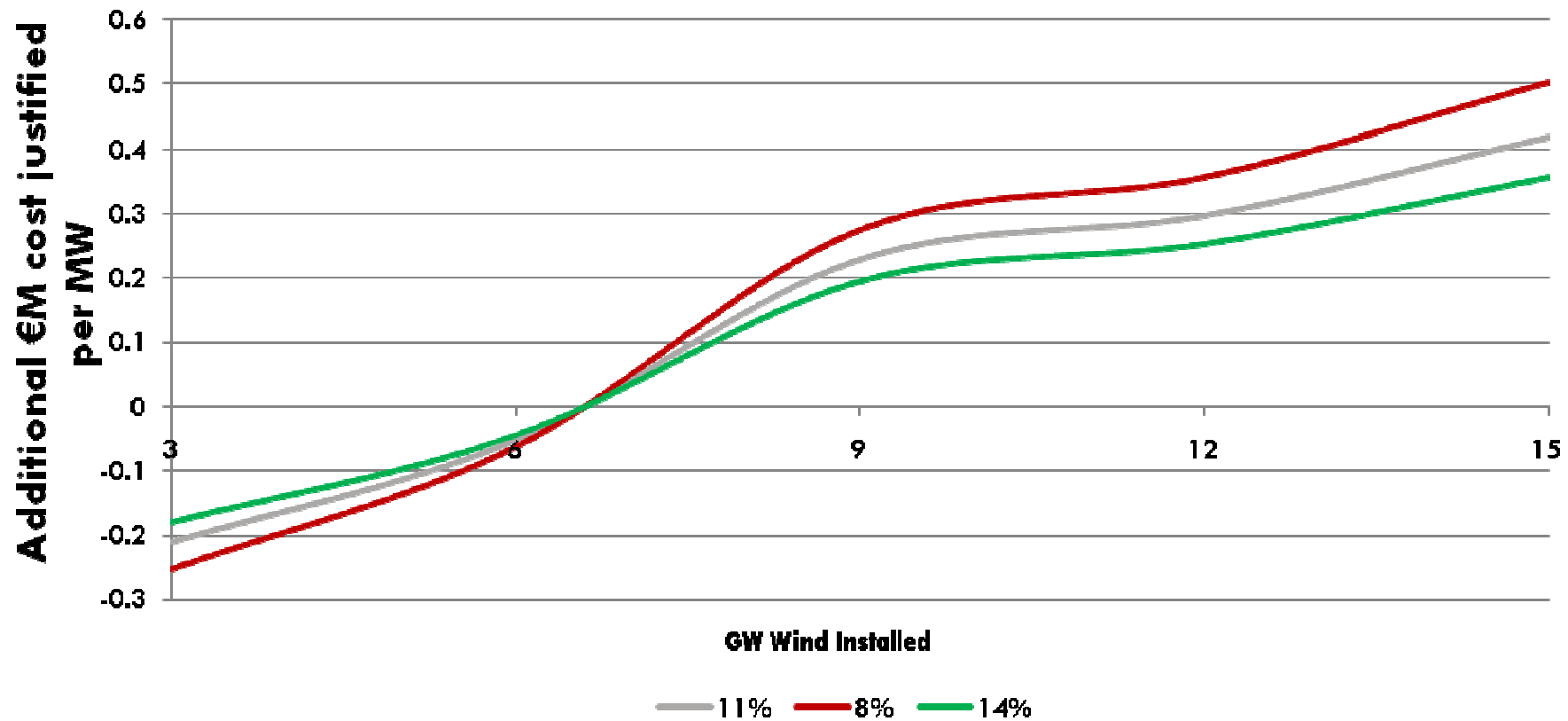
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- Storage causes increase in costs below very high levels of wind power
- May begin to saturate at higher levels – steepest climb between 6-9GW

Total system costs reduce as wind increases

Results - Economics

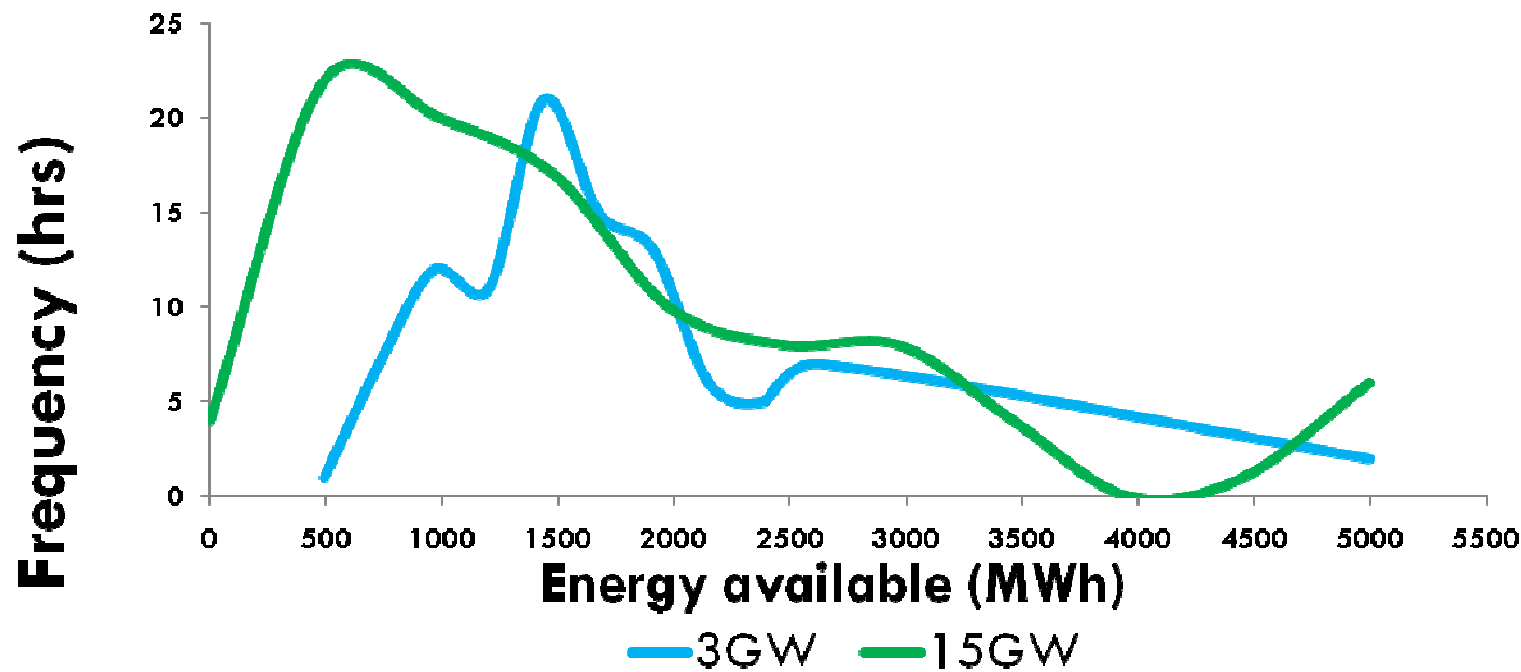


- 20 Years lifetime
- Actual additional cost may be much higher (€750 000 /MW)

'Capacity Credit' of Storage

- Capacity Credit calculations can be based on Equivalent Load Carrying Capability (ELCC)
- Storage: Energy Limited – May not be able to use ELCC directly
- Concept: Treat storage as conventional unit with energy limit –
 - Not exactly capacity credit – but shows operational issue impacting planning timeframe

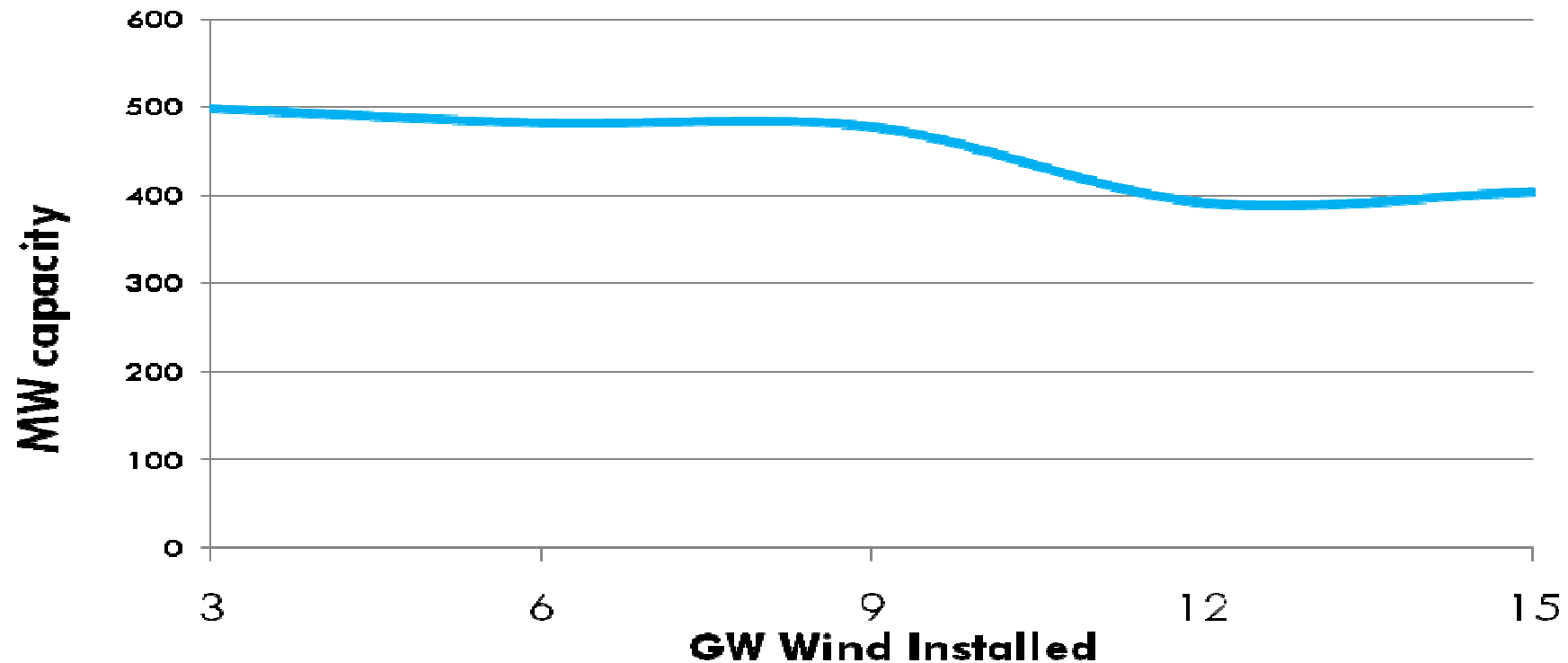
Initial Results



- As wind increases, chance of enough energy being in store at beginning of peak hour decreases
- This implies lower contribution to system reliability

Capacity Credit of Storage

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- Step change around 9-10GW
- This would then need to be put through usual ELCC calculations, with FOR etc

- 500MW storage pumped storage does not look like a good option when replacing conventional units
- Not needed when system examined on hourly resolution
 - Useful for reducing curtailment
 - May be useful in shorter timescales for other reasons
- Capacity Credit may decrease – more work needed using more sophisticated method

- Stochastic Unit Commitment when dealing with large amounts of wind
 - Less expensive/better performance than deterministic
- Pumped storage:
 - Reduces curtailment – only starts becoming a significant issue at very high wind penetrations
 - Cost savings do not seem to justify storage
 - Has a capacity credit – will be affected by level of variable, uncertain wind