

Pumped storage in systems with very high wind penetration

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Overview

- Introduction
 - Why storage is considered beneficial
- Test System/Model Used
- Results
 - When, if ever does pumped storage become a good option on a thermal/wind system?
 - Examination of system operation with and without storage
 - Examination of cost effects

Pumped Storage with wind

- Wind is inherently variable and uncertain
- Storage seen as good option – ‘make wind dispatchable’
 - Wind stored when blowing to be used when needed
- However, pumped storage has high capital costs, needs specific geology, and has associated efficiency losses
- Examine system with and without pumped storage (including removing already existing) for increasing wind
- Storage used for system to reduce costs during the day
 - Not for profit, but to benefit system
 - Economic reasons – not specifically to help wind or maintain reliability
 - Savings need to be large enough to justify additional capital costs

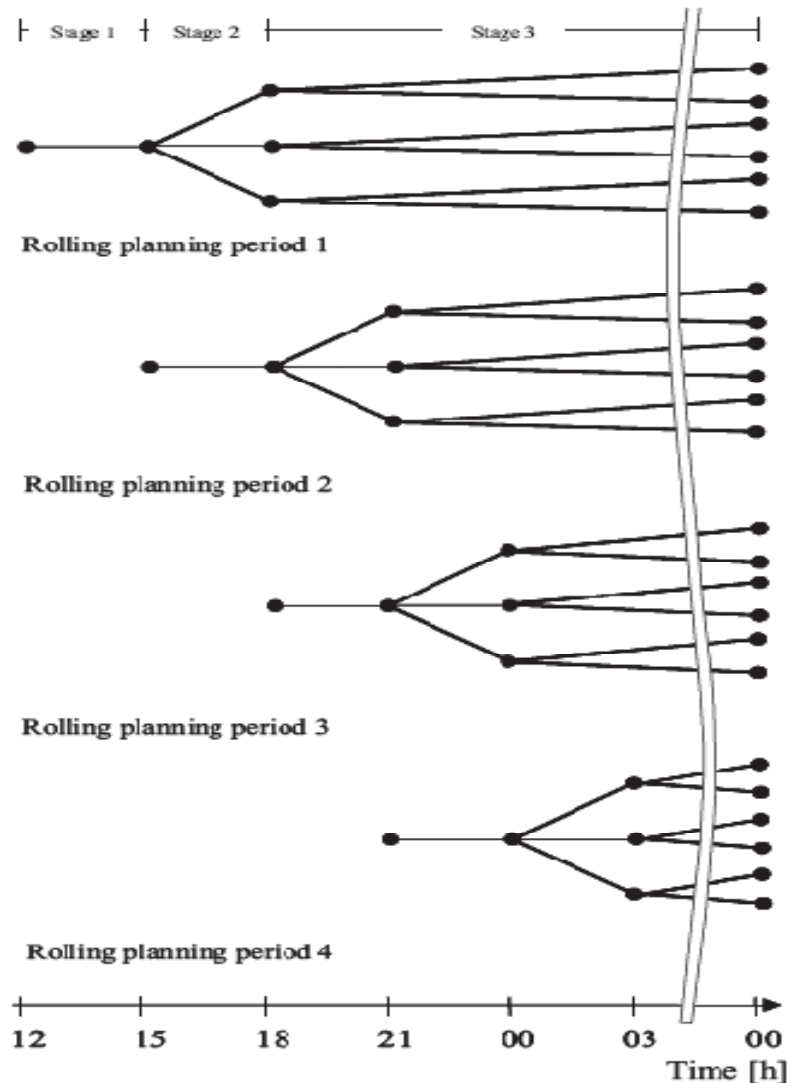
Pumped Storage today

- Approx 100GW installed worldwide
 - Mainly in places with good natural geology
 - Much of the available sites would have been used
- Storage, in many systems, would be too expensive
- Maybe with wind (or other variable RES), storage becomes attractive again
- Flexible plant, quick to react and can store excess wind to use when needed
 - One of flexibility measures available
 - Also Demand Side Resources, Interconnection, flexible plant

Model Used

- Wilmar Planning Tool
 - Originally used to study Nordic system
 - Adapted for All Island 2020 Grid Study
 - Main functionality is in Scenario Tree Tool (STT) and Scheduling Model (SM)
 - Outputs taken from STT used as inputs to SM
 - Scenario trees, other inputs and outputs - Access databases
 - GAMS language used for scheduling model (Cplex solver)

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 (min up time, start up time etc)

Test system

- Applied to possible Irish System in 2020
 - Portfolio (5) produced in Grid Study as base

□ 9.6 GW peak / 3.5 GW min

□ Interconnection to Britain – 1000MW

□ British units grouped together, deterministic

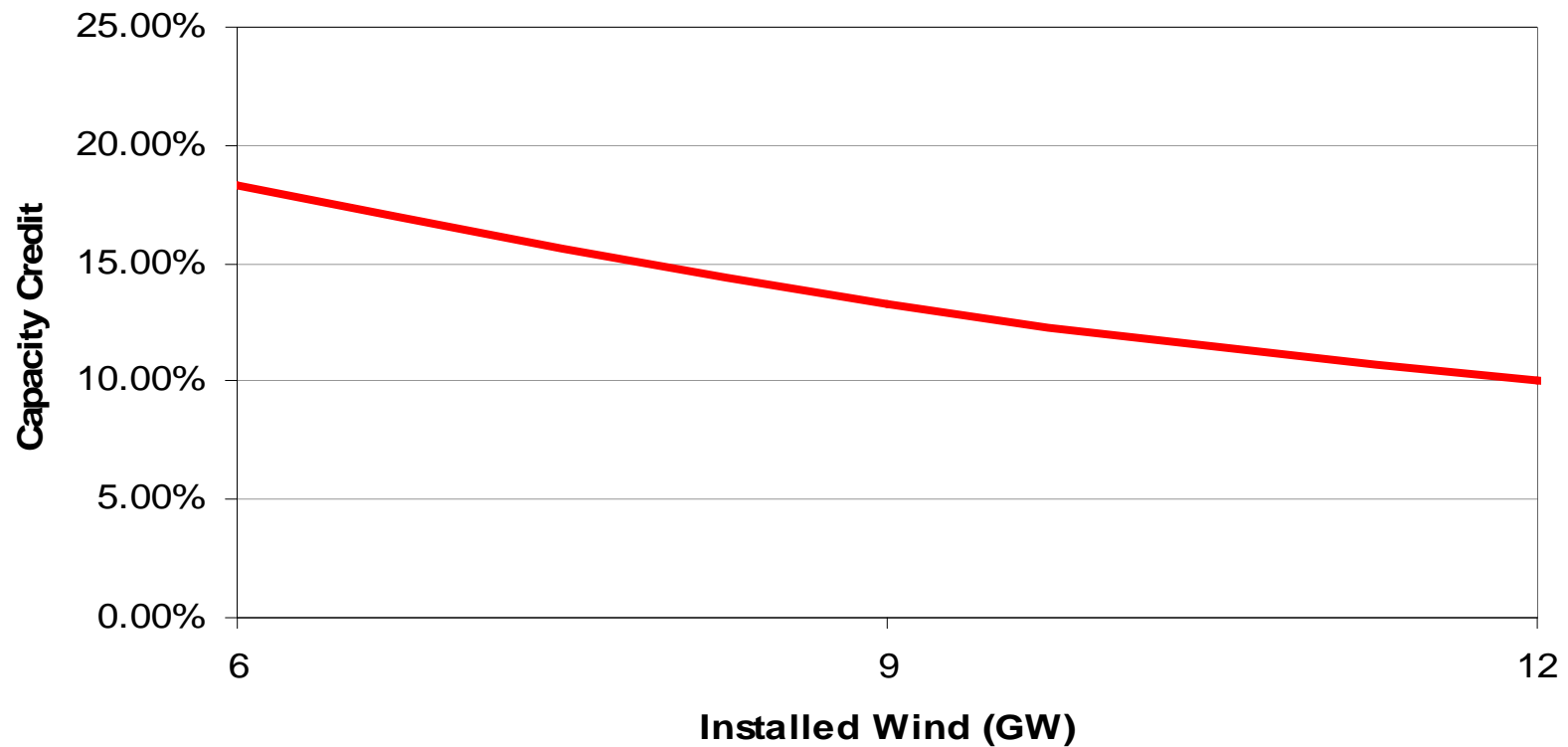
□ Annual run, with outages etc modelled

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	-

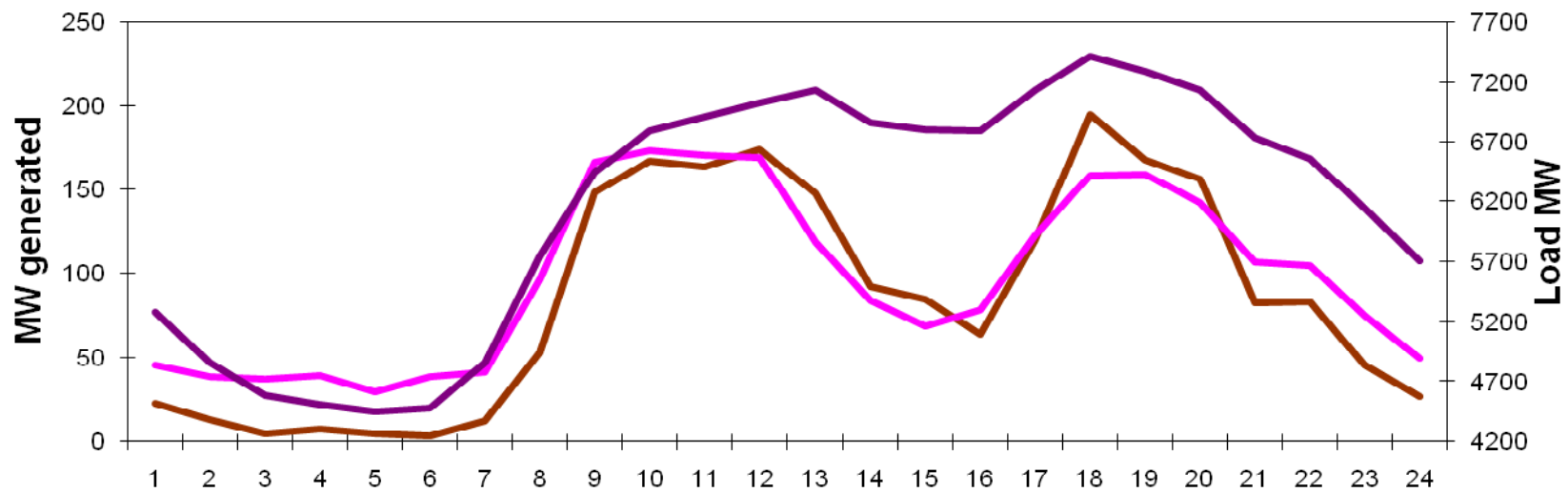
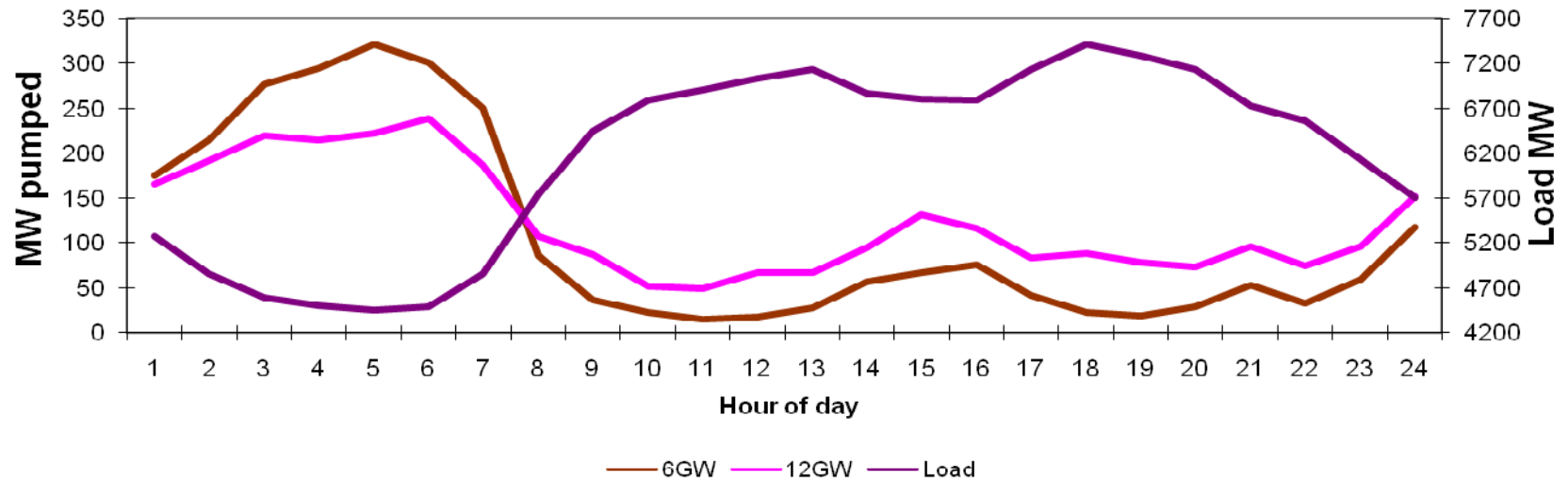
- Run for 6, 9, 12 GW (34%, 51%, 68% of energy) wind installed
- 500MW / 10 hr storage replaces conventional plant

Adding wind to system

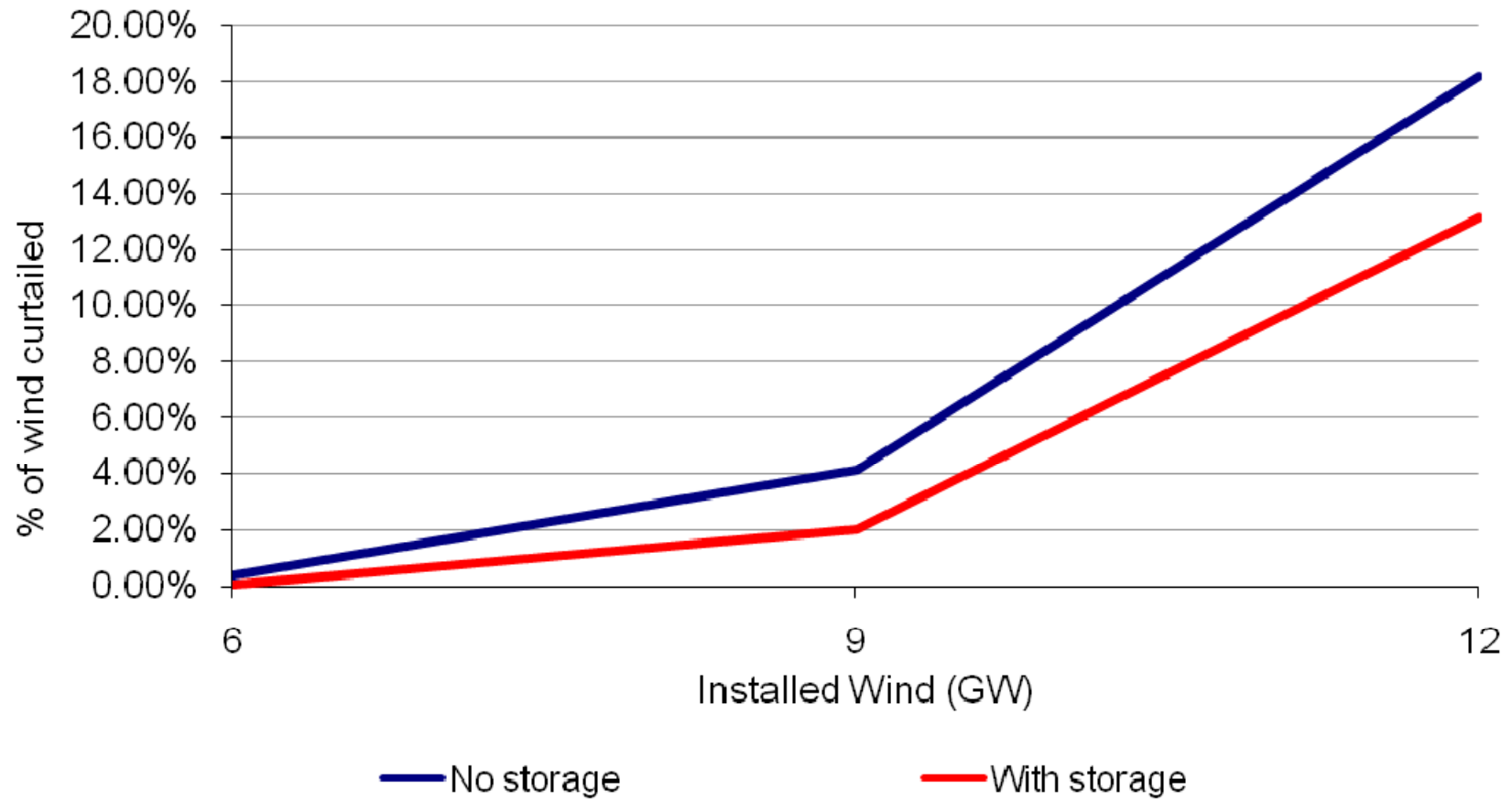


- Remove units to ensure reliability remains approximately the same

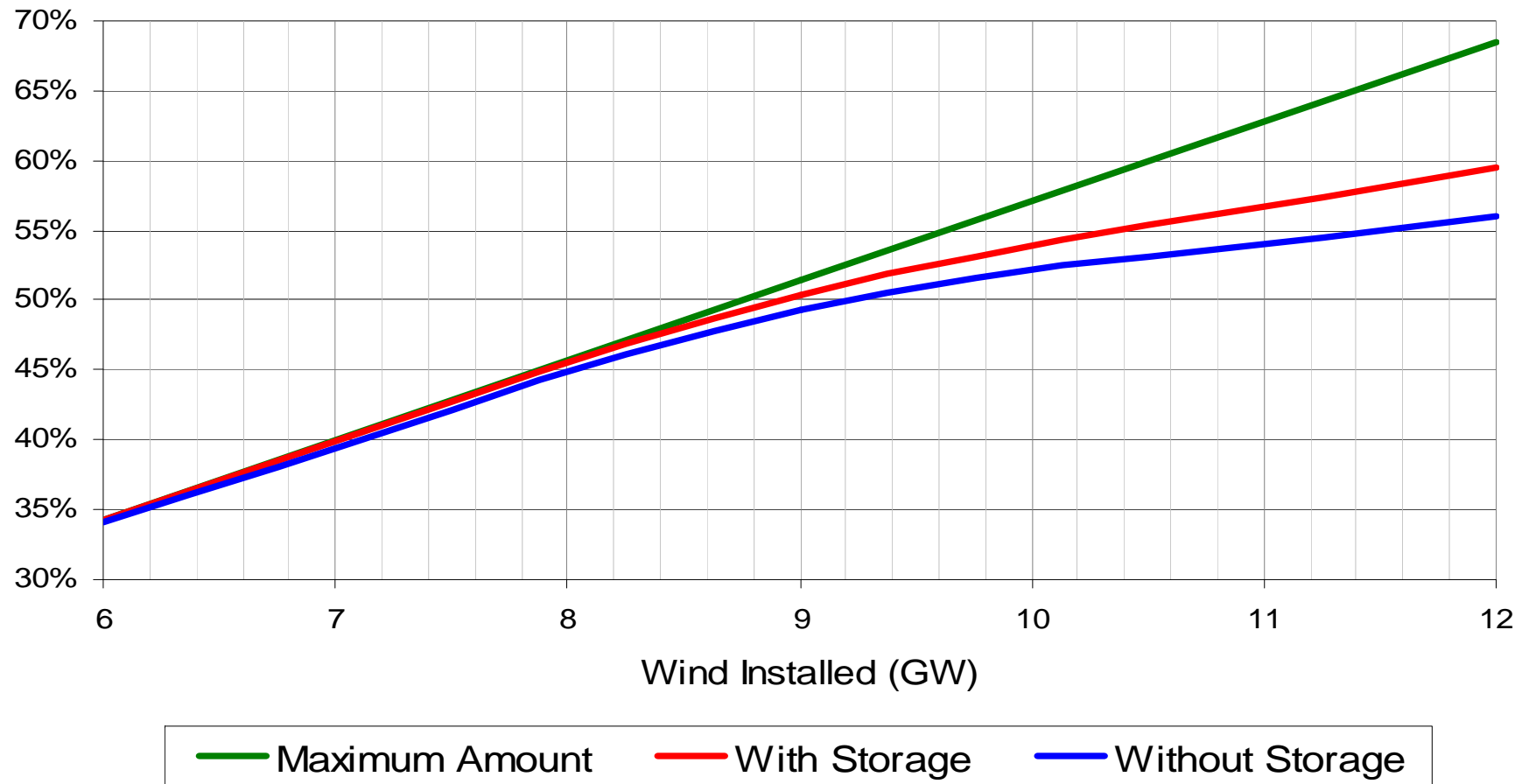
Operation of Storage



Curtailment

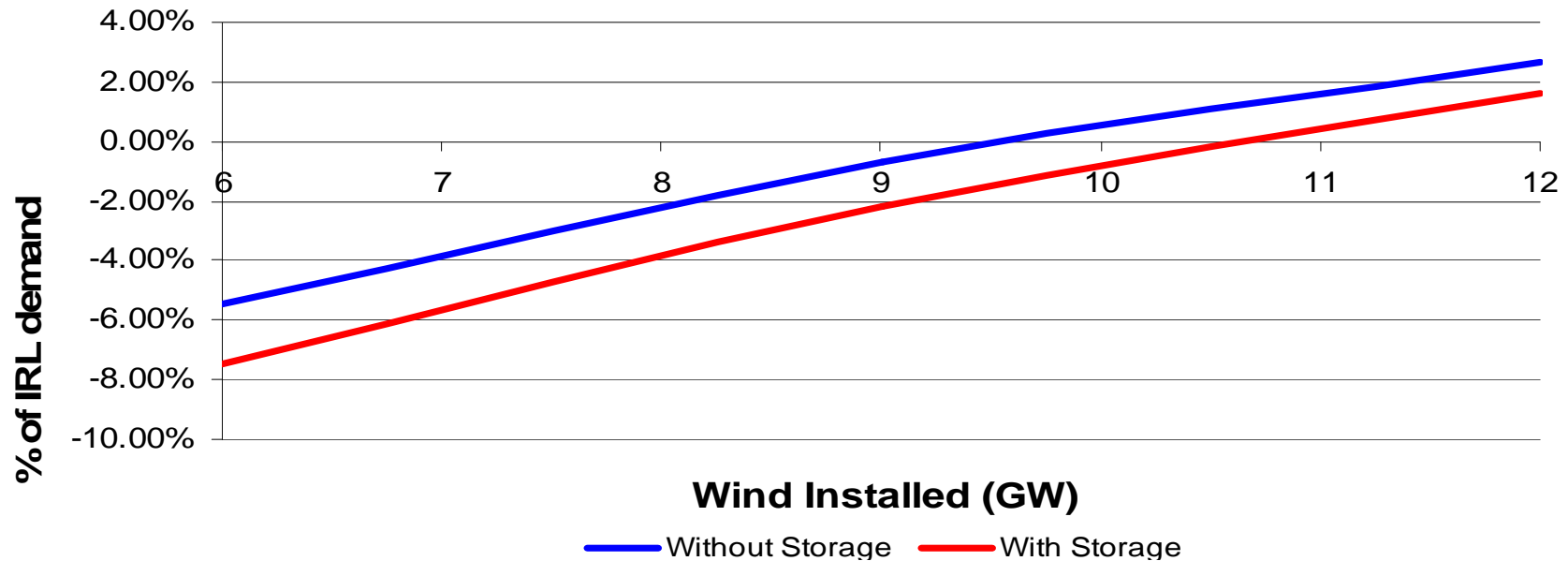


Penetration Level achieved



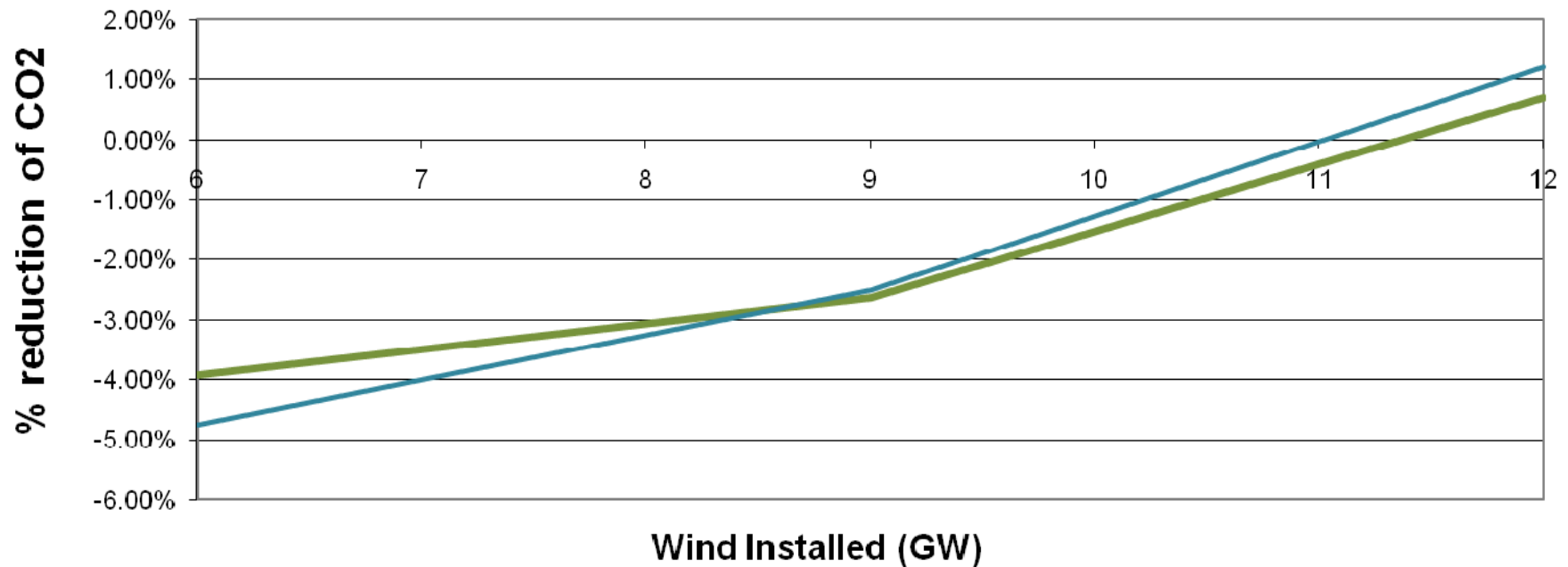
Operation of interconnection

Change in net export



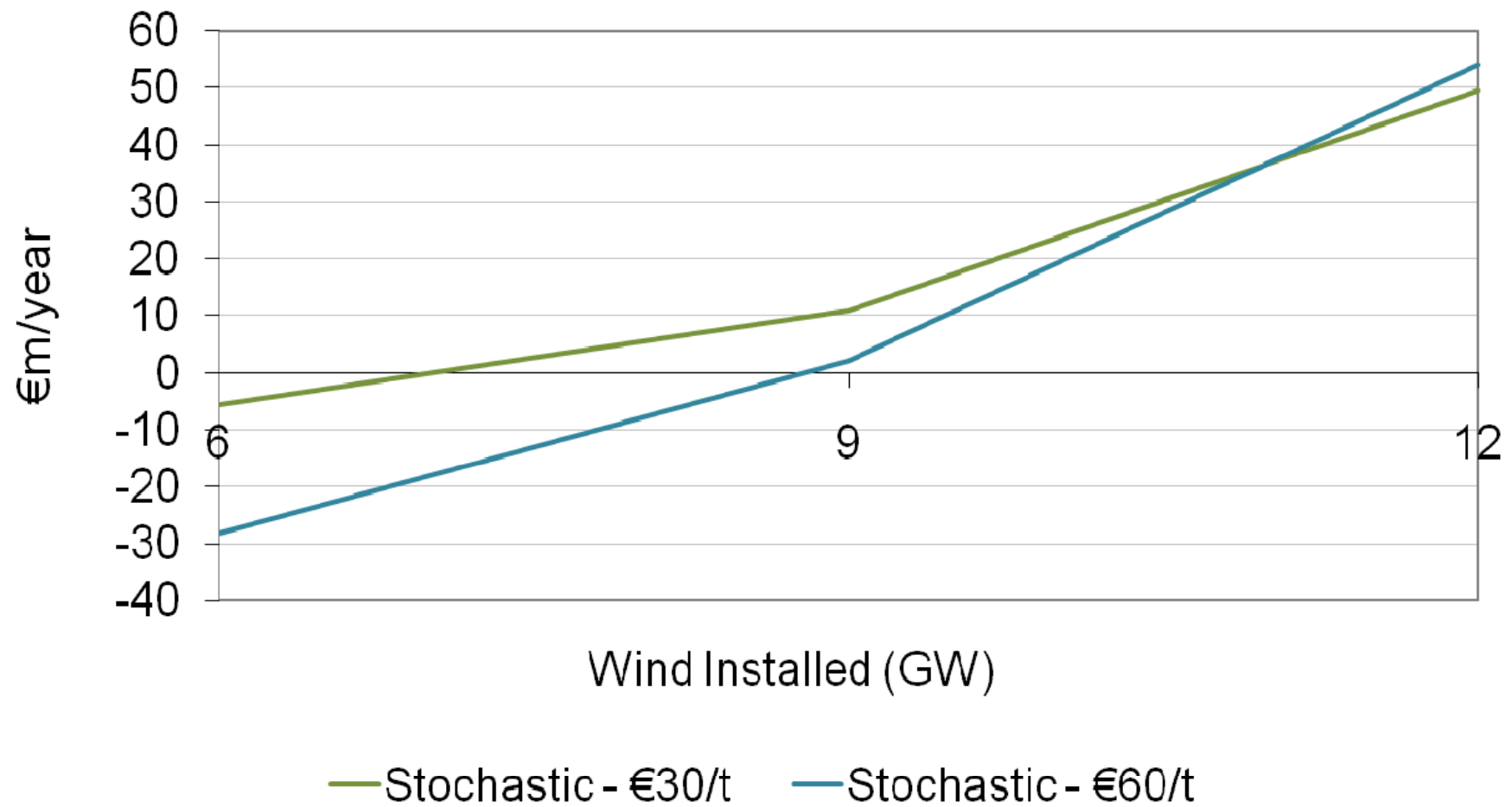
- GB System cheaper – storage allows more import from GB – regardless of wind
- Ireland net exporter at 11GW

CO₂ Emissions



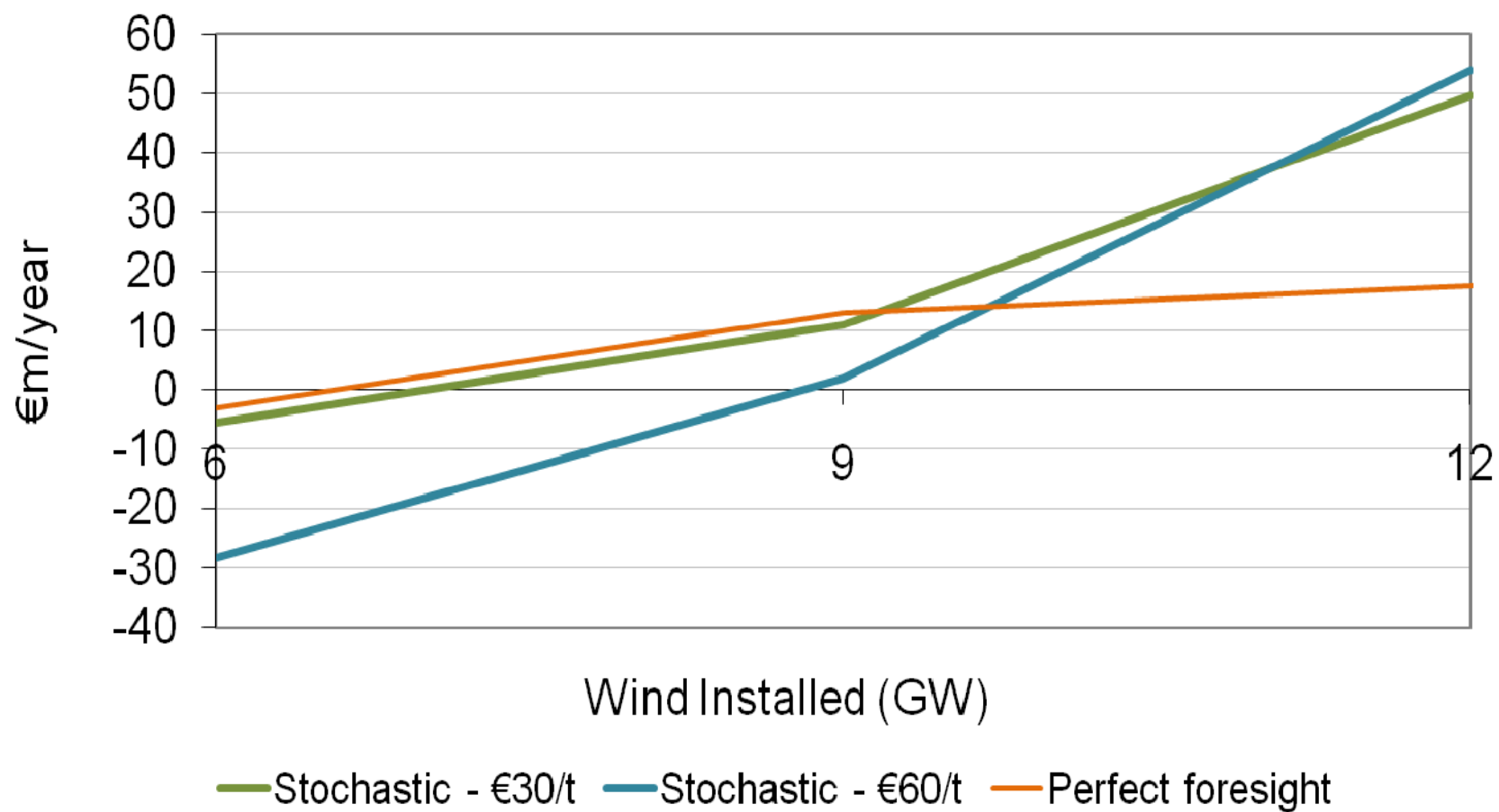
- Reduction compared to no storage case
- Both GB and IRL emissions – increase in one area may cause decrease in another

Costs

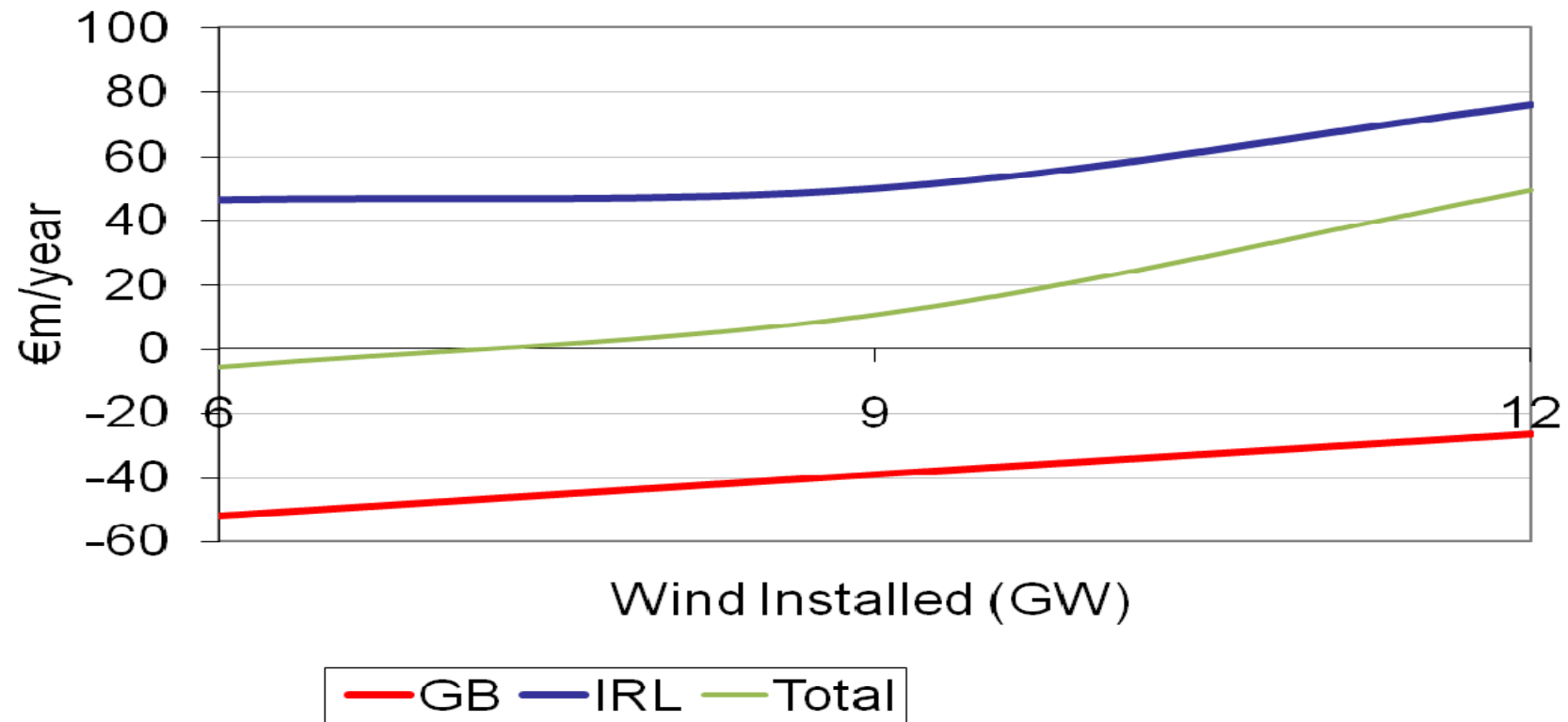


Effect of wind uncertainty

15



Costs by region



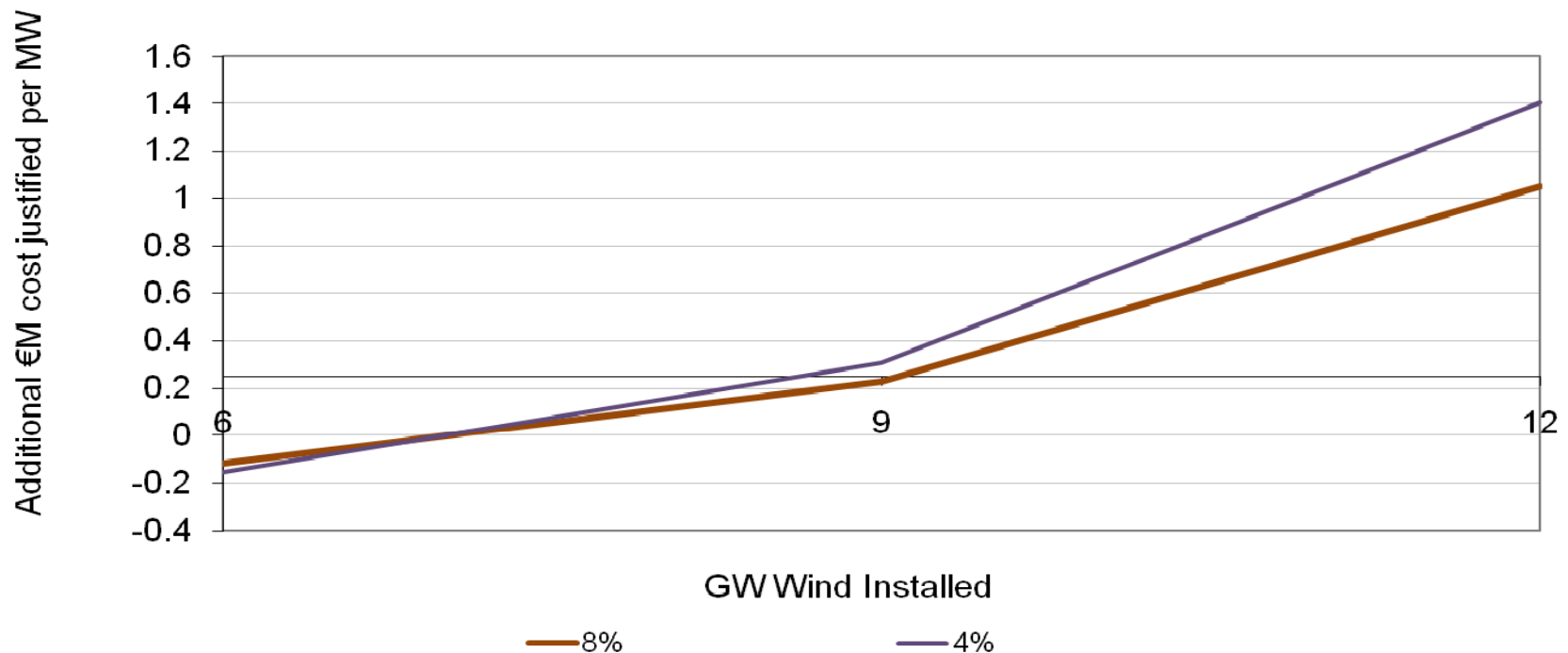
- Saving for Ireland outweighed by increase for GB until high enough wind level reached – would be reflected in interconnection payments

Justification of building storage

- These system cost savings need to be enough to justify building storage for the system
- Net Present Value of 20 yrs of savings need to be greater than difference in cost between storage and unit it replaces
- Different parameters for discount rate, lifetime etc examined

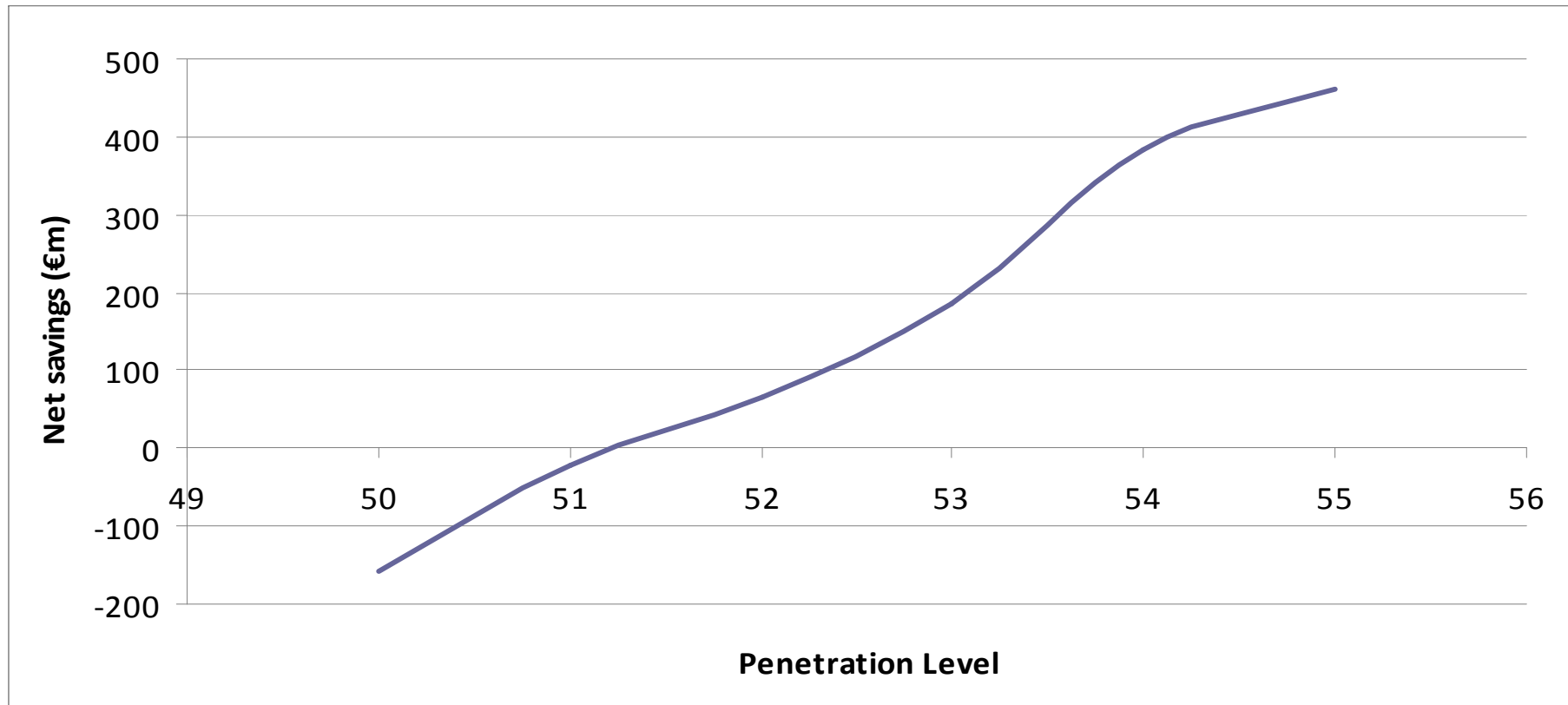
Capital Costs justified

Additional Cost Justified



- Discount Rate / Savings move line left/right
- Capital cost / lifetime moves justification line up/down

Net Savings



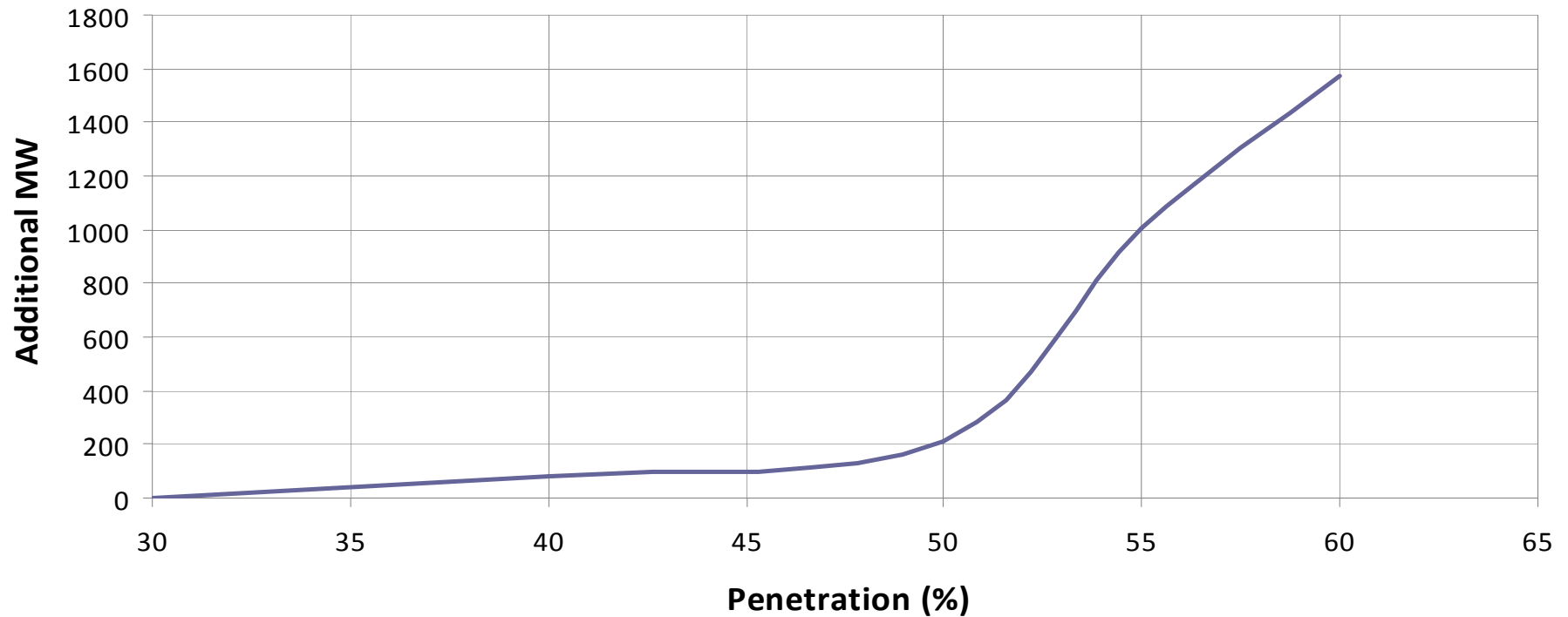
Y axis = (NPV of Additional Capital Costs of storage vs CCGT (with 40 yr lifetime) - €0.25m)
+ (NPV of Additional Fuel Costs, 20 yrs 5% DR)
- (Saved Capital Costs of Wind Turbines - €1.3m)

When is storage a sensible option?

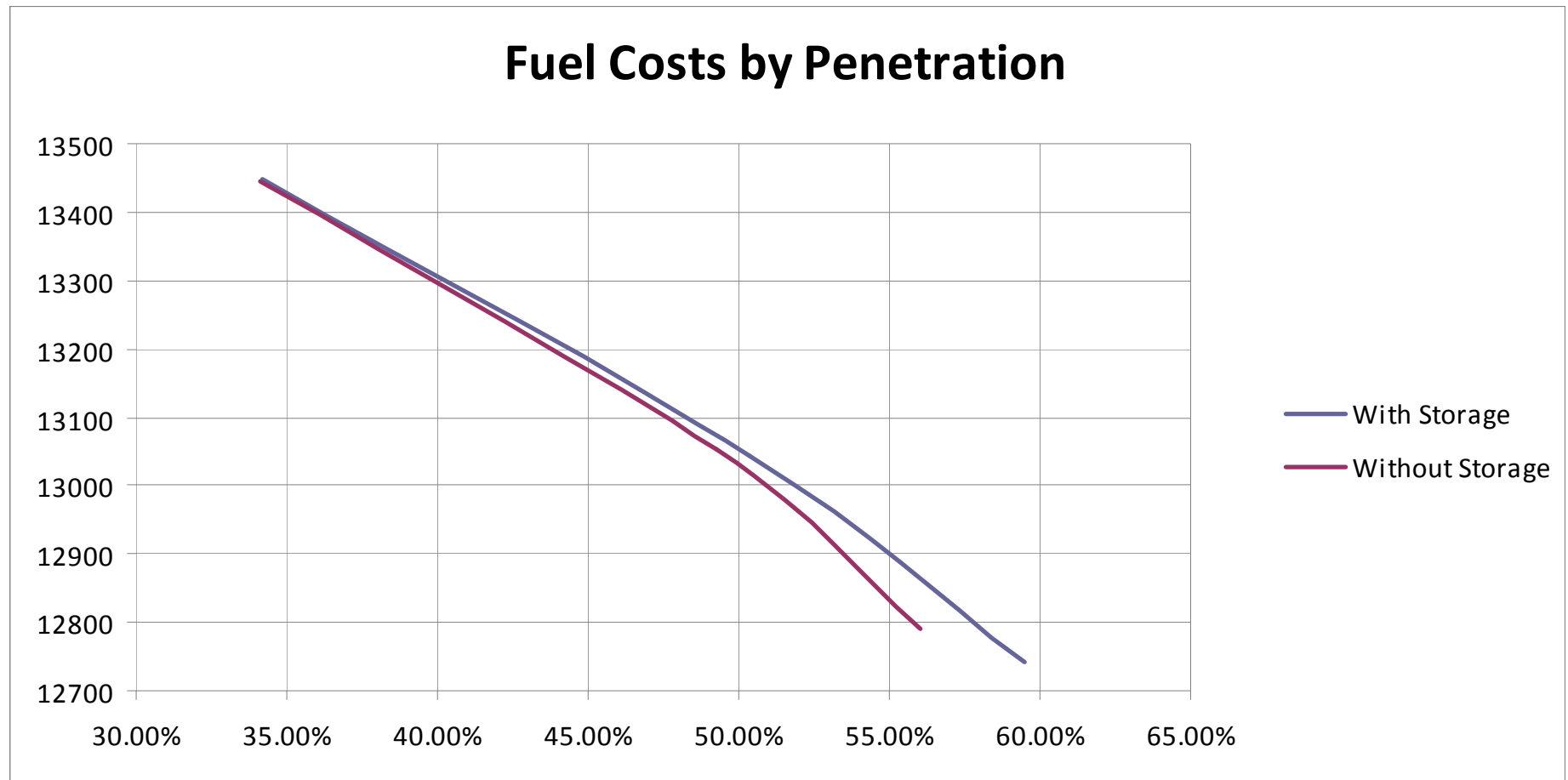
- For this particular system:
 - Depends somewhat, but not very significantly, on lifetime, discount rates received etc
 - If storage costs same as CCGT – 7GW
 - If storage costs double, with same lifetime and high DR – 11.5GW
 - Answer will lie somewhere between 2
 - Storage projects vary significantly depending on civil works
 - If lifetime, DR and capital costs known, this shows level of wind necessary

Saving on installed wind

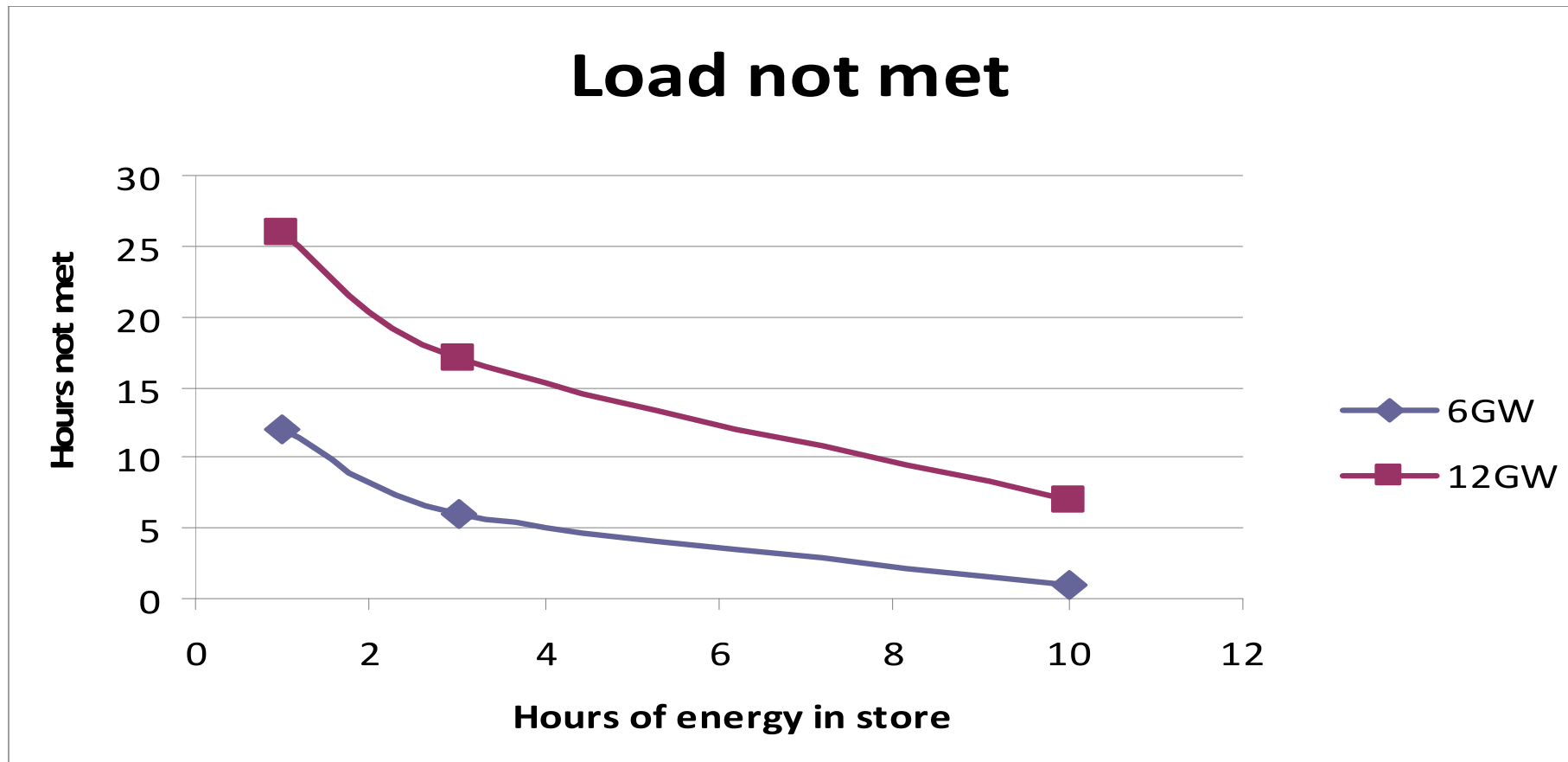
**Amount of additional wind needed to get to desired penetration
if no storage**



Fuel Costs



Reliability Effects



- Daily optimization used – smaller store cannot be relied upon as much

Conclusions

- Storage may start to be sensible option for system at high wind levels
 - However, 50% is extremely high on a synchronous system (40% seen as very ambitious by 2020)
 - Other options for flexibility may be better
 - Demand Side resources, interconnection, better market operation, better forecasting
 - Storage good for reducing curtailment in island system
 - Storage may make profit at lower level of wind – looked at system costs only
 - Or reduce need for transmission expansion

Conclusions (2)

- Uncertainty of wind makes the flexibility of storage more useful
 - If perfect wind foresight assumed, storage not as good
- Plant mix/Size of System/Wind Characteristics will all have effect
 - Results here for island system with high penetration of gas, low interconnection, good but variable wind