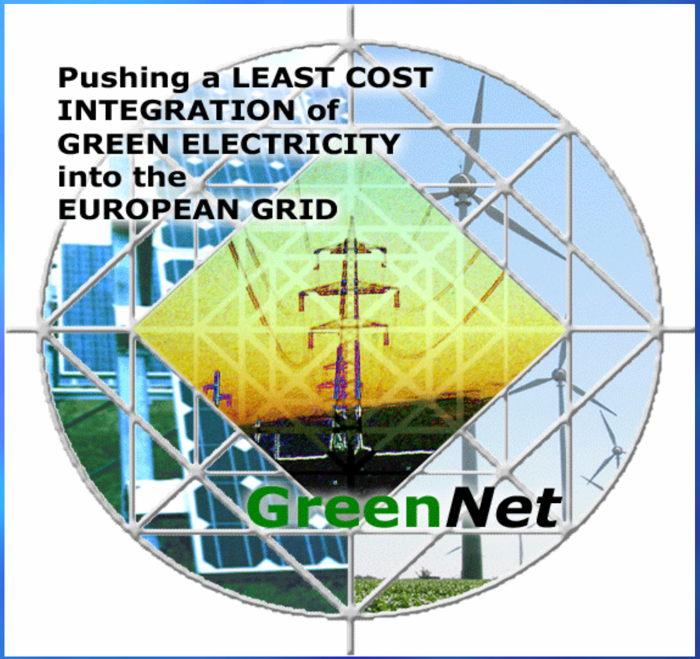
Modelling electricity storage applications: The UK case



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Green*Net* – Final International Dissemination Conference

Vienna, 14 December, 2004

Agenda

- Scope of GreenNet Workpackage 3
- Background to the modelling study & objectives
- Approach to evaluation of the value of storage
- Summary of key results
- Implementation of results in Green*Net*

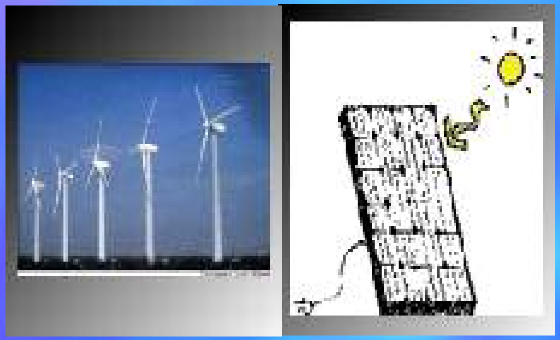
Scope: Cost & Technical Opportunities for Storage

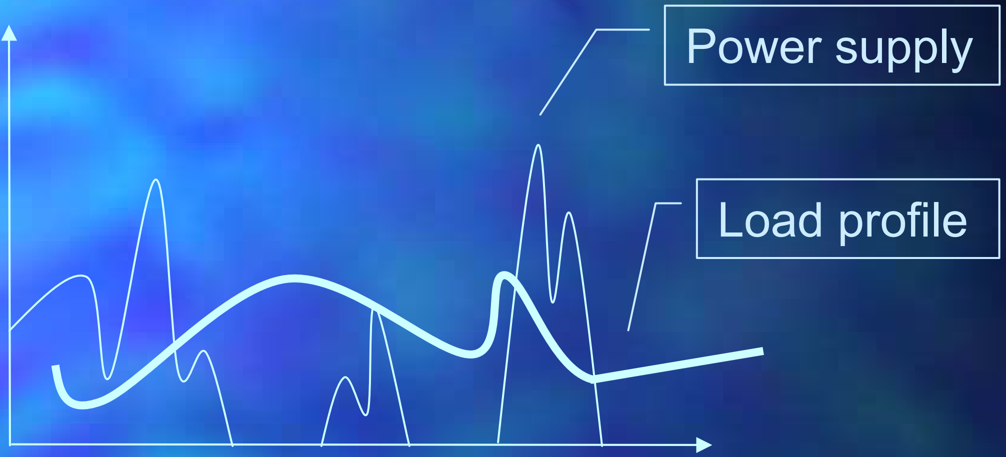
- Assessment of current status of storage technology options
- Applications of each technology option & an evaluation of market opportunities
- Development of a formal methodology for evaluation of storage
- UK case study: value of storage in balancing the system with increasing intermittent generation

Background

- Increasing intermittent renewables (e.g. wind) may displace electricity from large thermal generation plant (e.g. CCGTs)
- Intermittent generation less predictable (uncertainty rises above the normal level of uncertainty in balancing supply & demand) leading to increasing reserve requirements (additional balancing costs?)
- Locational (transmission) impacts

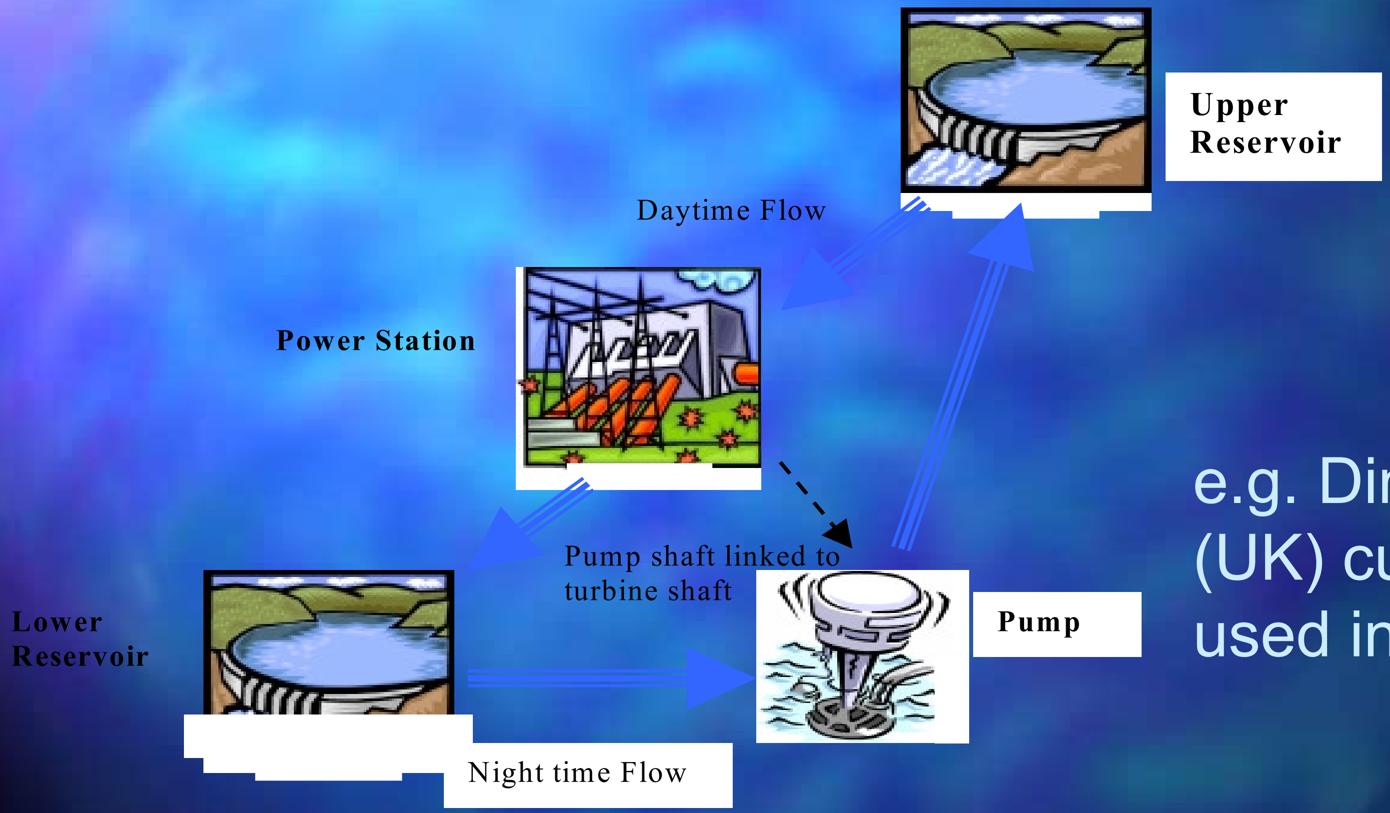
Role for Storage & DSM?





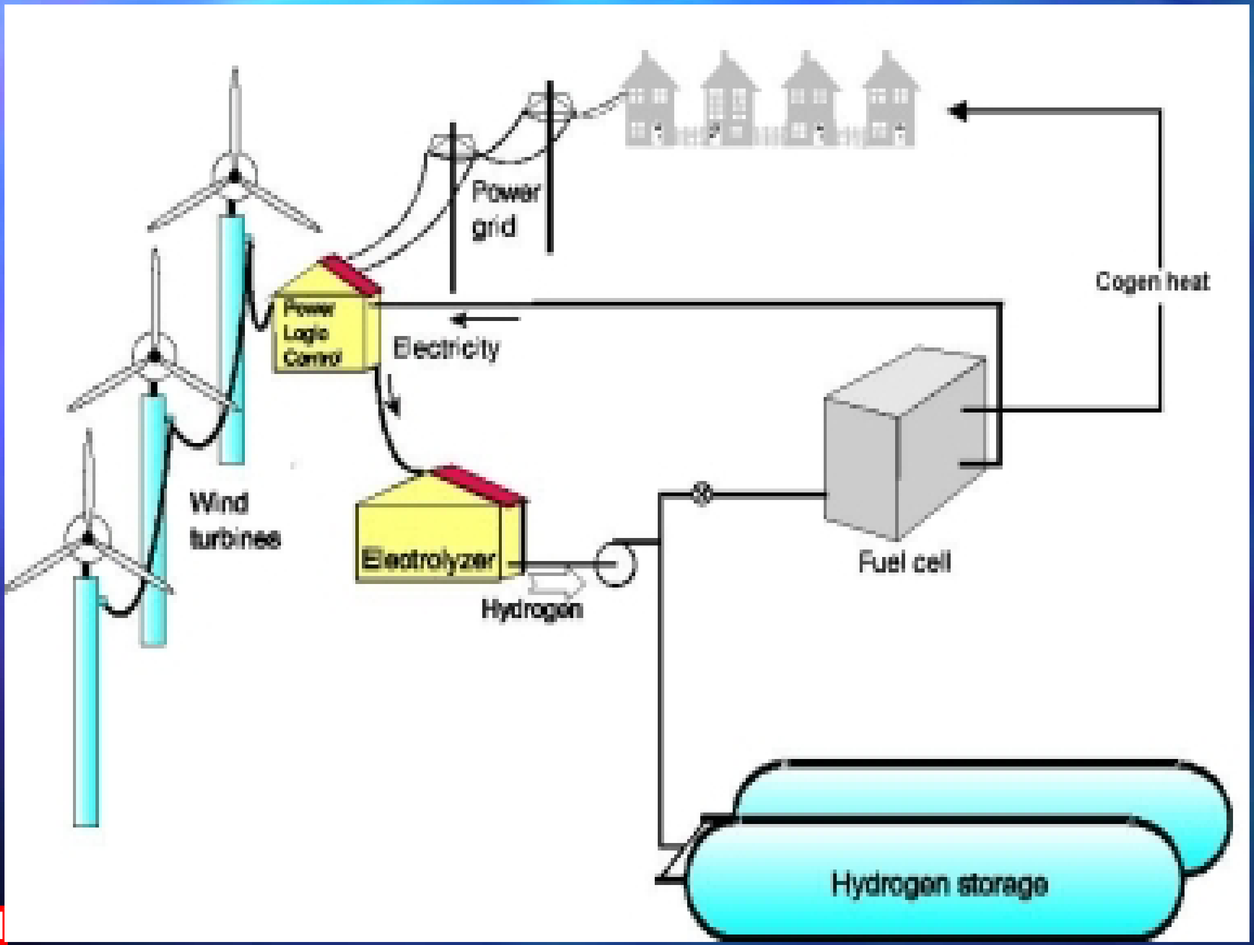
- **Increased penetration of RES-E**
  store power when in excess for later use
- **Increased value of energy**
  higher buy-back rates for predictable energy sources

Current Storage Technologies: Pumped Storage



e.g. Dinorwig (UK) currently used in arbitrage

Emerging Storage Options



e.g.Hunterston Hydrogen Ltd (UK): 100MW wind & hydrogen "balancing" scheme

Demand Side Management (DSM)

- Devices (e.g. water heaters) controlled to switch off at certain times (i.e. when intermittent generation output is low & shortage of supply) to lower demand
- Time-shifting consumption demand i.e. smoothing or "virtual storage"
- Variety of approaches (options evaluated in more detail WP5)

Objectives of the study

- To provide estimates of the *value* of storage and DSM in the balancing system with increasing penetration of intermittent generation in the context of the UK system

Approach

- At its core: Economic Dispatch of generation in system with conventional generation, wind, storage and DSM. Linear programming optimisation minimises fuel costs
- Hourly dispatch over 1 year, simulated using software model of power system
- Compare fuel costs in simulations with and without storage/DSM. Assess benefit of any savings

Assumptions

- Cost based approach (market arrangements not considered)
- Balancing task performed at system level not at individual generation/supply company level
- Arbitrage excluded
- Reliability & capacity performance equal to other plant
- Management of network constraints not considered
- Generic, flexible bulk storage technology

Economic Dispatch

- Optimal dispatch of conventional generation, storage & DSM

IT Power

Economic Dispatch

- Optimal dispatch: generation levels & use of storage/DSM

StorageWindDemandModel - [StorageWindDema1:2]

File Edit View Window Help

period	date	D-W Diff	load	wind	charged	discharged	effic loss	loadshed	windshed	dsm	gen 1	gen 2	gen 3	gen 4	gen 5
241	11 Jun: 00:00	0.000	23482.500	2115.224	-232.724	0.000	-46.545	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
242	11 Jun: 01:00	0.000	22305.000	2184.076	-479.076	0.000	-95.815	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
243	11 Jun: 02:00	0.000	21847.500	2153.868	-406.368	0.000	-81.274	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
244	11 Jun: 03:00	0.000	21067.500	2130.704	-663.204	0.000	-132.641	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
245	11 Jun: 04:00	0.000	20857.500	2164.376	-906.876	0.000	-181.375	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
246	11 Jun: 05:00	0.000	20895.000	2306.280	-1011.280	0.000	-202.256	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
247	11 Jun: 06:00	0.000	24390.000	2437.768	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
248	11 Jun: 07:00	0.000	31965.000	2612.592	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
249	11 Jun: 08:00	0.000	37770.000	2753.228	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
250	11 Jun: 09:00	0.000	40395.000	2831.156	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
251	11 Jun: 10:00	0.000	41085.000	2818.440	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
252	11 Jun: 11:00	0.000	41527.500	2805.796	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
253	11 Jun: 12:00	0.000	41782.500	2826.276	0.000	615.462	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
254	11 Jun: 13:00	0.000	40890.000	2811.700	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
255	11 Jun: 14:00	0.000	40335.000	2696.500	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
256	11 Jun: 15:00	0.000	39615.000	2560.552	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
257	11 Jun: 16:00	0.000	40185.000	2452.668	0.000	2000.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
258	11 Jun: 17:00	0.000	40357.500	2292.560	0.000	0.000	0.000	0.000	0.000	-28.235	220.000	220.000	220.000	220.000	220.000
259	11 Jun: 18:00	0.000	37785.000	2145.880	0.000	0.000	0.000	0.000	0.000	-28.235	220.000	220.000	220.000	220.000	220.000
260	11 Jun: 19:00	0.000	35475.000	2183.352	0.000	0.000	0.000	0.000	0.000	42.352	220.000	220.000	220.000	220.000	220.000
261	11 Jun: 20:00	0.000	34005.000	2246.528	0.000	0.000	0.000	0.000	0.000	14.117	220.000	220.000	220.000	220.000	220.000
262	11 Jun: 21:00	0.000	34650.000	2281.800	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
263	11 Jun: 22:00	0.000	33712.500	2268.340	0.000	344.160	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000
264	11 Jun: 23:00	0.000	28807.500	2219.640	0.000	0.000	0.000	0.000	0.000	0.000	220.000	220.000	220.000	220.000	220.000

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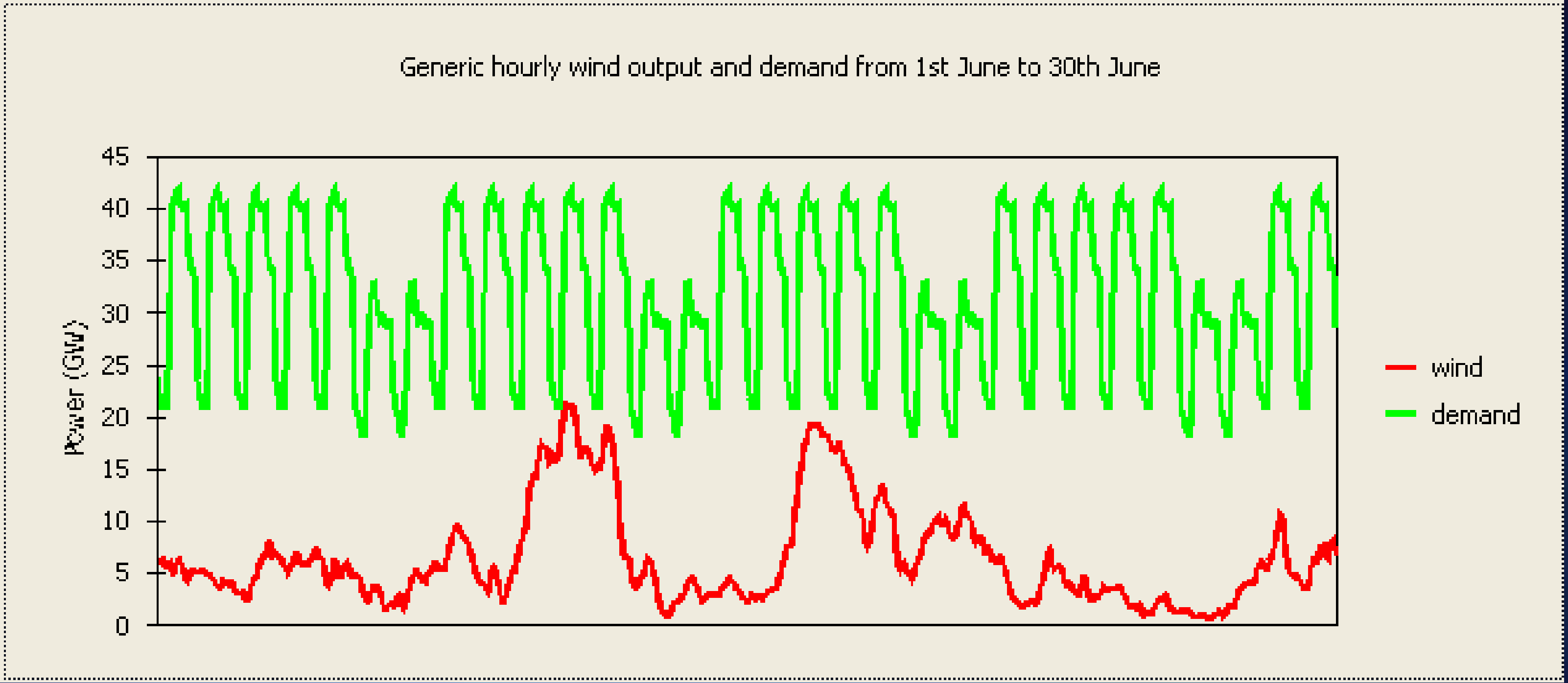
Wind and Demand

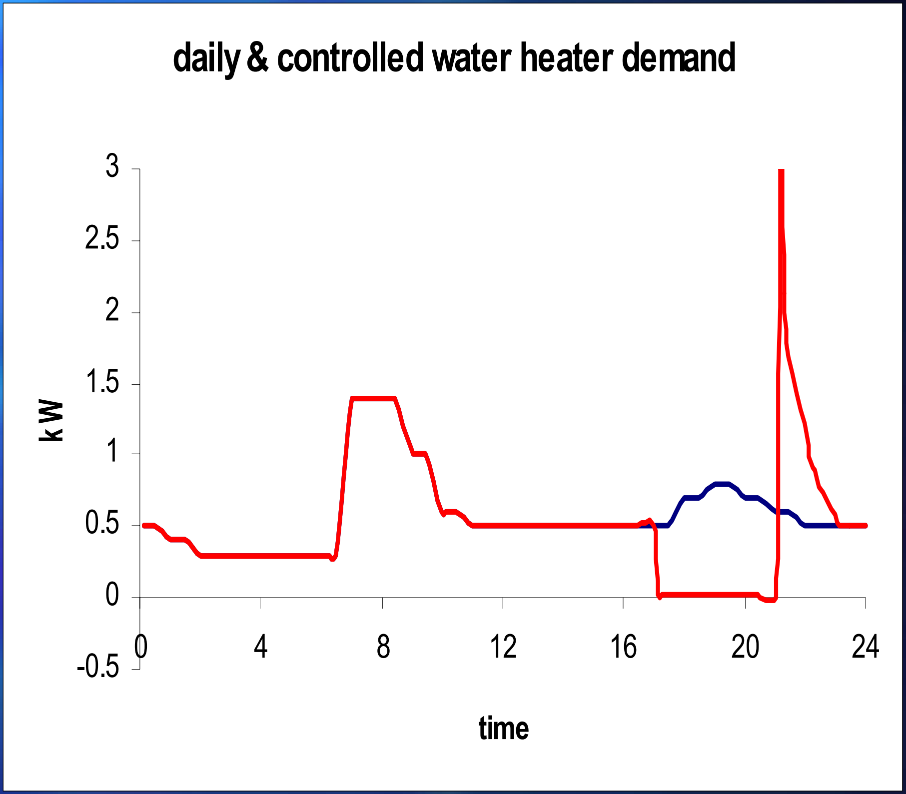
- Generic UK wind and demand profiles used



Above is an example of profiles with 30GW of wind

DSM: Demand Change Profiles

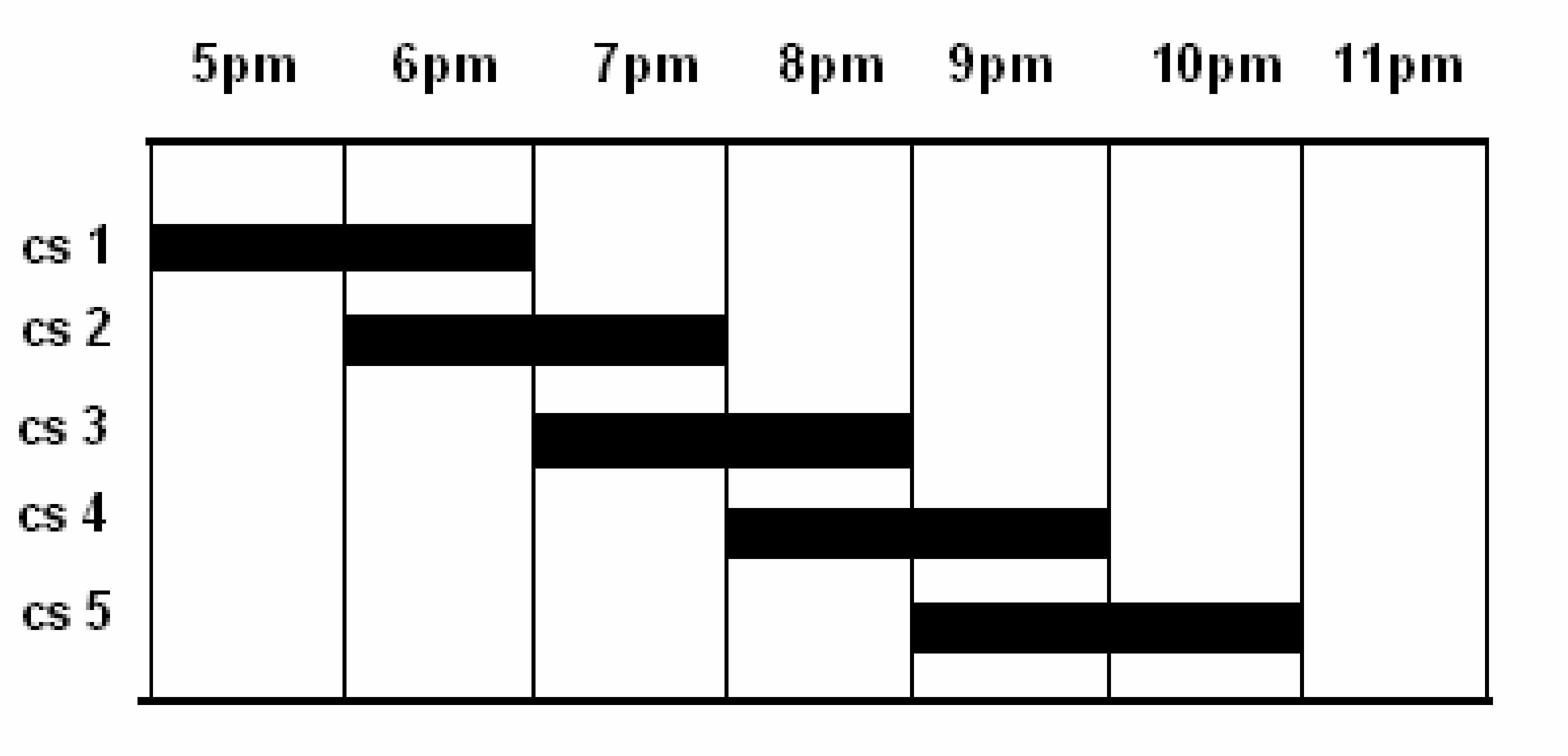
- Demand change profile for a device: a control period during which it is switched off and reduces demand, and a payback period when it is switched back on thus increasing demand.
- Way that energy is restored is dependent on the amount of energy shifted. Change profiles modelled outside our system



Power

DSM: Candidate Control Schemes

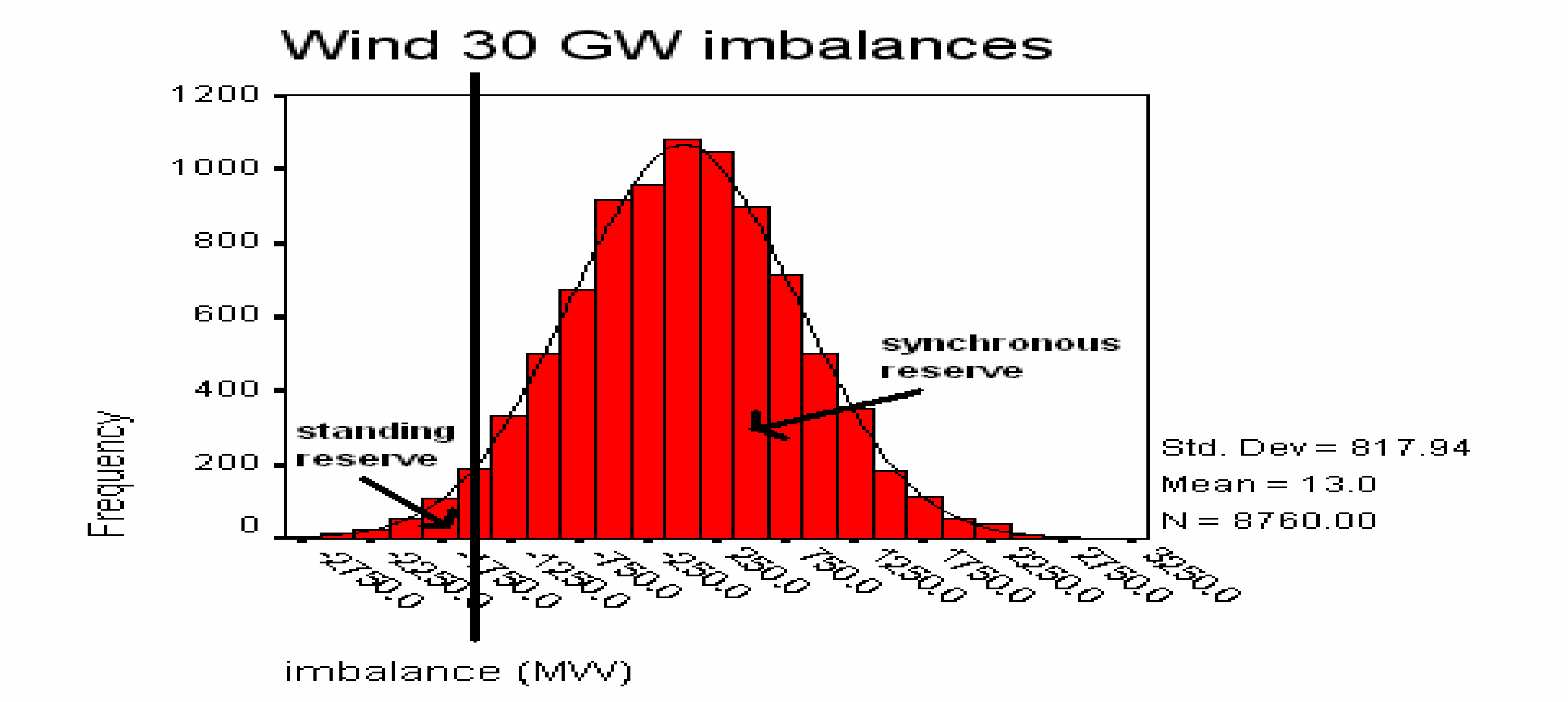
- DSM control schemes define the time of day that devices can be switched off, and for how long a period



Modelling Reserve

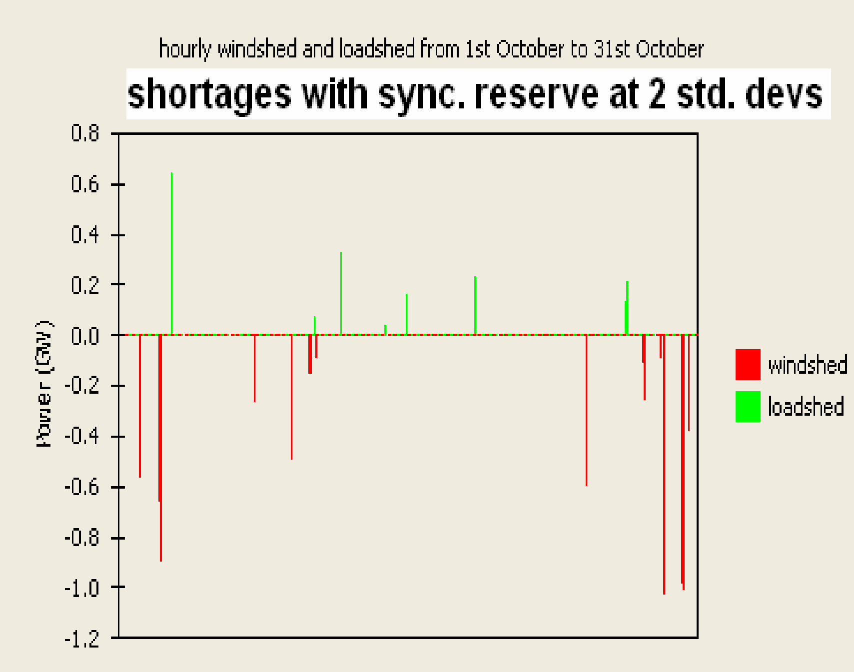
- Unit commitment is carried out using a "forecast" net "demand minus wind" profile, and economic dispatch is carried out using the "actual" profile
- The forecast profile is based on randomized additions/subtractions to the actual profile generated from a normal distribution in which the standard deviation is calculated in the same way as with reserve

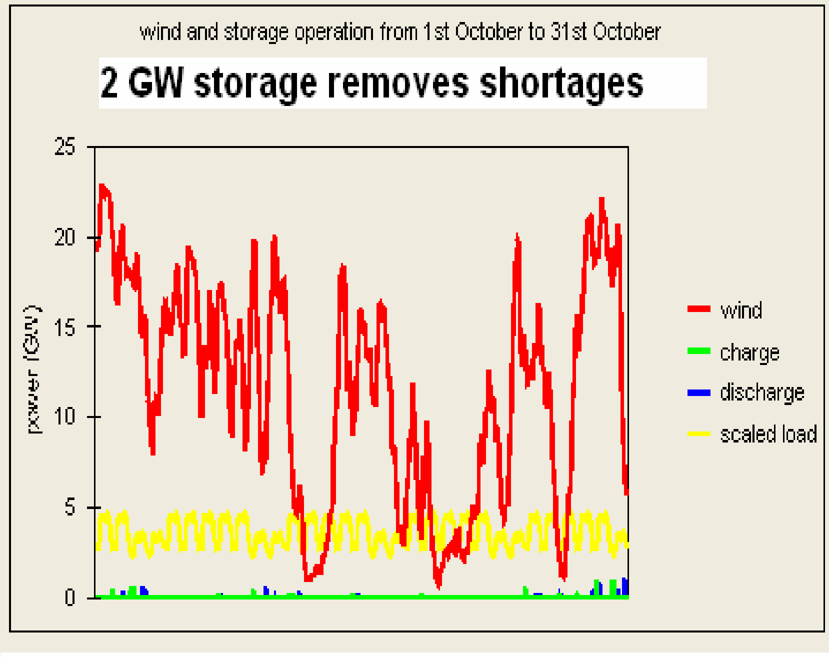
Reserve: Imbalances distribution



- Shortages occur at imbalances > 1690 MW when synchronised reserve is scheduled at 2 standard deviations

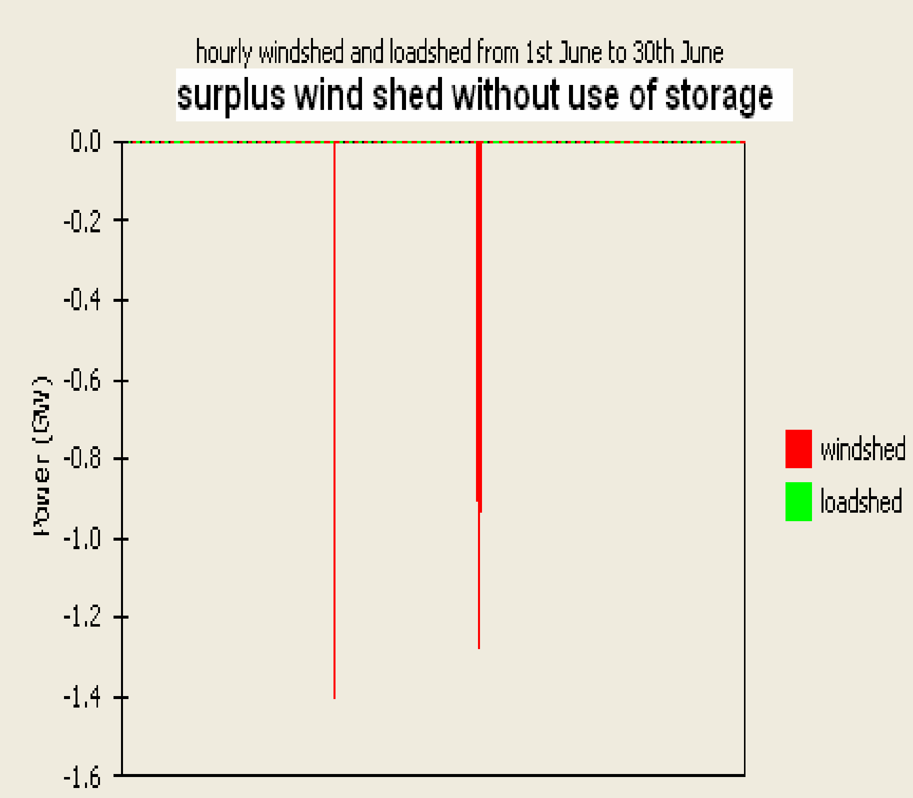
Storage used for reserve

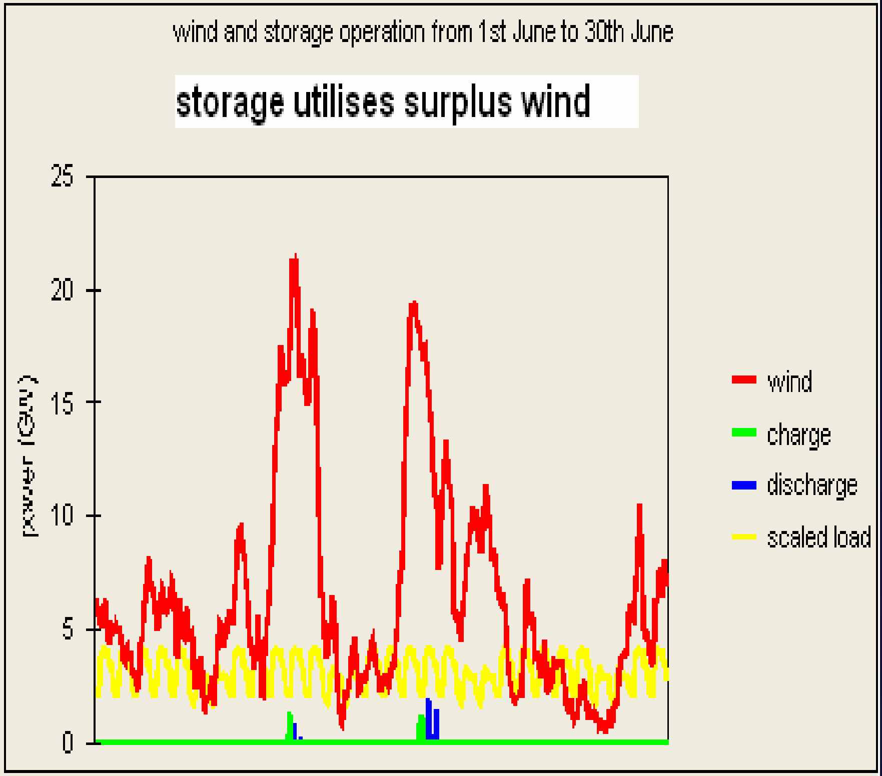




- 2 GW storage provides standing reserve for imbalances between forecast and actual net demand – wind profiles Results here are for 30 GW wind with standing reserve required to cover imbalances > 2 standard deviations
- Optimal dispatch automatically calculates storage use.

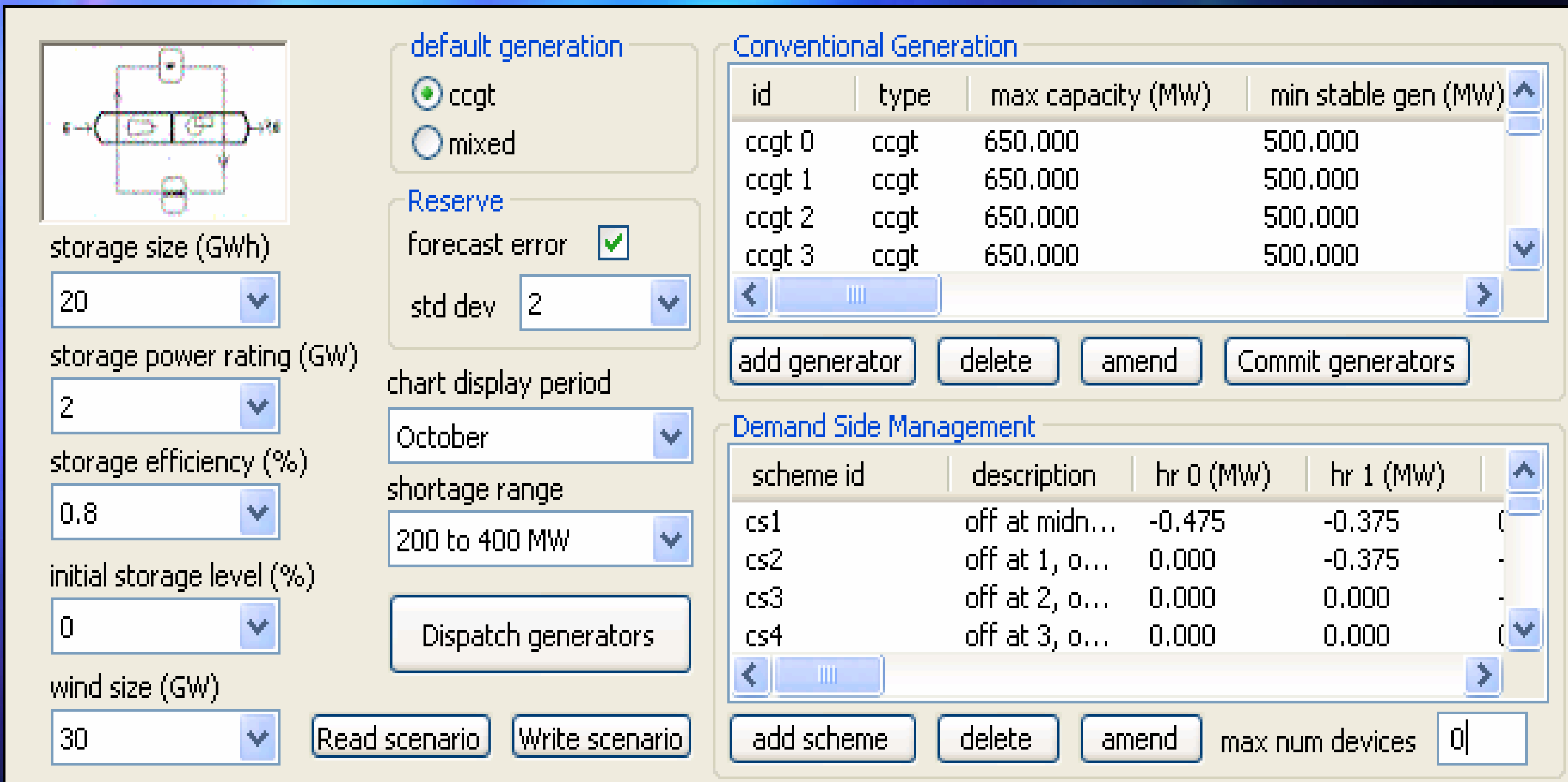
Utilisation of surplus wind





- Windshed occurs in June when wind at 30 GW. Optimal economic dispatch automatically calculates how storage can utilise surplus wind, remove wind shed, and discharge stored energy later to save fuel.

Main inputs window

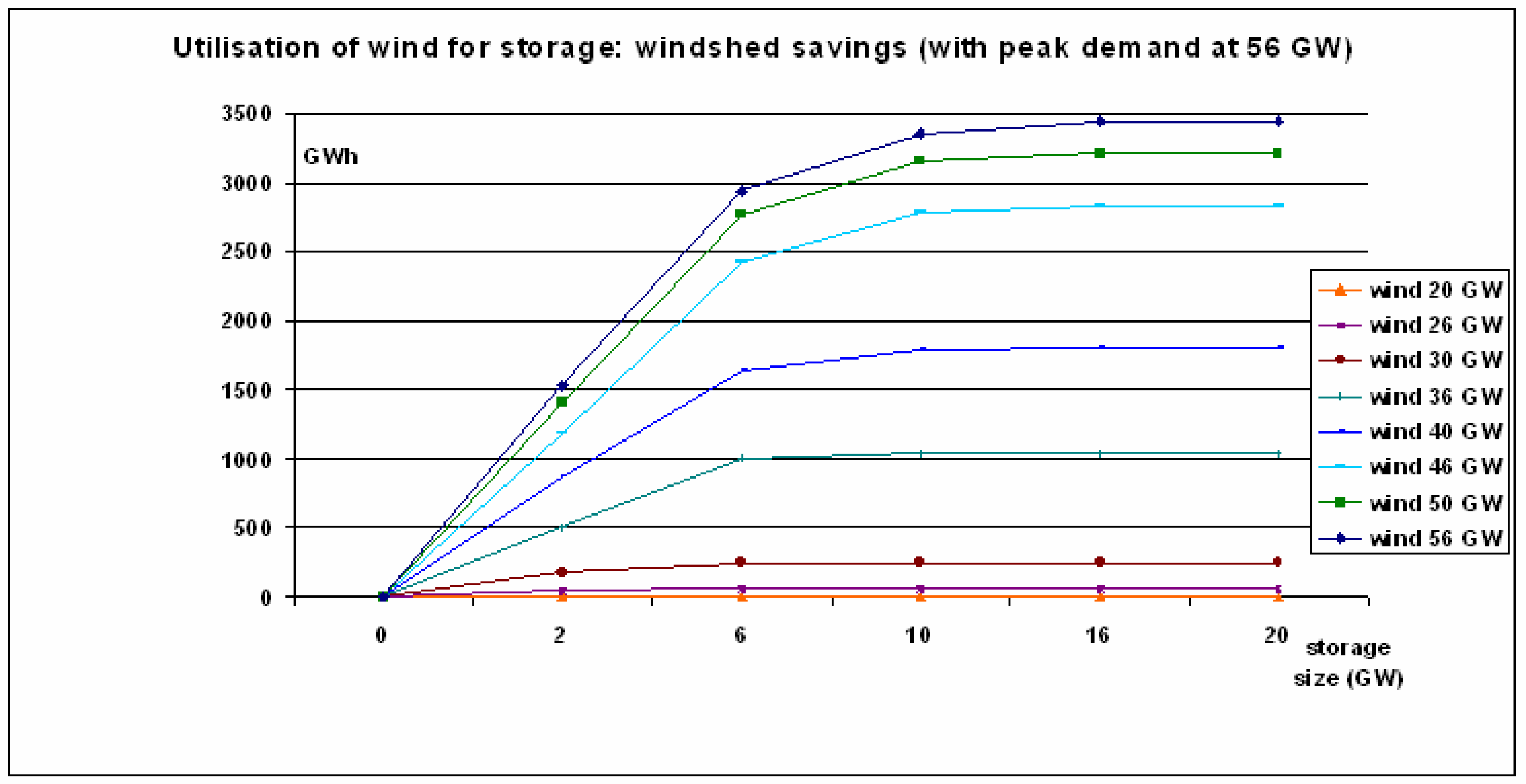


- Alter parameters to run many case studies

Storage case study parameters

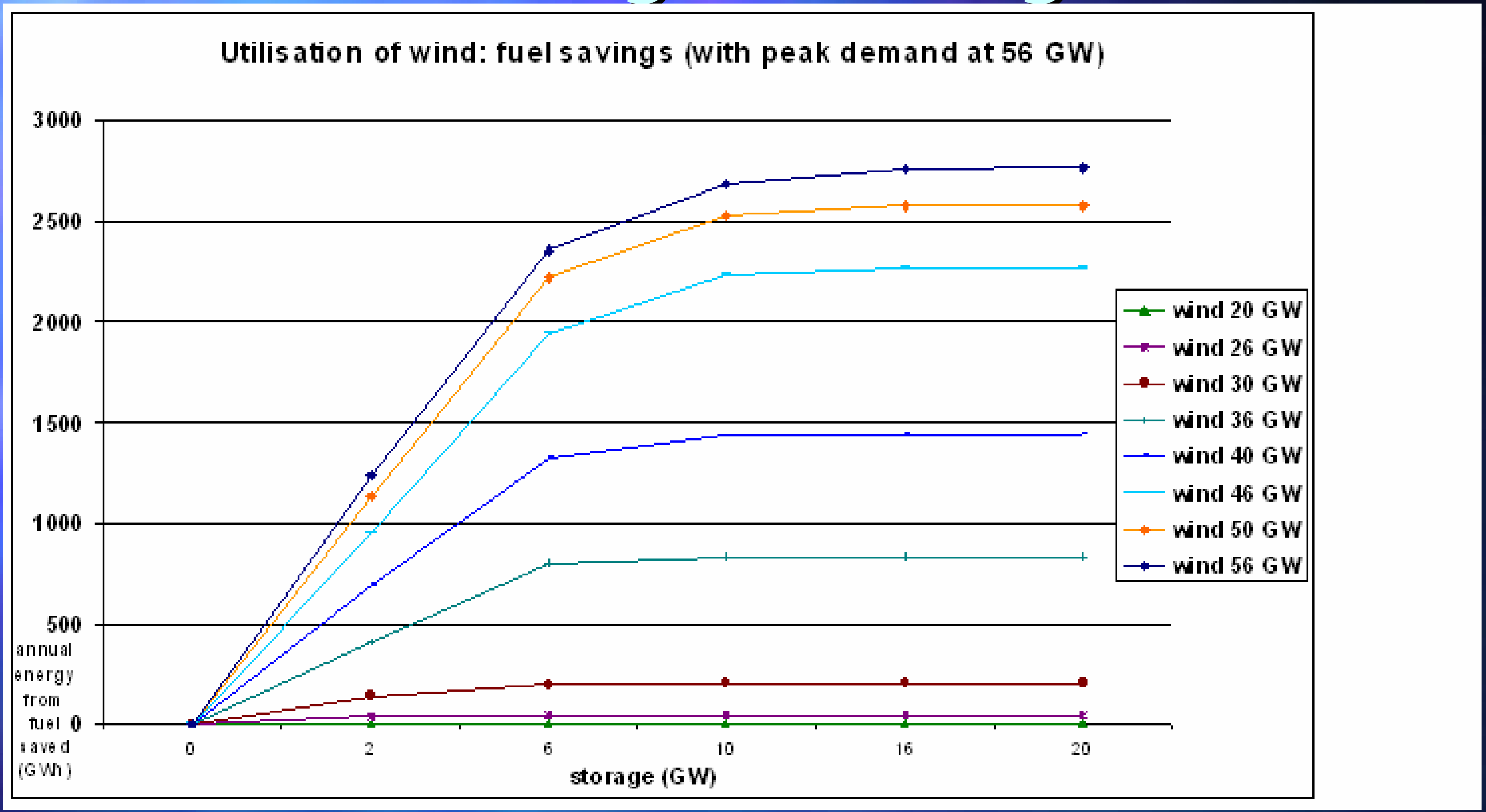
peak demand (GW)	max wind (GW)	Storage rating (GW)	Storage size (GWh)	Storage efficiency
56.79	20	0, 2, 6, 10, 16, 20	rating * 10 hours	80%
56.79	26	0, 2, 6, 10, 16, 20	rating * 10 hours	80%
56.79	30	0, 2, 6, 10, 16, 20	rating * 10 hours	80%
56.79	36	0, 2, 6, 10, 16, 20	rating * 10 hours	80%
56.79	40	0, 2, 6, 10, 16, 20	rating * 10 hours	80%
56.79	46	0, 2, 6, 10, 16, 20	rating * 10 hours	80%
56.79	50	0, 2, 6, 10, 16, 20	rating * 10 hours	80%
56.79	56	0, 2, 6, 10, 16, 20	rating * 10 hours	80%

Results: Windshed savings - storage



- storage beneficial for wind>20GW
- marginal benefits of additional storage capacity get smaller

Fuel savings - storage

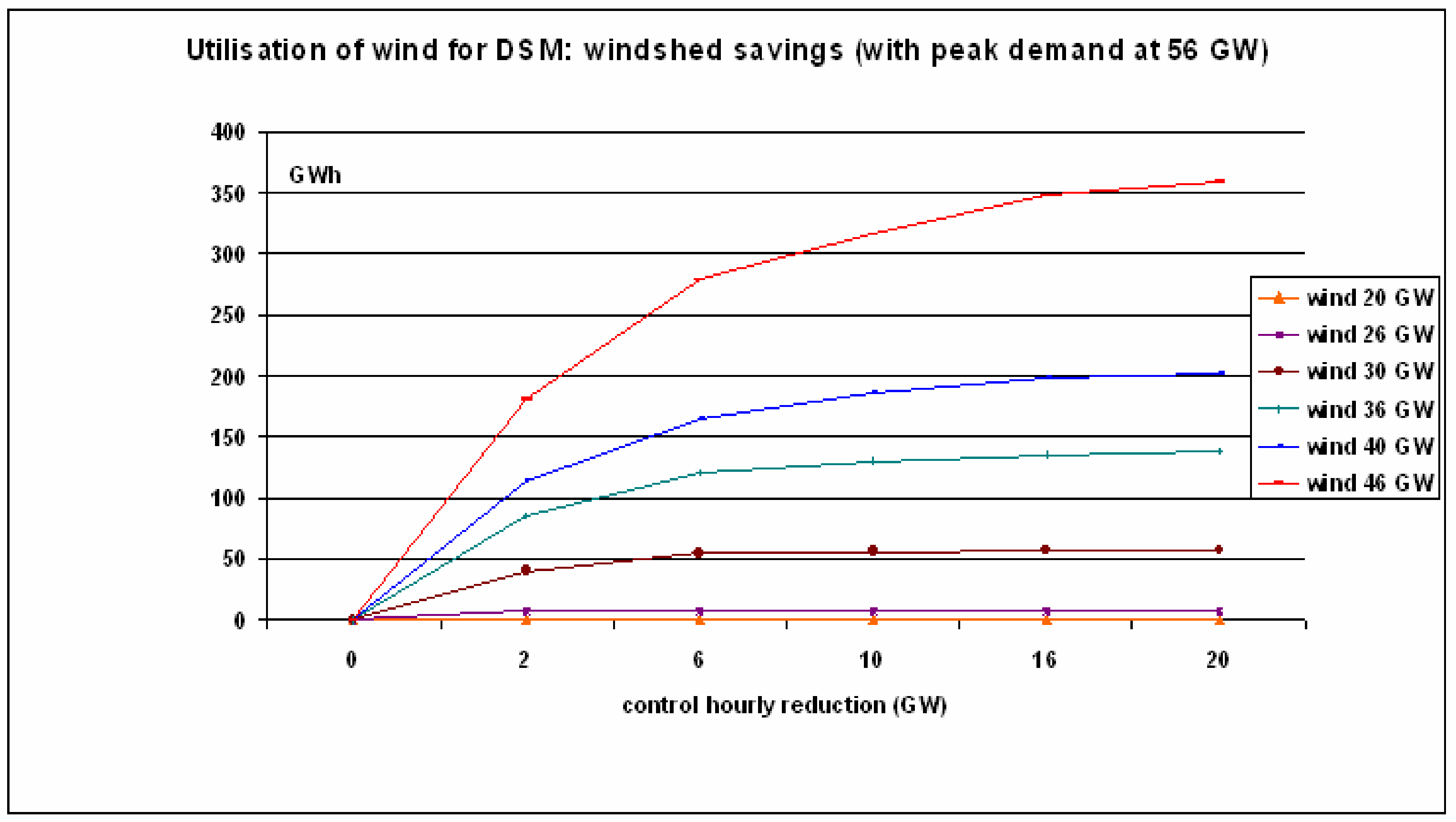


N.B. efficiency losses when charging reduce fuel savings

DSM case study parameters

Peak demand (GW)	Max wind (GW)	DSM number of devices	Hourly control period load reduction (GW)
56.79	20	0, 200, 600, 1000, 1600, 2000	2, 6, 10, 16, 20
56.79	26	0, 200, 600, 1000, 1600, 2000	2, 6, 10, 16, 20
56.79	30	0, 200, 600, 1000, 1600, 2000	2, 6, 10, 16, 20
56.79	36	0, 200, 600, 1000, 1600, 2000	2, 6, 10, 16, 20
56.79	40	0, 200, 600, 1000, 1600, 2000	2, 6, 10, 16, 20
56.79	46	0, 200, 600, 1000, 1600, 2000	2, 6, 10, 16, 20

Wind shed savings - DSM



Considerably less than storage!

Fuel savings - DSM

- Some fuel savings but much less than storage e.g. for 30 GW wind, savings of 56GWh, whilst for storage (80% efficiency) ~ 200GWh

Why low DSM potential?

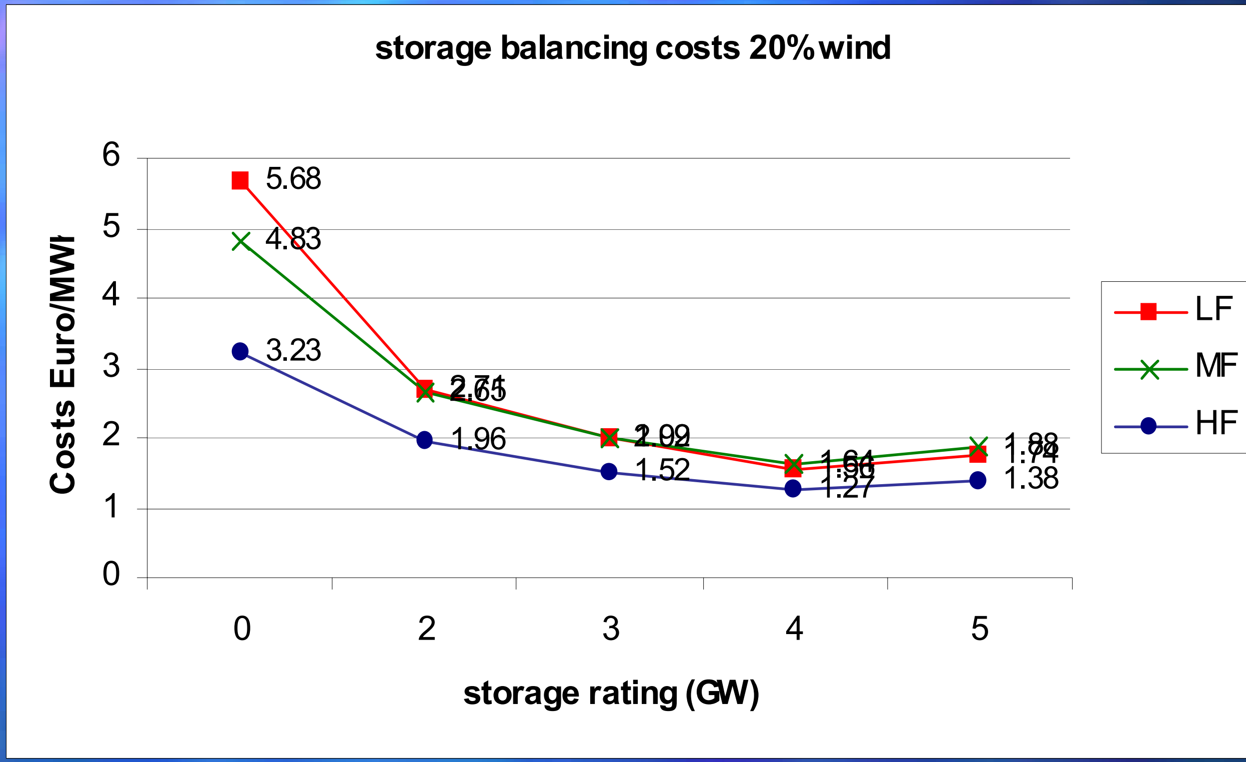
- Limitations in deployment of DSM
  - Payback of energy lost during the control period (how demand is restored to devices)
  - Timing issues (i.e. for use of surplus wind DSM devices must already be switched off)

Opportunities for Balancing

- Case study parameters

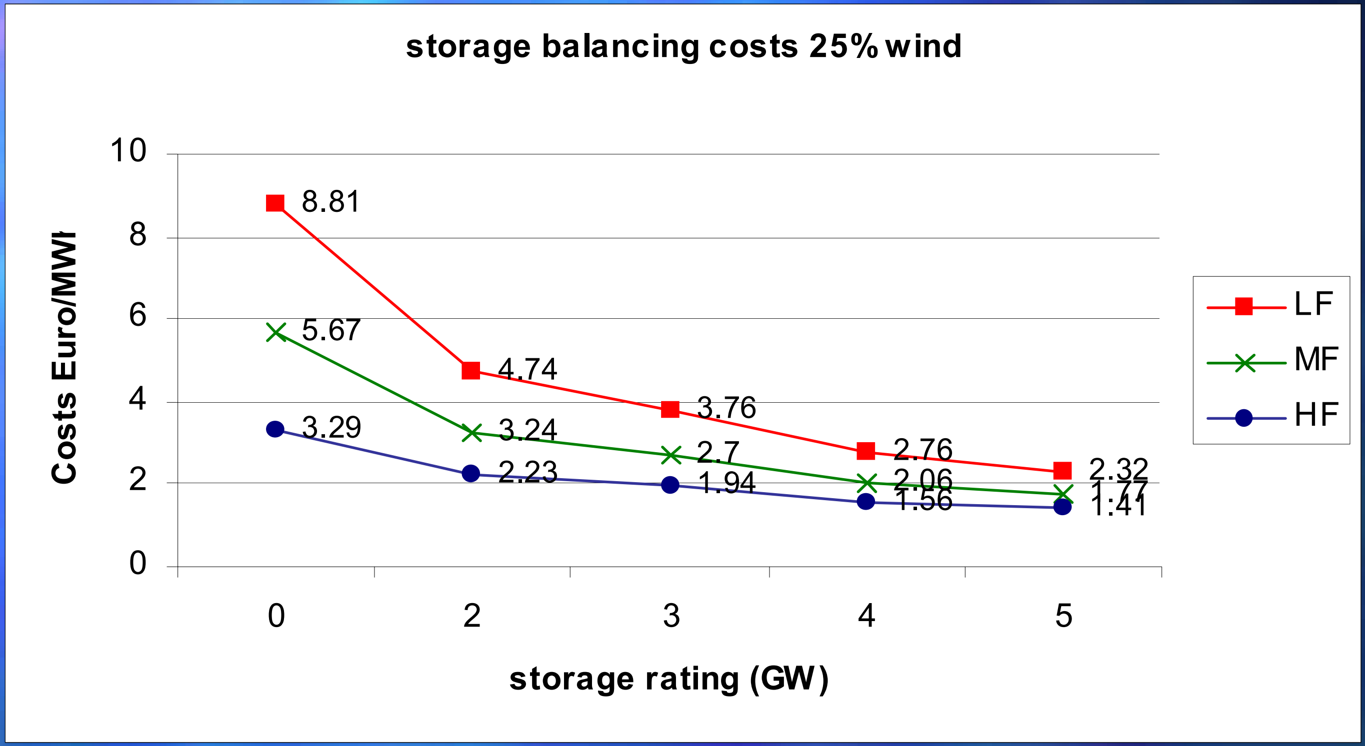
Storage Rating (standing reserve)	Storage efficiency	Storage energy	Wind penetration	Generation mixes
None	-		20, 25, 30 %	LF, MF, HF
2 GW	70%	40 GWh	20, 25, 30 %	LF, MF, HF
3 GW	70%	60 GWh	20, 25, 30 %	LF, MF, HF
4 GW	70%	80 GWh	20, 25, 30 %	LF, MF, HF
5 GW	70%	100 GWh	20, 25, 30 %	LF, MF, HF

Balancing costs for 20% wind penetration



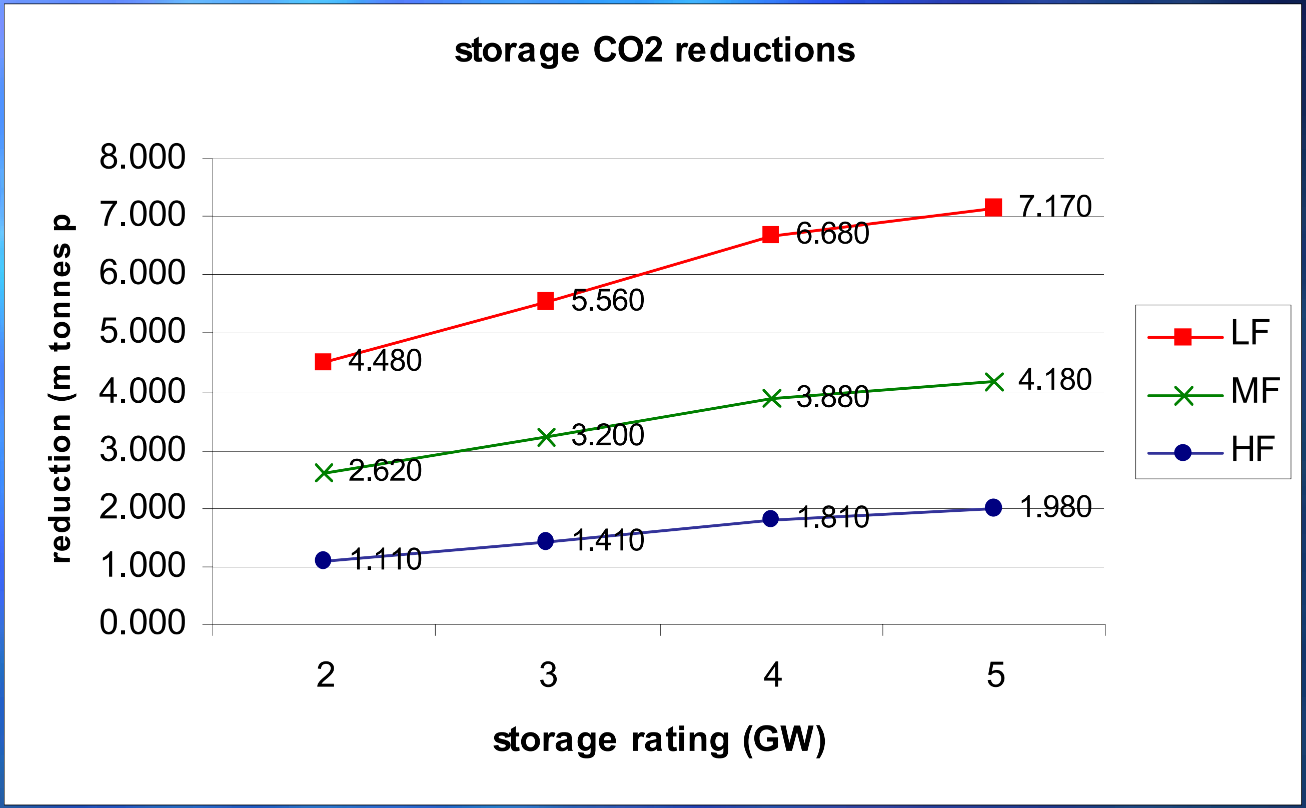
- Balancing costs greatest for LF system
- Costs begin to increase again for large amounts (5 MW of storage) due to not enough wind for storage!

Balancing costs for 25% wind penetration)



- Balancing cost reduction greatest for LF system
- Value of storage increases with size

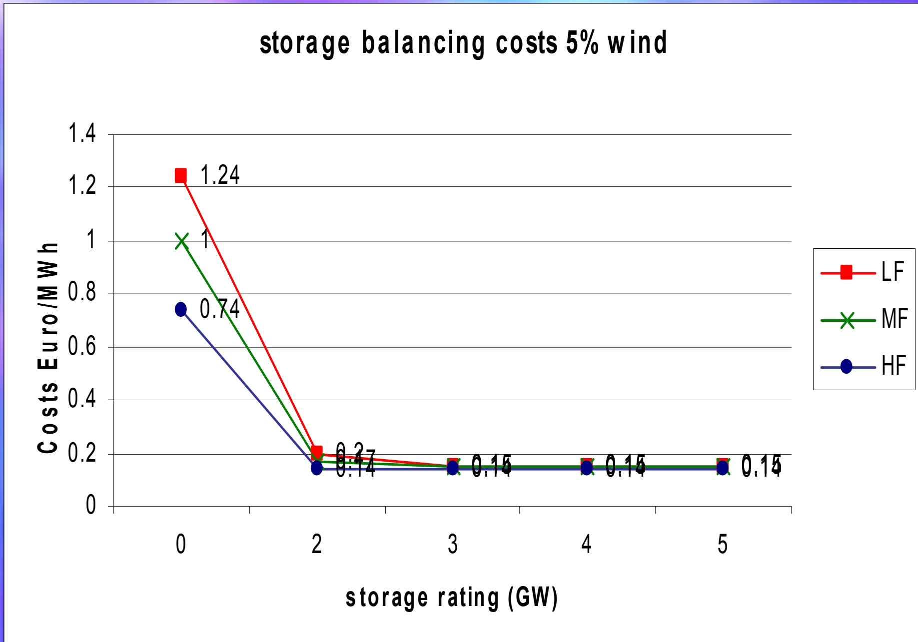
CO_2 reductions

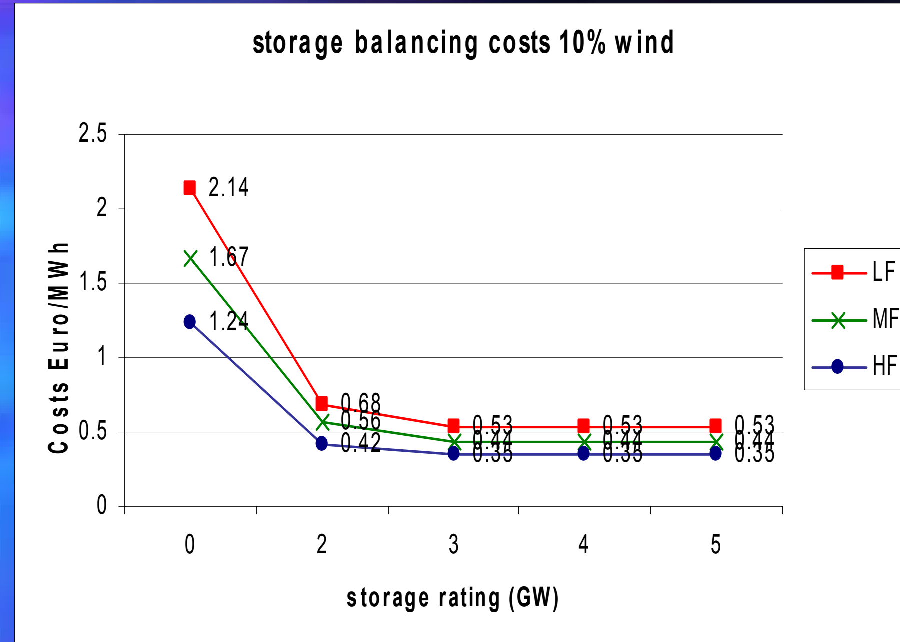


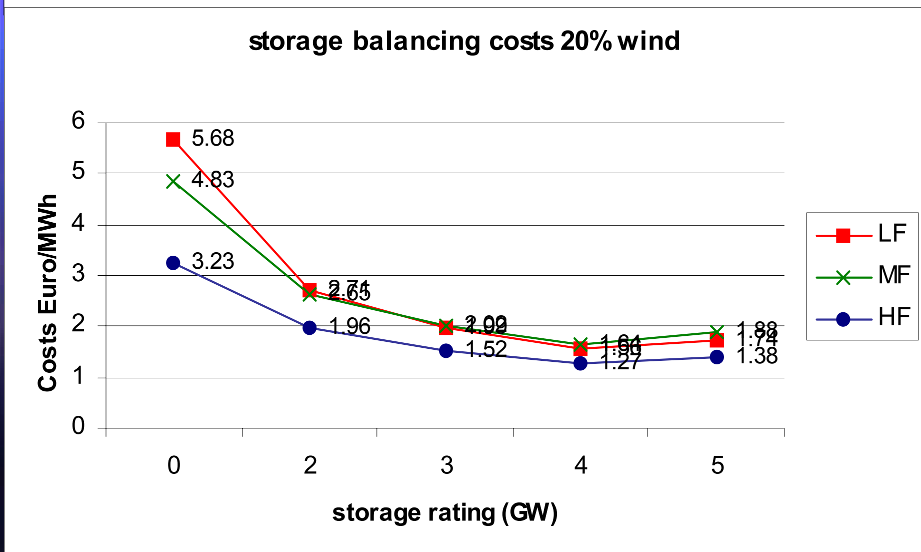
- Increasing storage size increases CO2 reductions & as flexibility decreases

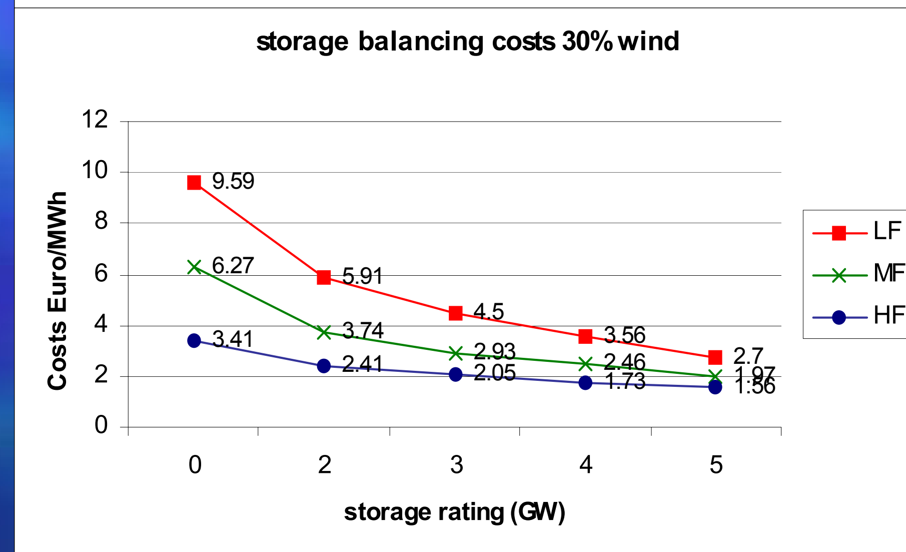
Integration of Results into Green*Net*

- Value of storage in terms of balancing costs
- UK results relevant for European grid as role of storage for providing standing reserve based on forecast uncertainty NOT demand (however SD of wind will be different – more predictable in Europe)


storage balancing costs 5% wind
Costs Euro/MWh
storage rating (GW)
LF
MF
HF
1.24
1
0.74


storage balancing costs 10% wind
Costs Euro/MWh
storage rating (GW)
LF
MF
HF
2.14
1.67
1.24
0.68
0.56
0.42
0.53
0.35


storage balancing costs 20% wind
Costs Euro/MWh
storage rating (GW)
LF
MF
HF
5.68
4.83
3.23
1.96
1.52
1.27
1.38


storage balancing costs 30% wind
Costs Euro/MWh
storage rating (GW)
LF
MF
HF
9.59
6.27
3.41
5.91
3.74
2.41
4.5
2.93
2.05
3.56
2.46
1.73
2.7
1.56

Conclusions

- Opportunities for storage in providing standing reserve seem promising (particularly for high wind penetrations)
- Storage used for reserve at lower wind penetration levels than in utilising surplus wind
- Storage results more promising than DSM results
- The use of storage & DSM due solely to the introduction of wind into the system
- Further study & refinement? EU 25 (European grid data, different storage technology cases, PV, wave, tidal penetration etc.)