Electricity Policy Research Group

Integrating wind generation in the UK electricity system

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- A summary

Integration of renewable generation

- New EU targets would require that up to 40% of the UK electrical energy is produced by renewables,
- Wind generation is presently the principal commercially available and scaleable renewable energy technology and wind will play a major role in delivering of the targets.
- There are 16 GW of applications to connect wind in Scotland and more than 8 GW offshore (England). Recently Government announced 33GW of offshore wind

- **Economics of the system with significant amount of intermittent renewables will be fundamentally different from the present conventional generation based system.**

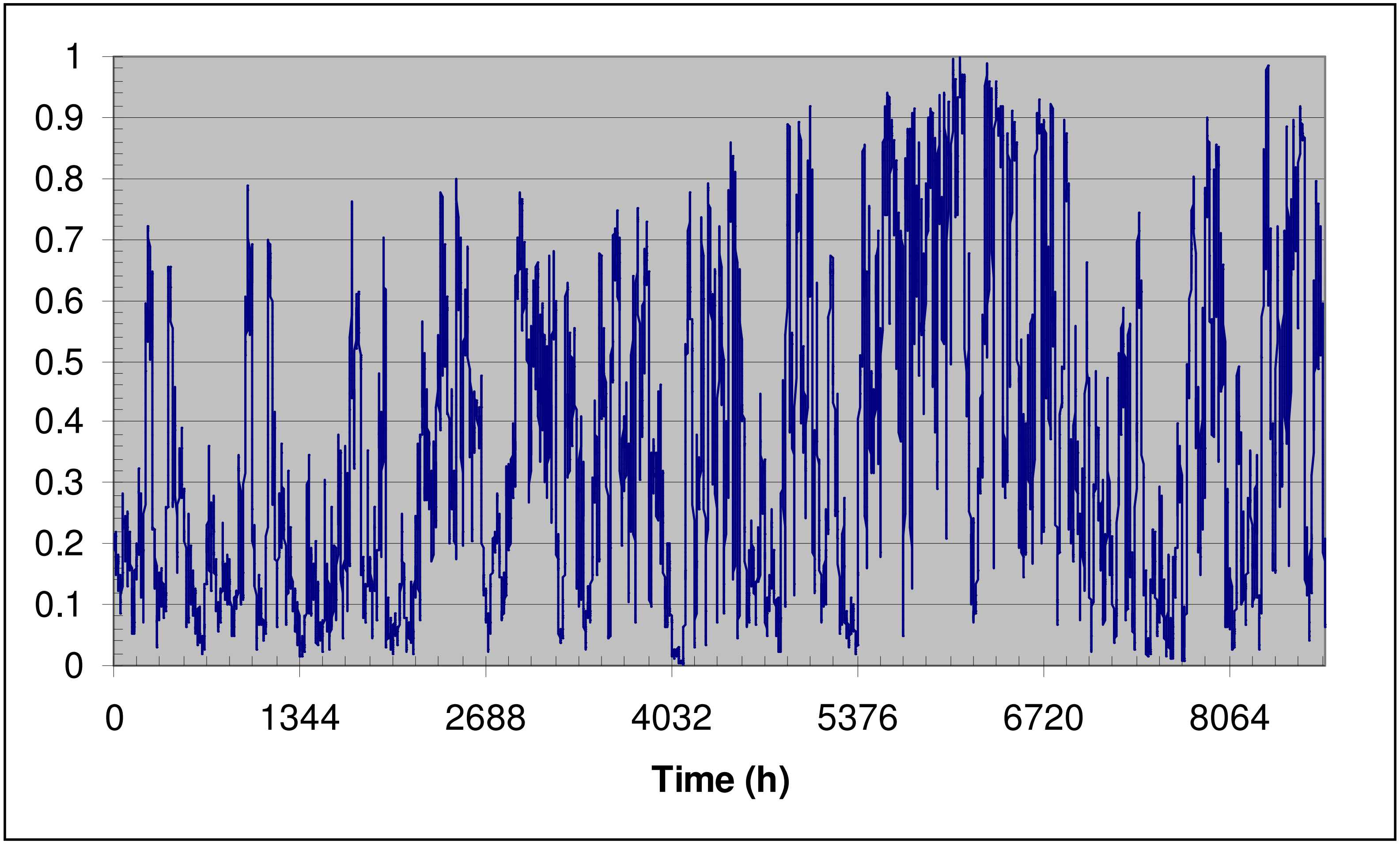
Challenges of integrating renewable generation /1

- Generation capacity adequacy
  - How "reliable" is renewable generation as a source? How much conventional capacity can it displace? Can interconnections help in firming up wind capacity value?
- Real time system balancing
  - What are the needs for flexibility and reserve? What are the costs? What is the role of storage, DS and interconnectors?
- Transmission networks requirements
  - How much transmission capacity is required to efficiently transport renewable power? Is transmission cost effective?

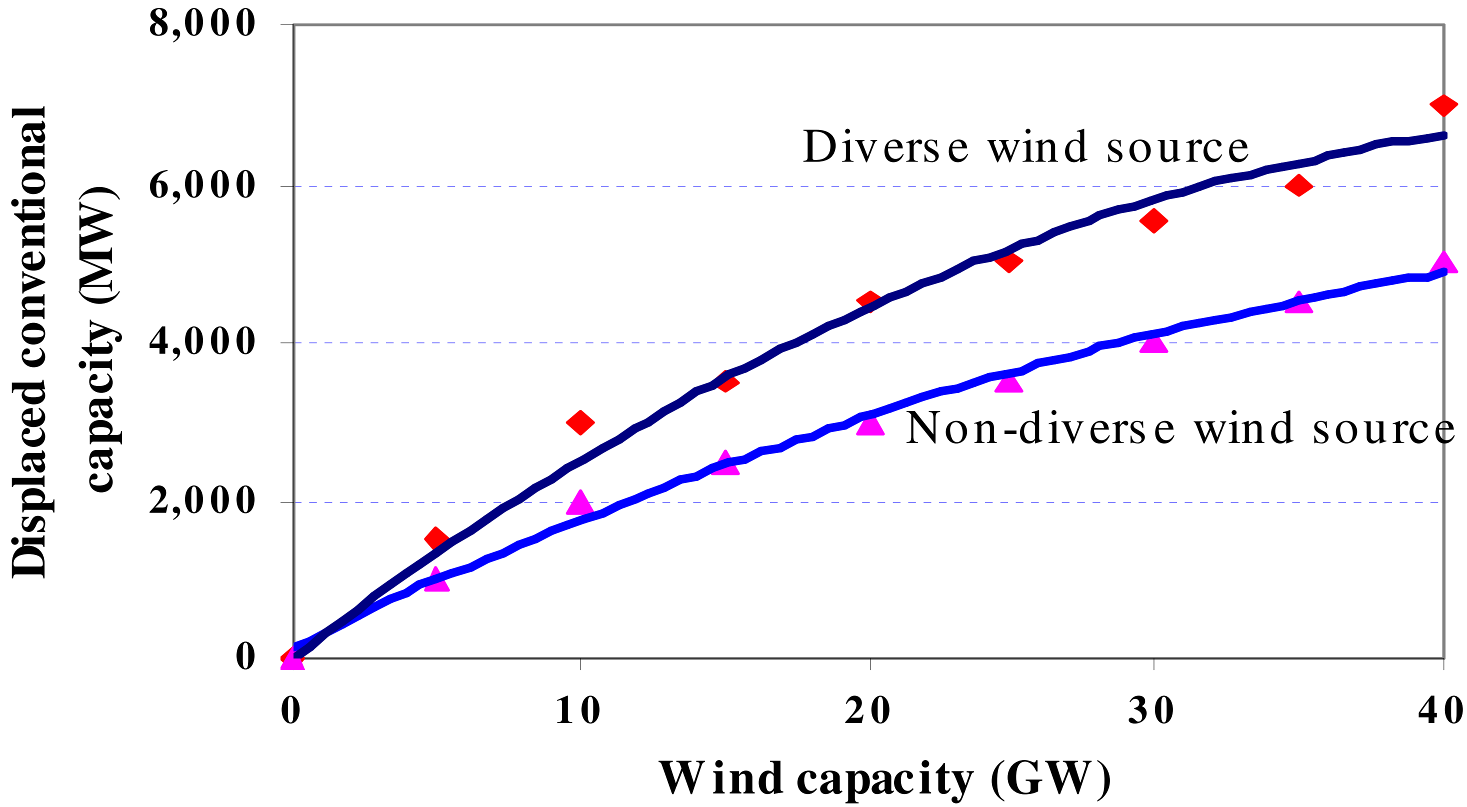
Challenges of integrating renewable generation /2

- System stability
  - What is stability performance of the system with new forms of generation? Can this technology contribute to improving stability?
- Technical, commercial and regulatory framework
  - Does the transmission access facilitate sharing of capacity? Does the market reward flexibility and security adequately?

How much can we rely on wind power?



Capacity value of wind



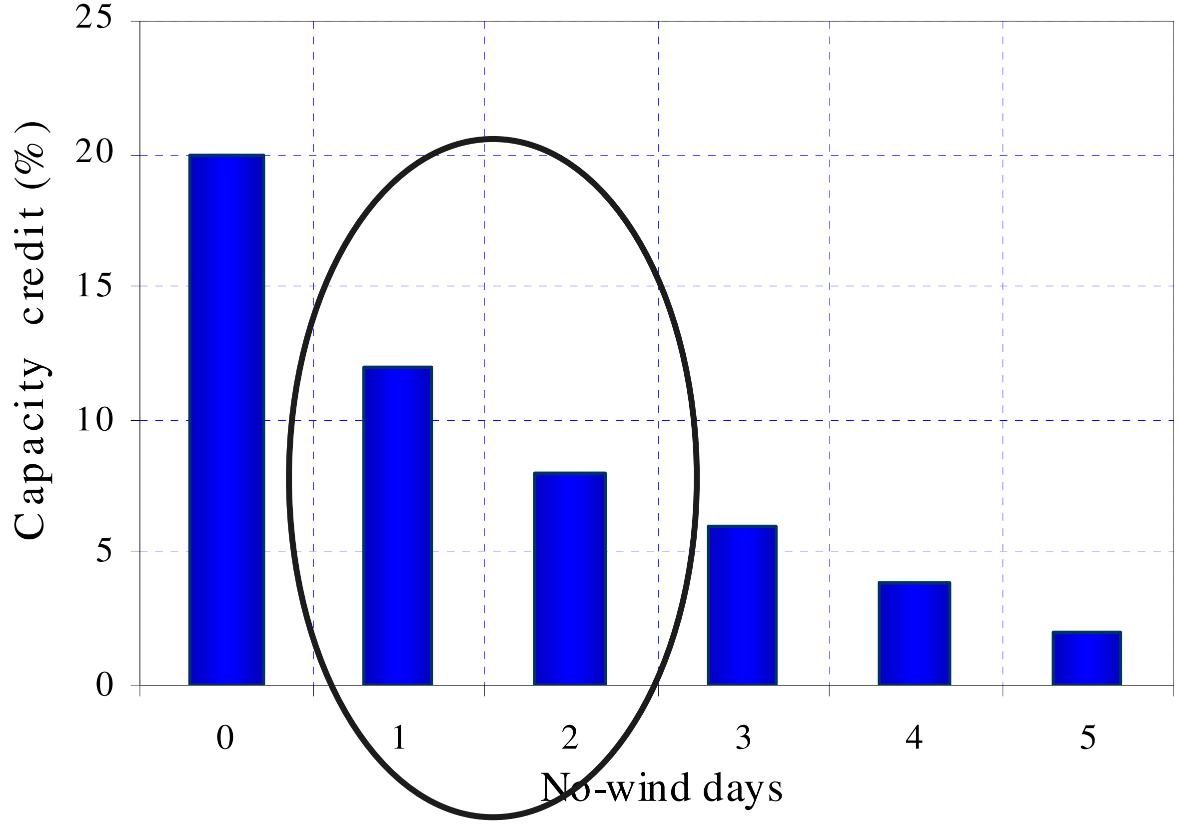
Ability of wind generation to displace the capacity of conventional plant is limited.

Capacity costs

- Driver of capacity cost: reduction in utilisation of incumbent generation system
- Value: direct function of the discrepancy in the displaced energy versus displaced capacity
- Additional capacity costs attributed to wind in £/MWh listed in table below
- Additional capacity costs attributed to base-load generation (e.g nuclear) ~5£/MWh

	Capacity Credit (%)			
Load Factor (%)	**0**	**10**	**20**	**30**
20	14.07	10.24	6.42	2.60
30	14.07	11.52	8.97	6.42
40	14.07	12.16	10.25	8.33

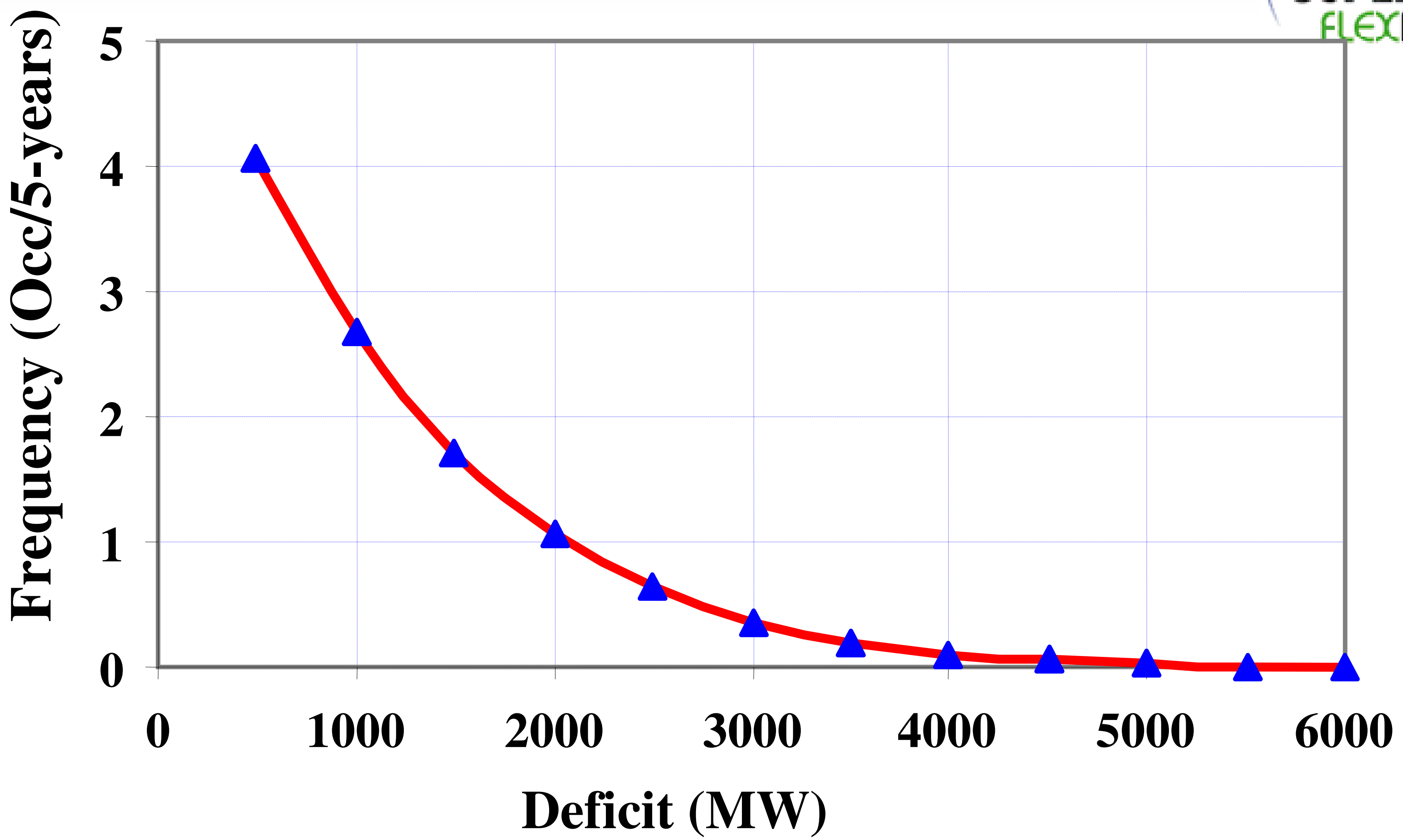
Effect of No Wind During Peak Demand On Capacity Credit Of Wind Generation



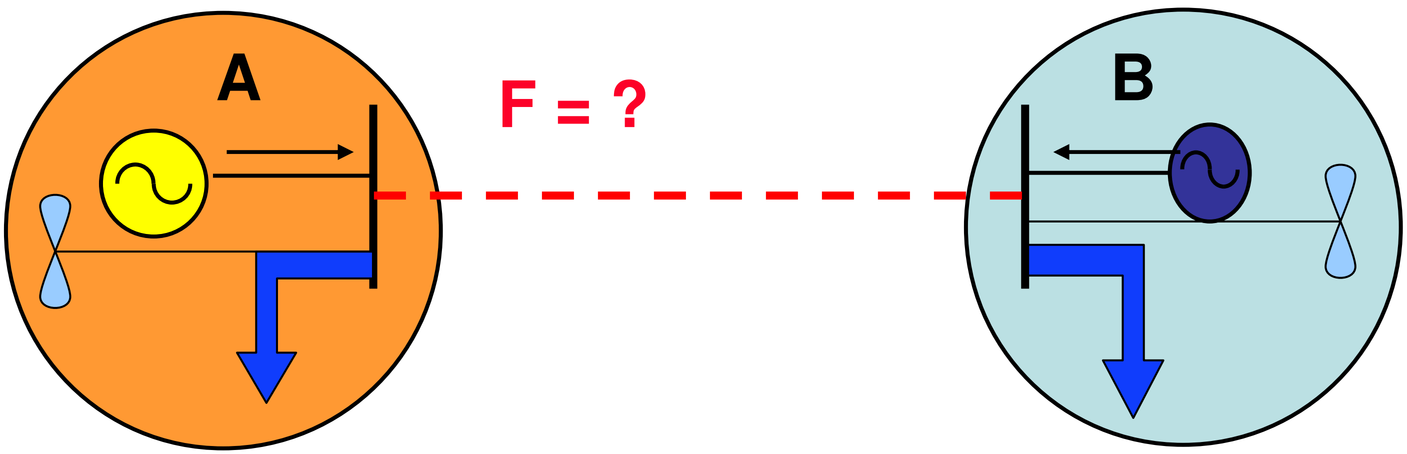
“Backup” options

- Conventional generation capacity - reduced utilisation
- Opportunities for Demand Side
- Interconnections: increasing diversity
  – Sharing of reserve between different geographical areas
  – “Firming” up wind by connecting wind farms in different areas

Opportunities for Demand Side



Firming up wind with interconnections



32 GW of C Gen
10 GW of Wind
25 GW of Demand

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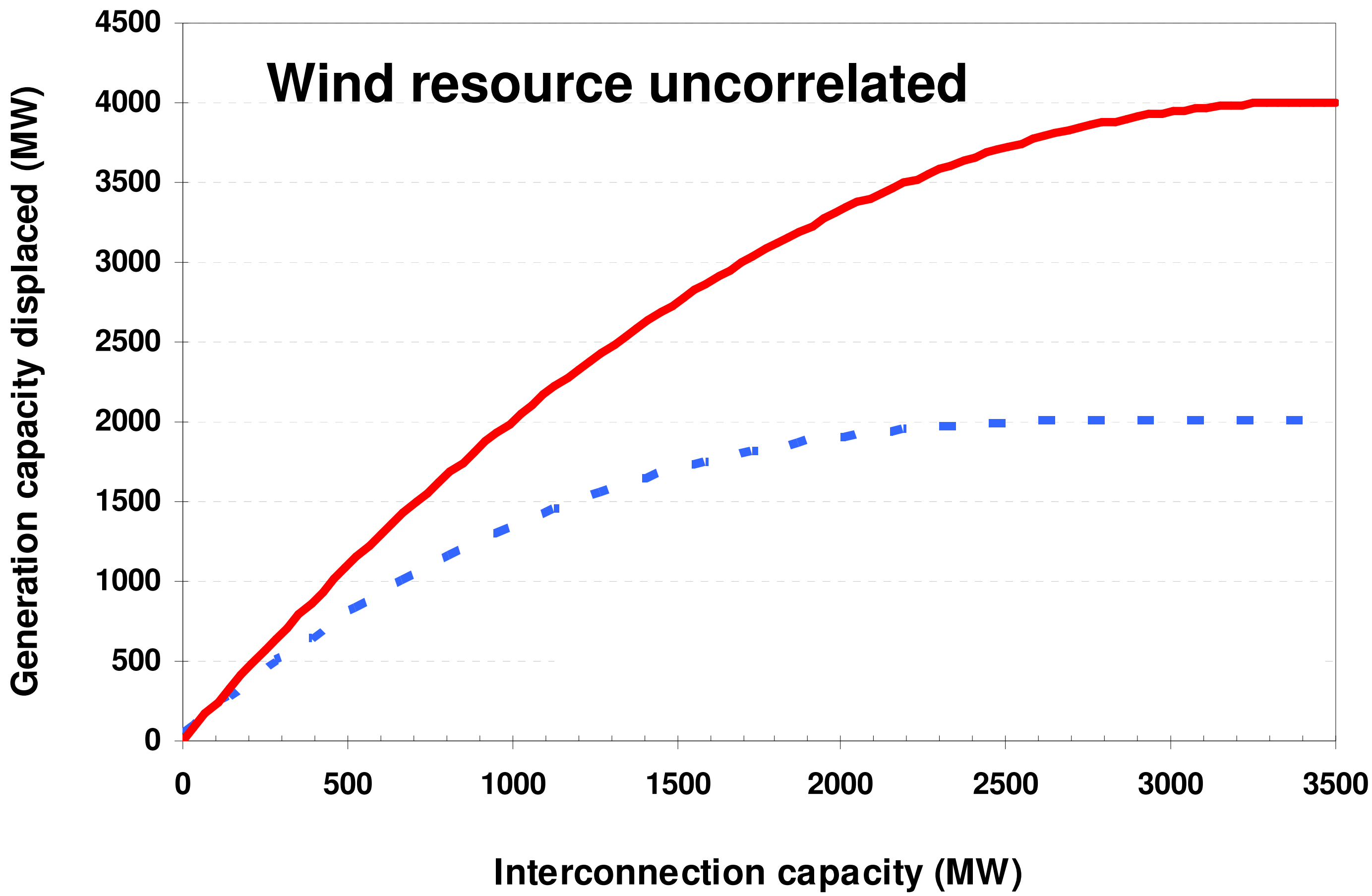
10 GW of Wind
25 GW of Demand

Firming up wind with interconnections

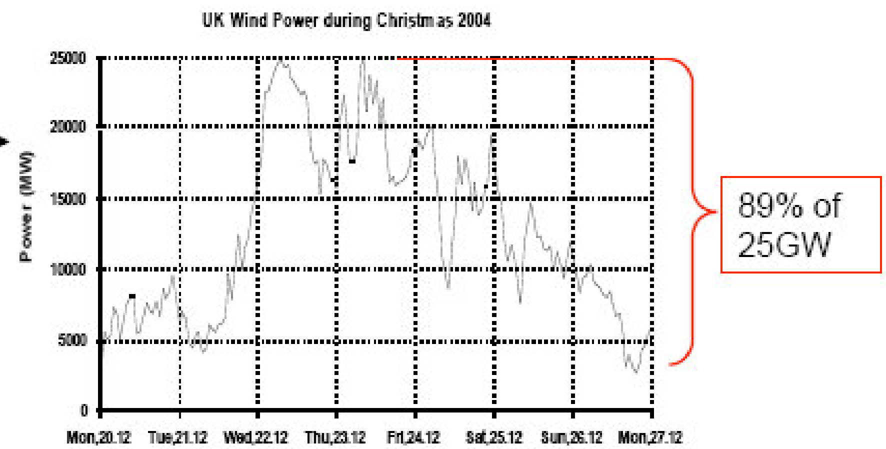


Oswald consulting: "Weather systems are much bigger than countries"

SUPERGEN FLEXNet

- In the week of Christmas 2004 E.ON Netz in Germany reported a major rise and fall in power from their wind fleet.

- For the same time, the UK model predicts the same occurring in the UK



Oswald Consultancy Ltd

SEDG centre for Sustainable Electricity & Distributed Generation

Balancing task

- Wind generation output is difficult to predict and is very variable
- Predictability:
  - Forecast error increases with prediction time horizon
  - Need for frequency regulation services and various forms of reserve will increase and hence cost of operation and CO2 emissions
  - Not all wind generation may be possible to accommodate simultaneously
- Variability:
  - Increased need for flexible plant

Key drivers of costs

- **Generation system parameters** – technology and technical characteristics, fuel cost, start up costs, flexibility (minim stable generation, ramp rates, minimum up and down times), CO2 output
- **Intermittent generation characteristics** – predictability and variability (***area occupied***)
- **Reserve allocation policy** – spinning versus standing, forms of standing reserve are considered are conventional generation (e.g. OCGT), storage and Demand Side Management, Interconnectors

Estimates of wind forecast error and reserve requirements for 26GW of wind

Lead Time [Hours]	Standard Deviation [MW]	Likely maximum change [MW]	Extreme change [MW]
0.5	360	1,090 – 1,450	2,600
1	700	2,100 – 2,800	3,950
2	1,350	4,050 – 5,400	6,550
4	2,400	7,200 – 9,650	13,500

4 hours may be required to schedule large CCGT

Likely additional reserve requirements

Reserve options

- **Reserve provided by synchronised (fossil fuel) plant running part loaded**
  - Cost driven by loss in efficiency of part loaded plant (20%CCGT and 10-15% coal)
  - Increased emissions
  - Additional plant needed to compensate for running part loaded
  - *Energy delivery accompanies provision of reserve*
  - Cost of providing reserve with nuclear plant could be considered
- **Reserve provided by standing plant**
  - Use standing plant with higher fuel cost if and when needed
  - Can be provided by plant (e.g OCGT), storage and DSM
- **Optimal mix of synchronised and standing reserve**
  - Balance between cost of holding synchronised reserve and cost of exercise of standing reserve
  - Impact on wind power that can be absorbed

Generation systems studied

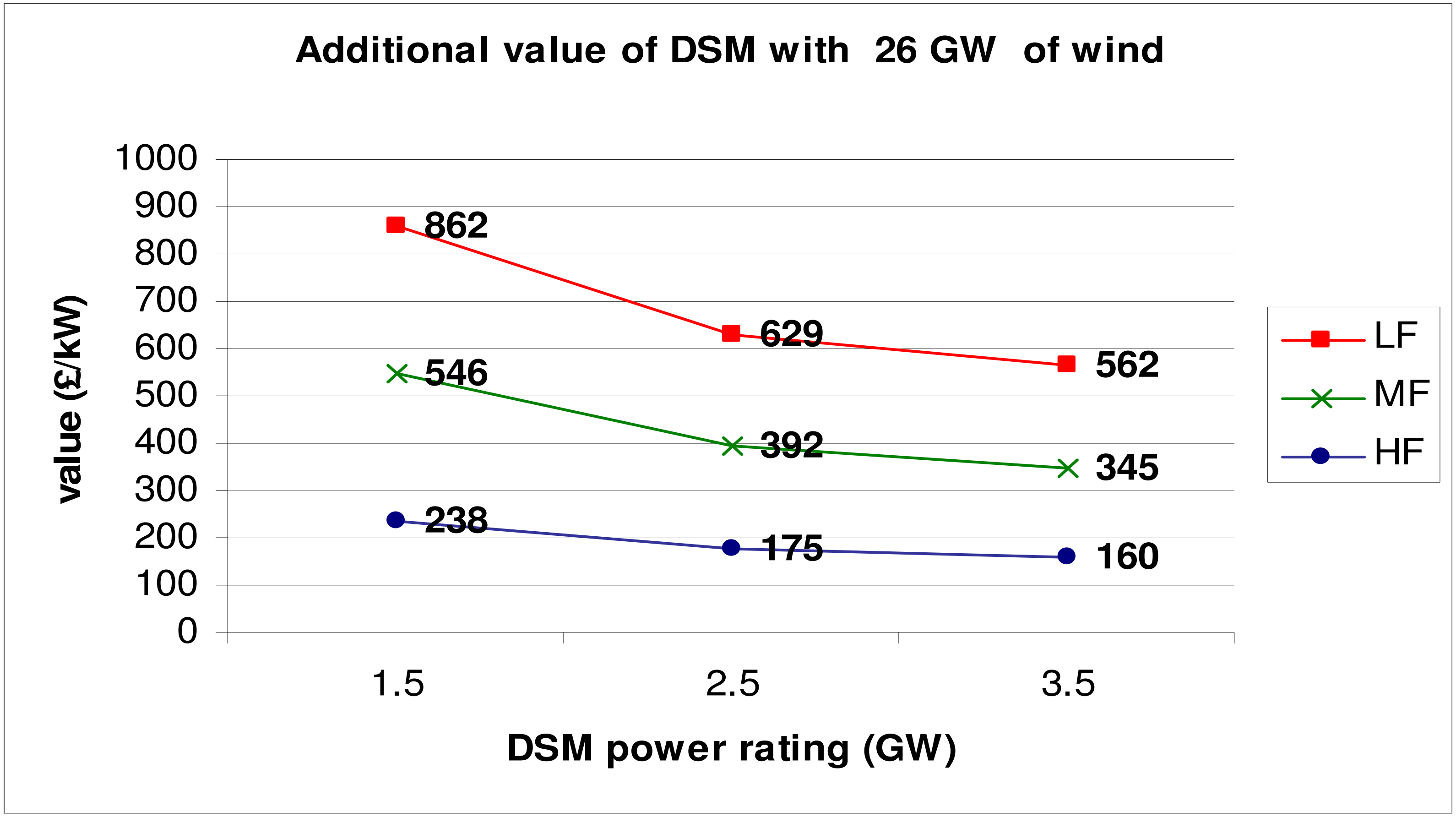
Generation System	*Parameters*	Inflexible Generation	Generation of moderate flexibility	Flexible Generation
Low Flexibility (LF) Generation System	MSG	100%	77%	50%
	Capacity installed	8.4GW	26GW	>25.6GW
Medium Flexibility (MF) Generation System	MSG	100%	62%	50%
	Capacity installed	8.4GW	26GW	>25.6GW
High Flexibility (HF) Generation System	MSG	N/A	N/A	45%
	Capacity installed	0 GW	0GW	>60GW

Surplus energy: impact of flexibility and role of interconnections

Generation flexibility → Reserve policy ↓	High Flexibility	Medium Flexibility	Low Flexibility
Demand 70 GW	364	654	1322
Demand 56 GW	455	1187	2822

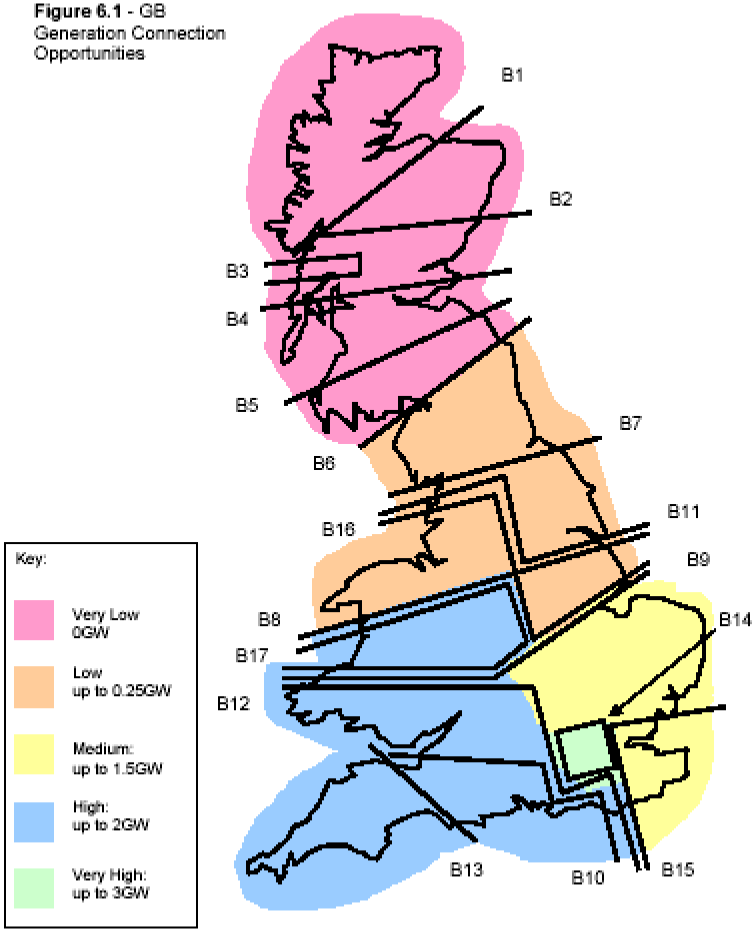
Number of hours of surplus electricity

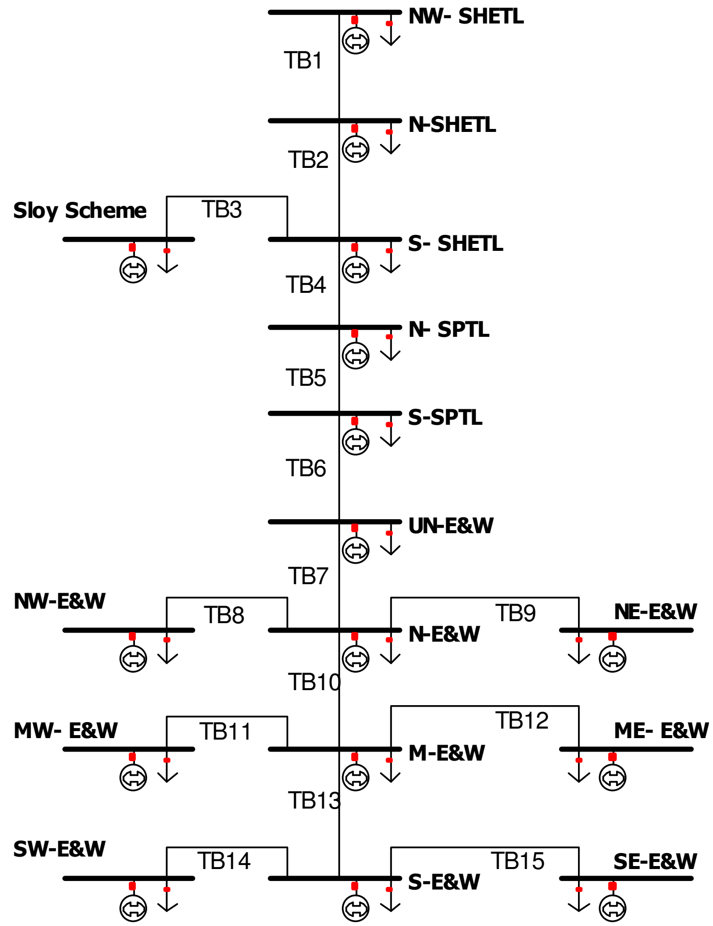
Potential for DSM



Impact on the GB Transmission System

Figure 6.1 - GB Generation Connection Opportunities





Shift in the nature of the network investment and operation

- Historically, reliability driven design of transmission network to meet peak demand requirements, tended to deliver economically efficient solution (limited constraints)
  - GB SQSS imposes such requirements for transmission capacity that enables all conventional generation to run at (almost) full output simultaneously.
- This will need to change with considerable penetration of wind energy
  - Wind has a limited contribution to security of supply; requirements for maintaining conventional generation capacity
  - Large capacity margins, generation capacity significantly exceeds demand
    - Example: 60GW peak demand supplied with 72 GW of conventional generation =>20% capacity margin); add another 26GW of wind (that displaces say 5GW); installed capacity 93 GW to supply 60GW of peak=> more than 50% capacity margin
  - Network capacity should be shared between : e.g. on windy days, wind will tend to occupy transmission capacity, on non-windy days conventional generation takes over

Cost benefit analysis

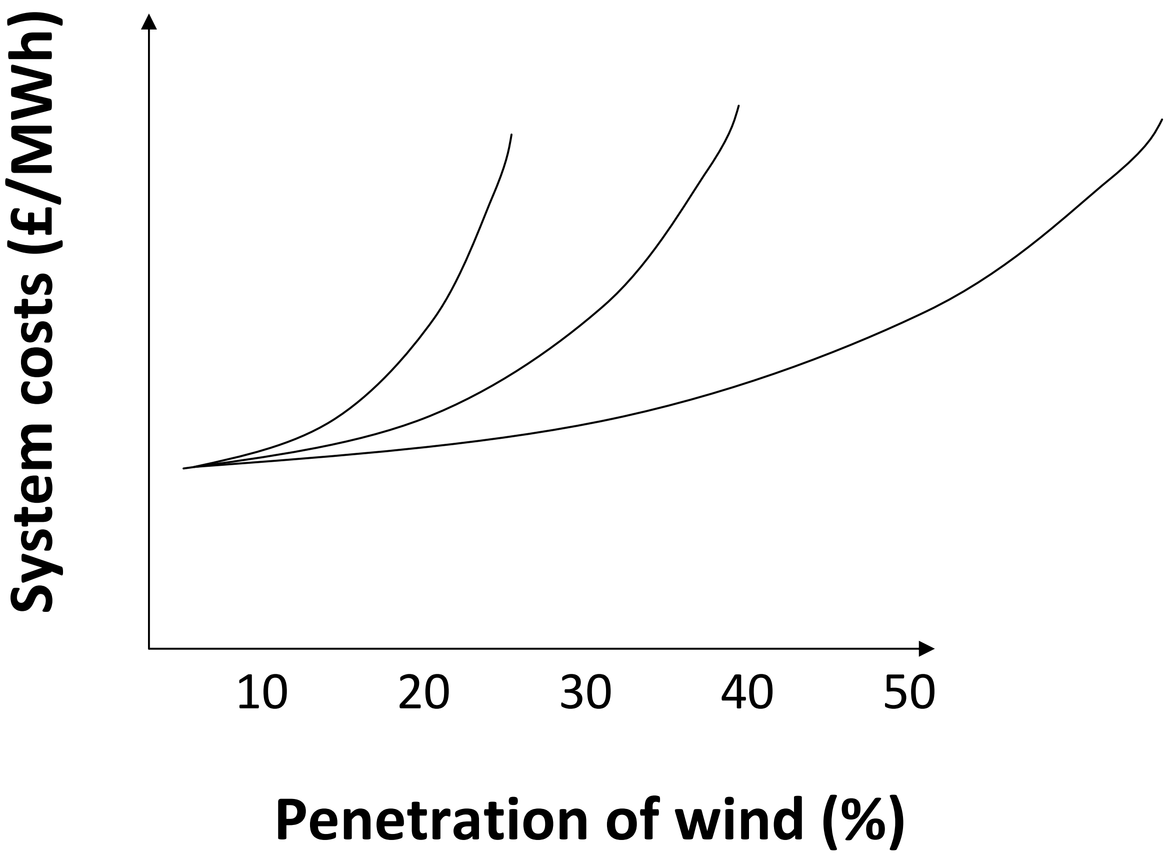
- Cost-benefit analysis: balancing cost of transmission investment against the benefits of reinforcement, i.e. reduction of constraint costs over the life span of the investment (approach adopted in the development of SQSS for offshore networks)
- Two general approaches to economics driven investment decision making
  - Centralised; develop an appropriate CBA within GB SQSS
  - Decentralised; exclude CBA from the standard
- In systems with wind generation, economics likely to drive larger transmission capacities than reliability considerations
  - Depending on the relative magnitude of (marginal) cost of constraints (incurred by constraining conventional generation in Scotland on windy days and constraining on conventional generation and England), versus (marginal) cost of transmission
  - It is not justified to constrain off wind power significantly
- Economic efficiency driven increased transmission network capacity suggest that the reliability of the network will be higher than in present system

Transmission boundary capacities

From	To	Security	Economics
NW-SHETL	N-SHETL	2100	2437
N-SHETL	S-SHETL	3500	3571
S-SHETL	N-SPTL	3300	4110
N-SPTL	S-SPTL	4100	3564
S-SPTL	UN-E&W	4300	5357
UN-E&W	N-E&W	4700	4935
NW-E&W	N-E&W	2400	1942
NE-E&W	N-E&W	5600	2218
N-E&W	M-E&W	8700	7870
MW-E&W	M-E&W	6800	4798
ME-E&W	M-E&W	5400	4459
M-E&W	S-E&W	8100	8434
SW-E&W	S-E&W	3400	2781
SE-E&W	S-E&W	5100	1438

Total installed capacity of generation (conventional plus wind) in Scotland, in the study, is 19.5GW and local load of 6.5GW.

Magnitude of the overall system integration costs?



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