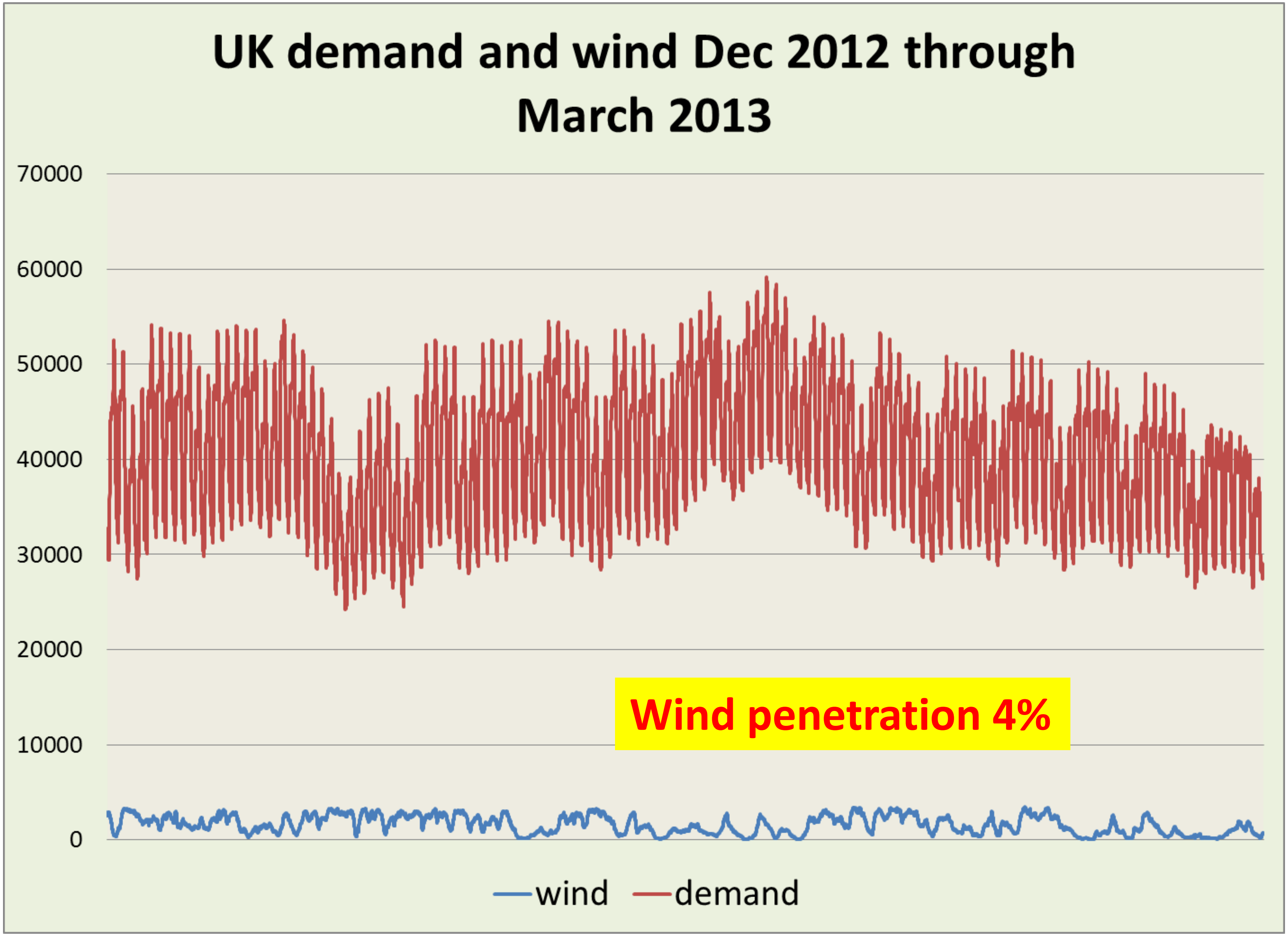
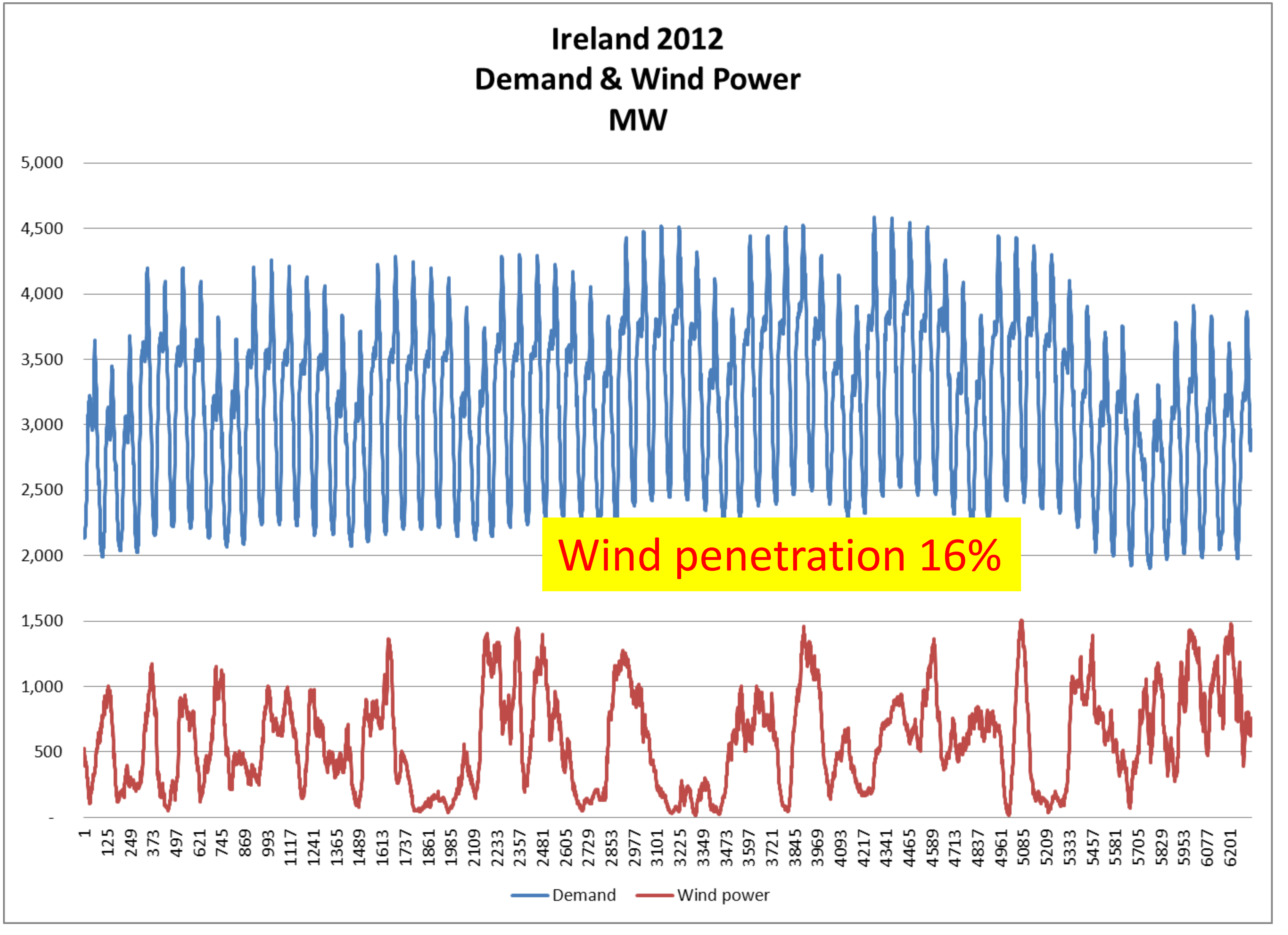
Wind imbalance in UK
Technical solutions for mitigation

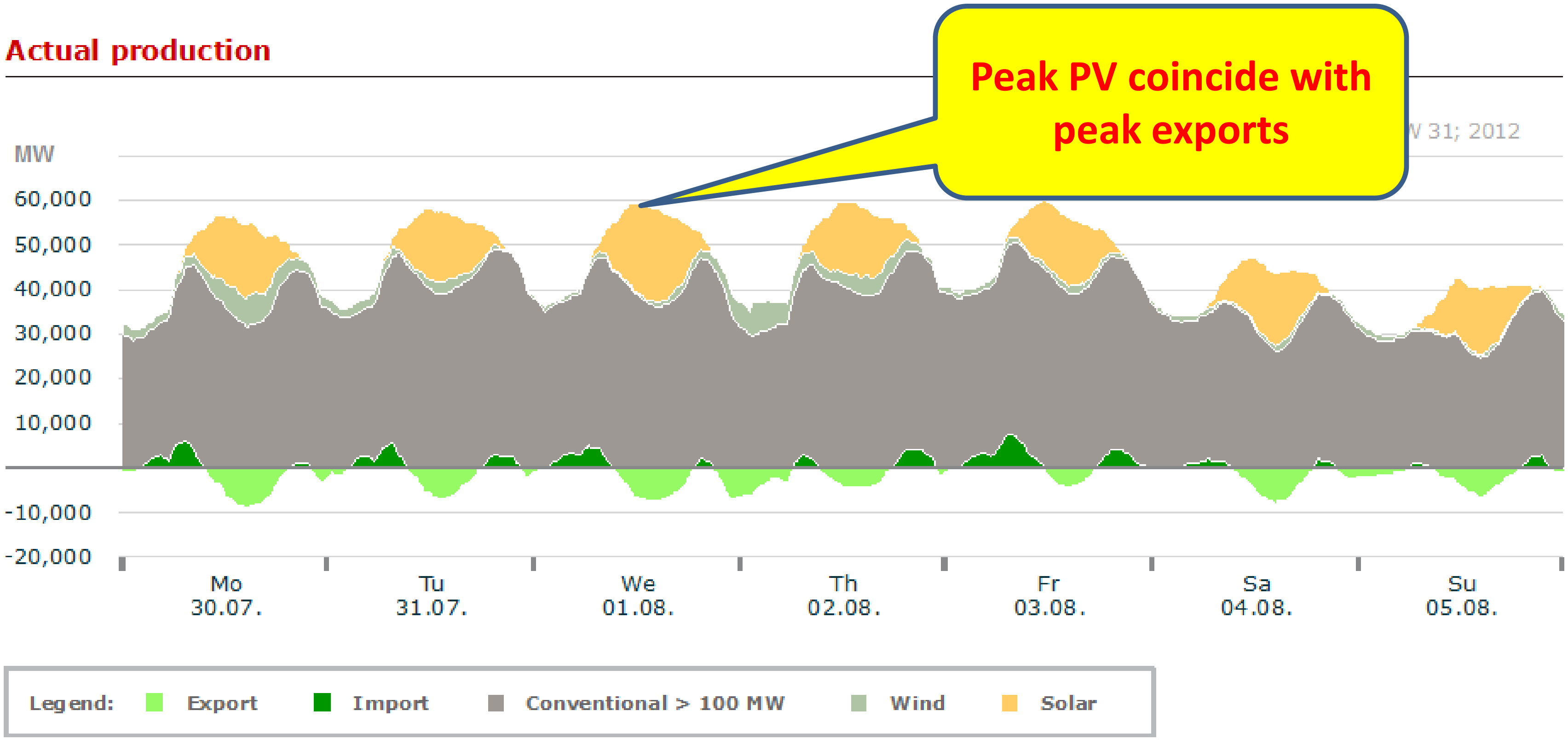
Background

- Wind generated power in the UK during the winter 2012 – 2013 was about 4% of all electricity generated. This contrasts with
  - Ireland, an electricity island like UK, where wind generated 16% of all MWh during 2012
  - Denmark, where wind generates the equivalent of 25% of electricity consumed and is enroute to generating 50% of all electricity consumed by 2020
  - Germany, where wind and PV generated 15% of all electricity in 2012 on a rapidly rising curve


UK demand and wind Dec 2012 through March 2013
70000
60000
50000
40000
30000
20000
10000
0
Wind penetration 4%
wind
demand


Ireland 2012
Demand & Wind Power
MW
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
Wind penetration 16%
1
125
249
373
497
621
745
869
993
1117
1241
1365
1489
1613
1737
1861
1985
2109
2233
2357
2481
2605
2729
2853
2977
3101
3225
3349
3473
3597
3721
3845
3969
4093
4217
4341
4465
4589
4713
4837
4961
5085
5209
5333
5457
5581
5705
5829
5953
6077
6201
Demand
Wind power

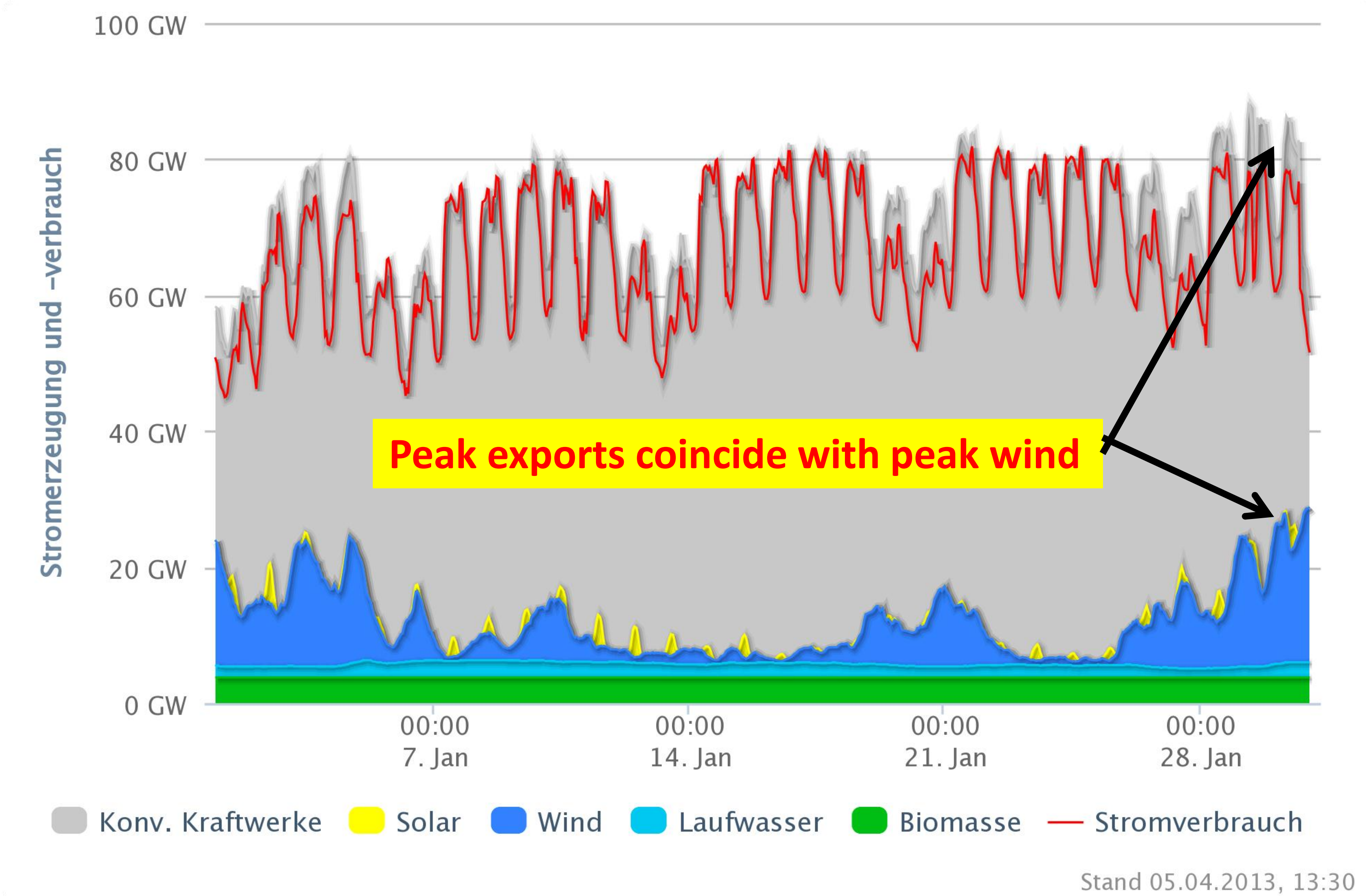
Germany – week 31 2012

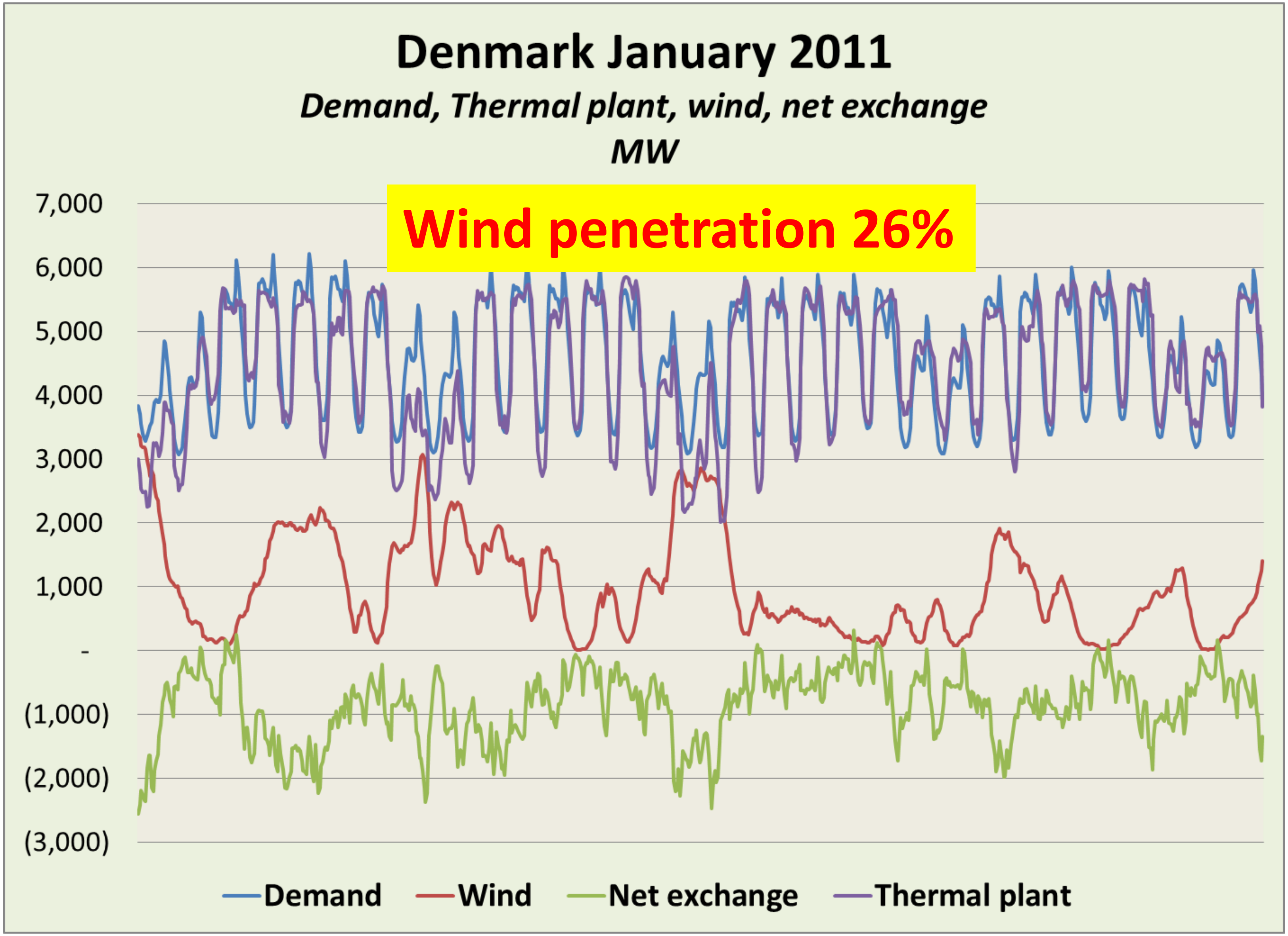


Graph: Bruno Burger, Fraunhofer ISE; Data: EEX, http://www.transparency.eex.com/de/

Fraunhofer ISE

Germany, January, 2013





Net flows of power in and out of Denmark inversely follow wind input

Main mitigation strategies for system balancing

- Ireland
  - Wind curtailment and centralized control
  - Inter-connection with UK
- Germany
  - Wind and PV curtailment, until mitigated by grid and distribution strengthening
  - Use of inter-connectors throughout middle Europe
  - Market mechanisms (in short term) like virtual power
  - Longer term, wider use of technical solutions (like storage)
- Denmark
  - Heavy use of inter-connection with larger, hydro-based neighbours
  - Transfer of heating from fossil fuel to wind (heat pumps)
  - Electrification of transport (if feasible)

Ireland – ”dispatch down” 2011

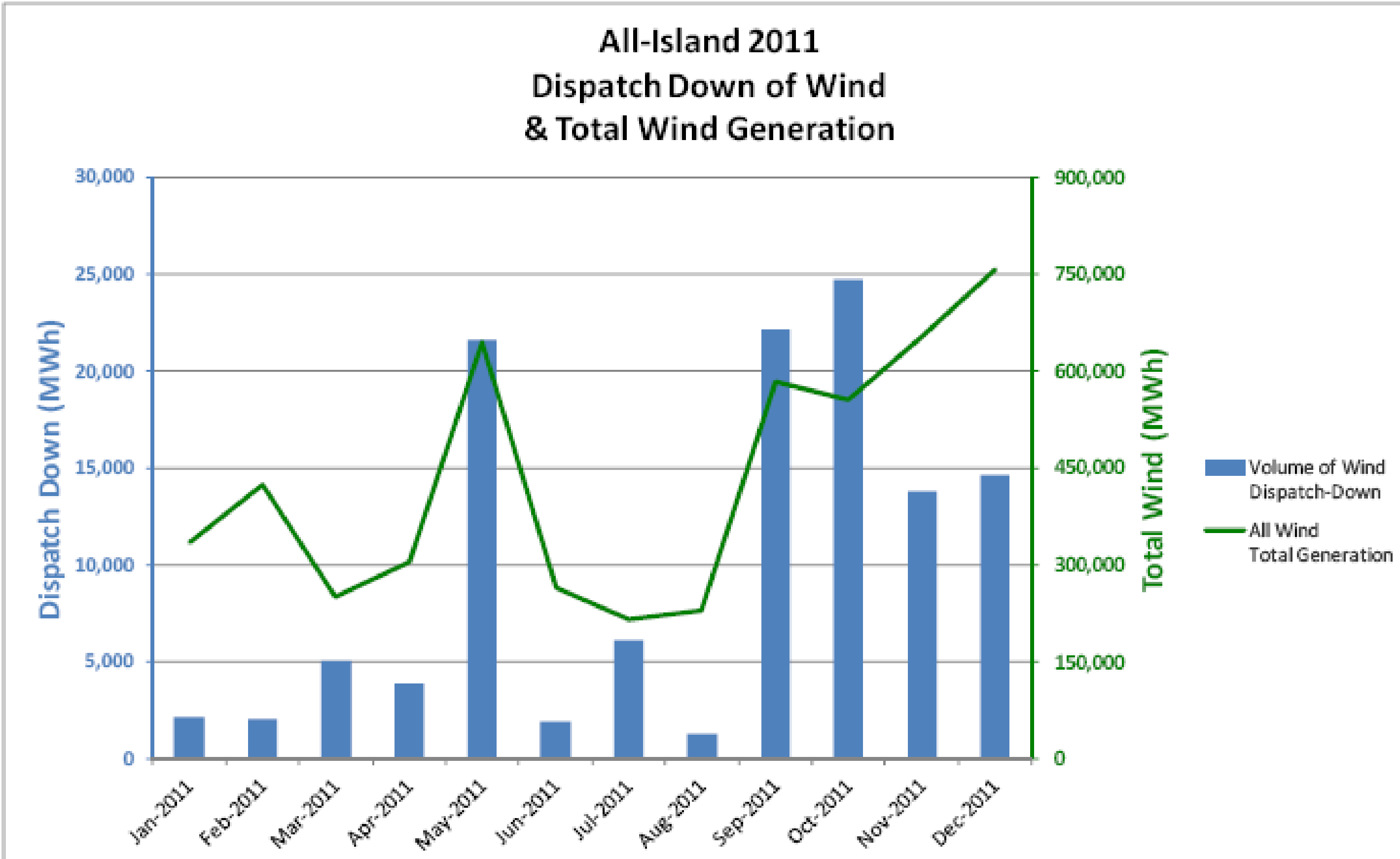


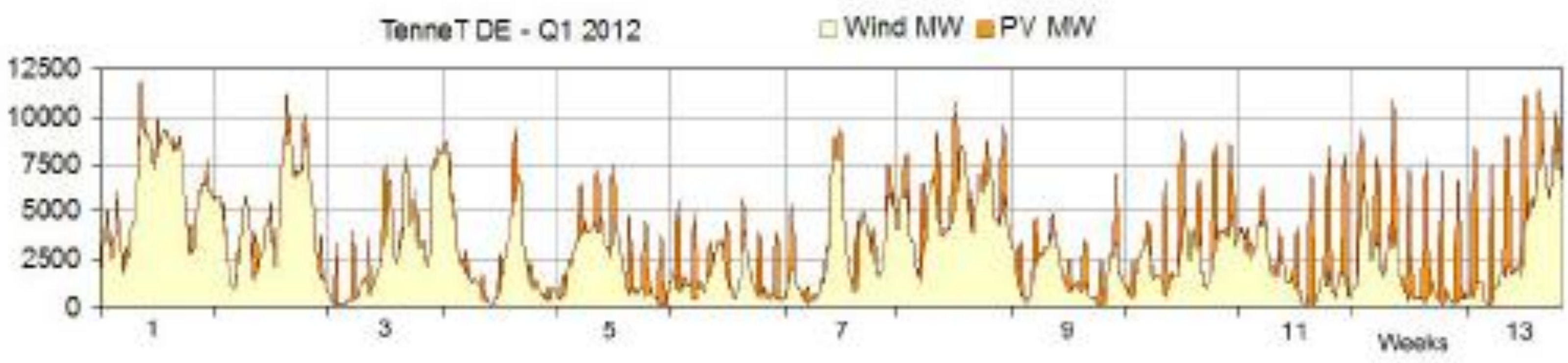
Figure 3 Ireland and Northern Ireland dispatch-down of wind 2011

High wind months result in higher curtailment

Germany

Curtailments for 23% of the time within Tennet's control area, Q1 2012 (anecdotal example)

- Wind yellow, PV orange



- Heavy use of neighbour's systems for exports is causing stability issues in Poland and Czech Republic
  - Who are responding with the construction of phase-shifting transformers
- Developing market based technical solutions like virtual power plants (VPPs)
- Massive future development of electricity storage technologies at all points in the electricity supply chain

Denmark

- Peak demand 2012 about 6.2 GW
- Inter-connection capacity in 2012 5.9 GW
  - By 2014, 6.6 GW
  - By 2020, possibly 8
  - All made possible by being effectively an electrical highway between the much larger Nordic and EU systems
- Electricity is intended to displace fuel for district heating (mid-term)
- Electricity is intended to displace fossil fuel in transport (longer term, if feasible)
  - EV sales only 7% of Government targets in 2012
  - Vehicle to Grid looks unlikely with presently available batteries

TSO can curtail wind power but this measure is rarely used

Curtailment, whether directly compensated or not, will add cost to weather dependent energy and must be innovated away

Mitigation measures review

Priotitised according to cost effectiveness

1. Virtual power plants (VPPs)
2. Improved wind forecasting
3. Reduce gate closure by increasing fast-acting STOR
4. Electricity storage
5. Storm-ride through turbines
6. Inter-connection between systems
7. Centrally operated curtailment and ramping control

Mitigation measure – 1

Formation of virtual power plants (VPPs)

- **Definition**: a system that relies upon software systems to remotely and automatically dispatch and optimize generation, demand-side, or storage resources (including plug-in electric vehicles and bi-directional inverters) in a single, secure web-connected system
- ICT, together with:
  - site specific wind forecasts
  - remotely operated stop, start and ramp controls for wind turbines
  - can collectively reduce the uncertainty of the output of widely distributed wind generators
  - dispatchable plant and demand-side measures can completely eliminate uncertainty

A VPP operator need own no generating assets

Economic drivers for VPPs

- Promises among the lowest up-front cost measures to reduce the imbalance risk to weather-related generators caused by forecasting uncertainty
- Principle investment is in existing and well tested information and computing technologies
  - And of course management skills
- Interesting variety of VPPs are setting up business in the USA and Germany

VPP developments in Germany

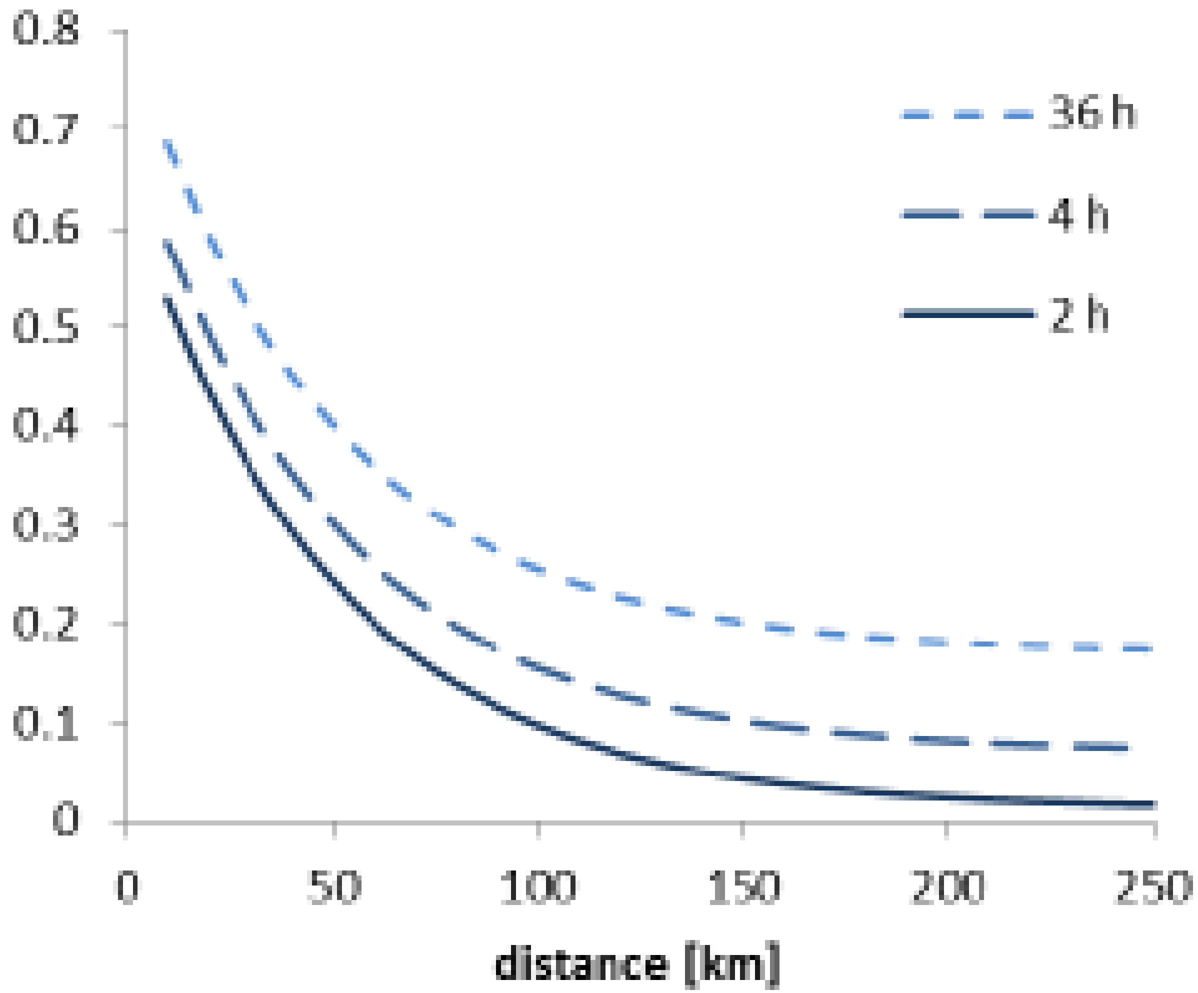
- The growing difficulties of balancing Germany’s 4 inter-connected electric systems as the capacity of weather dependent generators at all levels of the system has increased, has stimulated a large number of innovative players
- All the major generators and equipment suppliers are studying various configurations of ”intelligent” distributed power plants

A wave of new VPP formations in Germany

- Statkraft, in joint venture with *Energy & Meteo Systems*, announced the formation of ”Germany’s first intelligent wind park” in October 2012,
- This is a VPP comprising 15 turbines selling direct marketed wind power into the German market
- ...and featuring ”stepless remote control”

Correlation of two wind parks depending on the distance of the wind parks and time of forecast

Source: DIW Berlin, Discussion paper 1162, 2007



Vattenfall's VPP features combined wind and heat production

- Electric power is used to drive existing and new heat pumps in 200,000 housing units
- Each housing unit has a heat storage capacity (hot water tank) that allows for a high degree of flexing on the demand side
- The power supply side is mainly based on directly marketed, unconstrained wind turbines...
- ...so that the VPP thus created can deliver the electric equivalent of a 200 MW central power plant by the end of 2013

Source: Vattenfall Brochure, *The Virtual Power Plant, wind power meets heat*

Siemens, for Munich's municipal utility and RWE

- Siemens, using its distributed energy management systems, put two virtual power plants into operation during 2012.
- A new virtual power plants enables the Munich municipal utility company to run six of its cogeneration modules, five hydroelectric facilities, and one wind-power plant more efficiently and economically than if they were operated separately.
  - This facility has a combined output of 20 megawatts.
- The second was set up for RWE and consists of a number of similar components to those in Munich.
- Initially this will have an output of 20 megawatts but will be expanded to 200 megawatts by 2015.

Expandability is a key feature of VPPs

VPPs UK practioners include...

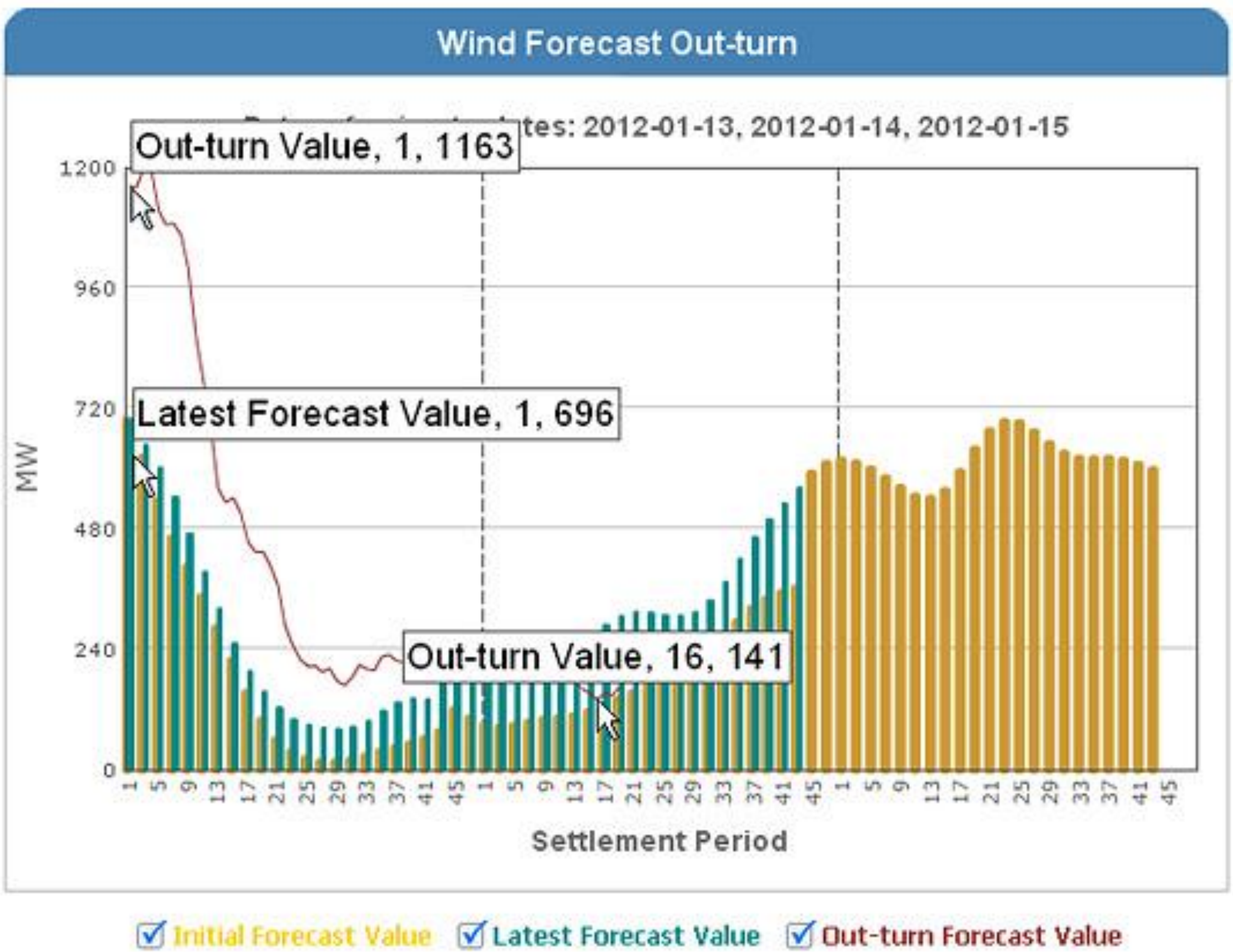
- UK practitioners include:
- Flexitricity
  - Well established UK business
  - Matches demand-side players able and willing to flex demand with owners of standby generation equipment who can derive income from an existing asset
    - Often standby diesels
  - Sells power regulating services to National Grid
- Kiwi Power
  - Focuses on demand-side customers willing and able flex to demand

There is no reason why weather dependent generators could not become partners to existing players

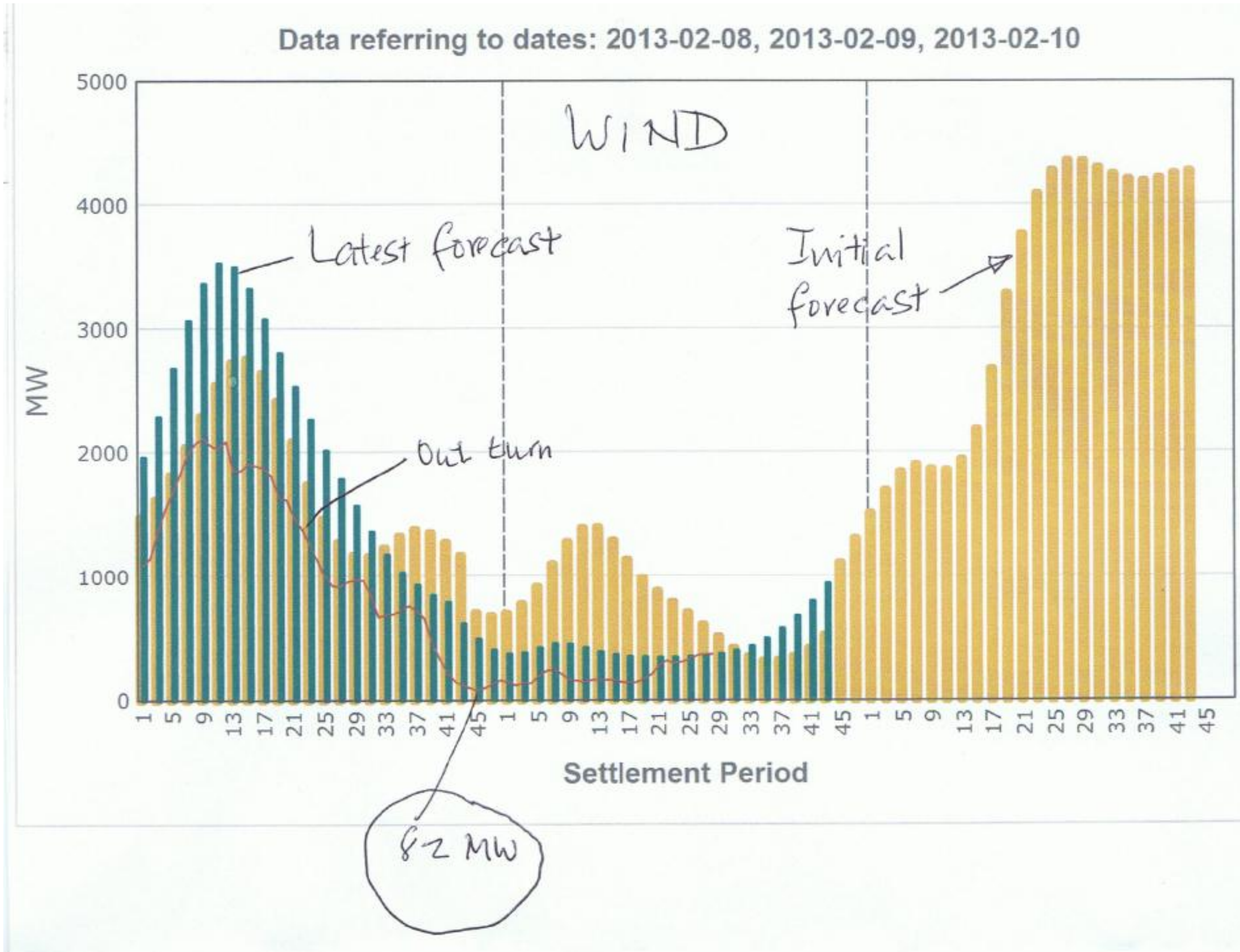
Mitigation measure – 2
Improved wind forecasting

- Better weather forecasting is without cost but it **cannot be mandated**
- In general, weather forecasting, in particular wind forecasting, is improving because the financial benefits from improvements far outweigh the costs of incremental investment
- The storms mentioned in the previous section were examples of weather events being under-estimated
- But the day to day technology is far from perfect as the following slides indicate

13 January 2012



8February 2013



Improvements to wind forecasting

- Forecasting wind is a hugely competitive business with many players each striving to reduce weather risk from their energy clients' business model
- The UK energy market supports a wealth of weather and in particular wind and temperature forecasting companies
  - Resolution is allowing ever better forecasts
  - With ever improving resolution at specific locations
- Further improvement cannot be mandated by decree but must depend on incremental improvements brought on by better computing technology and better understanding of atmospheric movements

We expect that the forecasts will show a 65 per cent improvement by 2025 and be 85 per cent better by 2040
(Deutsche Banks, *The State of Electricity storage*, 2012).

Mitigation measure 3

Reduce gate closure by increasing fast-acting STOR

- The primary function of Short Term Operating Reserve (STOR) is to deliver fast-starting power and fast response demand reduction in the event of a sudden major loss of power in the system
- This is presently supplied by pumped hydro, industrial customers with interruptable contracts and a growing fleet of distributed, fast-start, dedicated diesel engines
- A higher concentration of weather related power production requires adequate spinning reserve to deal with the weather related events as seen in the storm events of the winter 2011 - 2012

Types of fast acting reserve

- It takes 3 hours notice to bring a CCGT or up to 4 hours for other large thermal generating plant before they can synchronise on the grid
  - Causing high fuel consumption and emissions with each stat and stop event
- A much larger capacity of flexible, fast start units could reduce reliance on central power plants
- The higher running costs of such units could be offset by their lower capital cost and faster start and stop régime
- **These power plants can be integrated into VPPs**
  - **A disadvantage is their use of fuel and high specific emissions**
- Electricity storage, at prices that are at the same general level of new fossil plant, (£1000 - £2000 per kW) is becoming available
  - **With out emissions**

Mitigation measure 4
Electricity storage

- Pumped hydro capacity in UK amounts to:
  - Dinorwig, North Wales, 1,728 MW/9 GWh
  - Ffestinog, North Wales, 360 MW/1.3 GWh
  - Cruchan, Scotland, 400 MW/8.8 GWh
  - Foyers, Scotland, 300 MW/6.3 GWh
- Total 2,788 MW/25.4 GWh
- It is doubtful that much, if any, new pumped hydro capacity can be accommodated in UK, for geographical and environmental amenity reasons

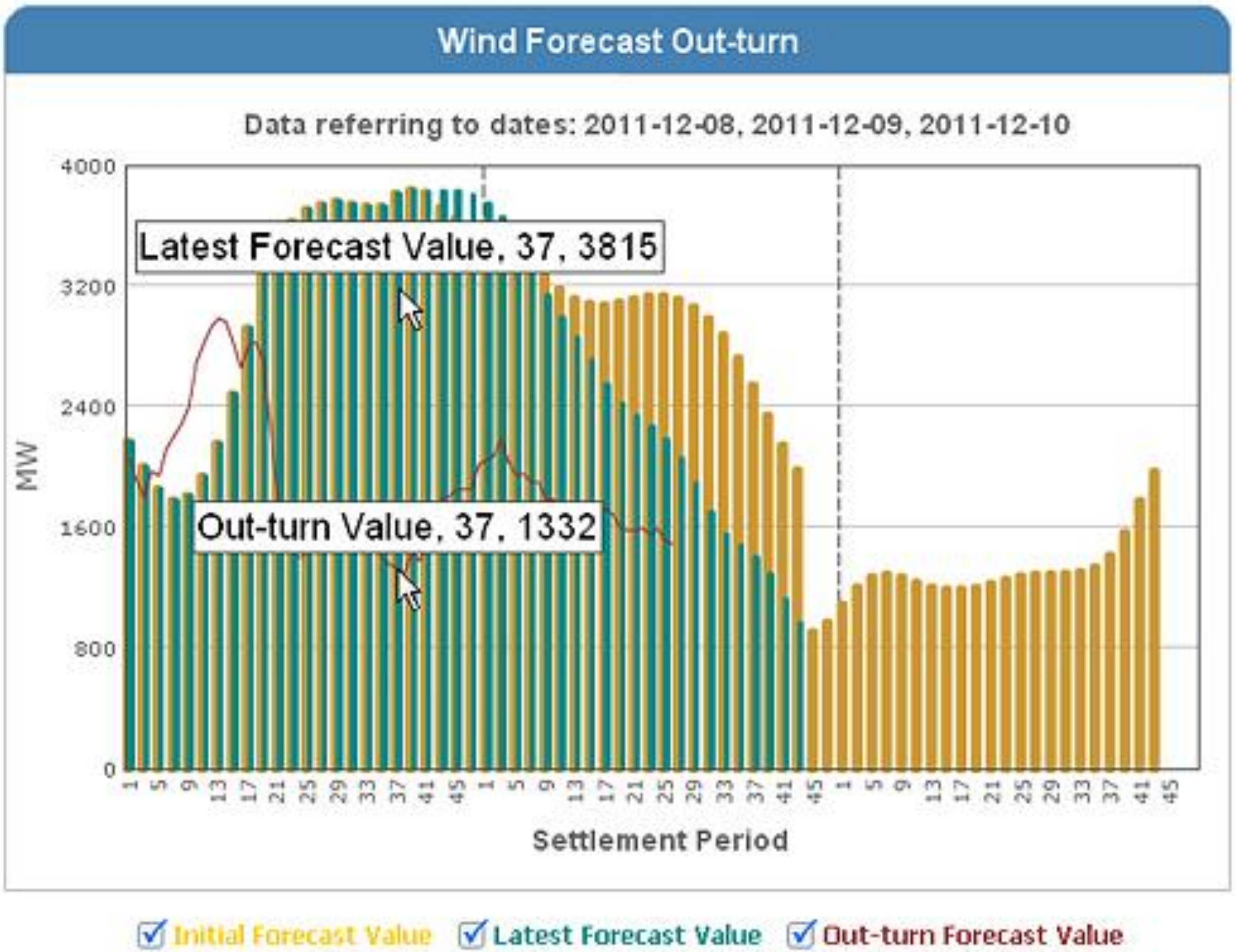
Germany foresees more electricity storage as an indispensable feature of the Energiewende

- Germany has 6.3 GW of pumped hydro and 400 MW of compressed air energy storage (CAES)
- As in UK, expansion of pumped hydro will be limited by geographical & environmental constraints
- VPPs are foreseen as an economic and rapidly implementable solution but one that will eventually run out of capacity for dealing with overall shortages and surpluses of energy

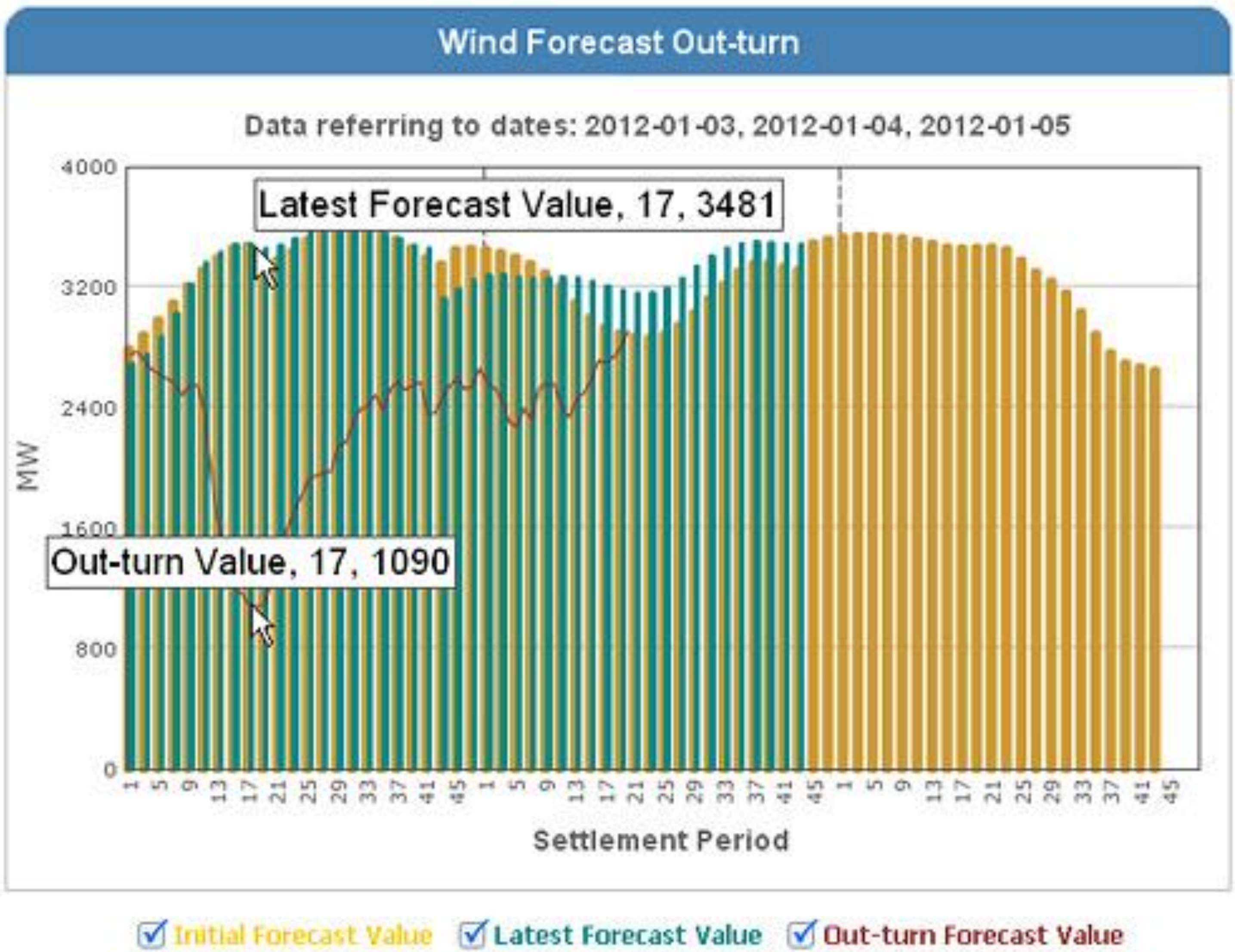
Mitigation measure - 5
Storm ride-through turbines

- During the winter of 2011 – 2012, there were a number of storm events in UK, each causing a large number of turbines to close down simultaneously, for self-protection
- These events caused a major deviation of wind turbine output from that forecasted
  - No national blackout occurred
  - Sufficient reserve must have been previewed & in place
- From a then fleet capacity of just over 5000 MW, the deviations from forecasted were in the range of 2400 MW
- A much larger fleet of similar turbines could result in a grid ”event”

Storm, 8 December 2011



Storm, 3 January 2012



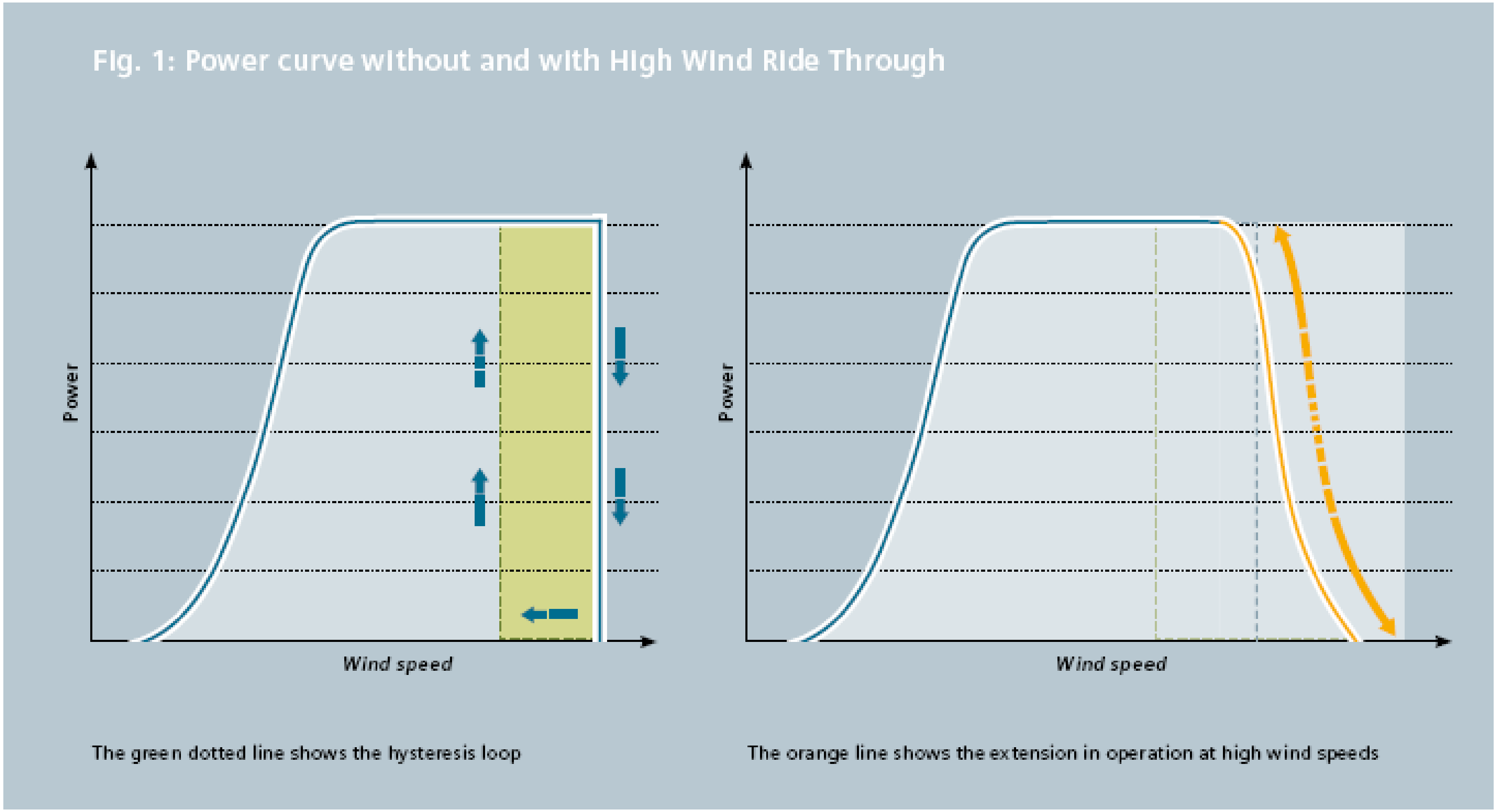
Most turbines stall at 25 m/s wind speed for their own protection

- Until now, most turbines cut-in and start producing power at around 3.5 m/s wind speed
  - Reach full rated power at 14 – 15 m/s wind speed
  - and maintain full rated power until the wind speed is 25 m/s when they cut out and turn off
- This is what happened in both storm events shown on the previous slides

High wind ride-through turbines

- Two turbine manufacturers, Enercon and Siemens, have developed storm ride-through technology that allows power production at wind speeds over 25 m/s
- And gently softens the stall, bringing power production

Example: Siemens' storm control



The green dotted line shows the hysteresis loop

The orange line shows the extension in operation at high wind speeds

Enercon offers higher full rated output and a softer stall

Storm ride through Financial consequence

Advantages

- Storm ride through could be especially beneficial for off shore turbines where wind speeds are greater and wind farms are very large
- Higher overall output per turbine

Disadvantages

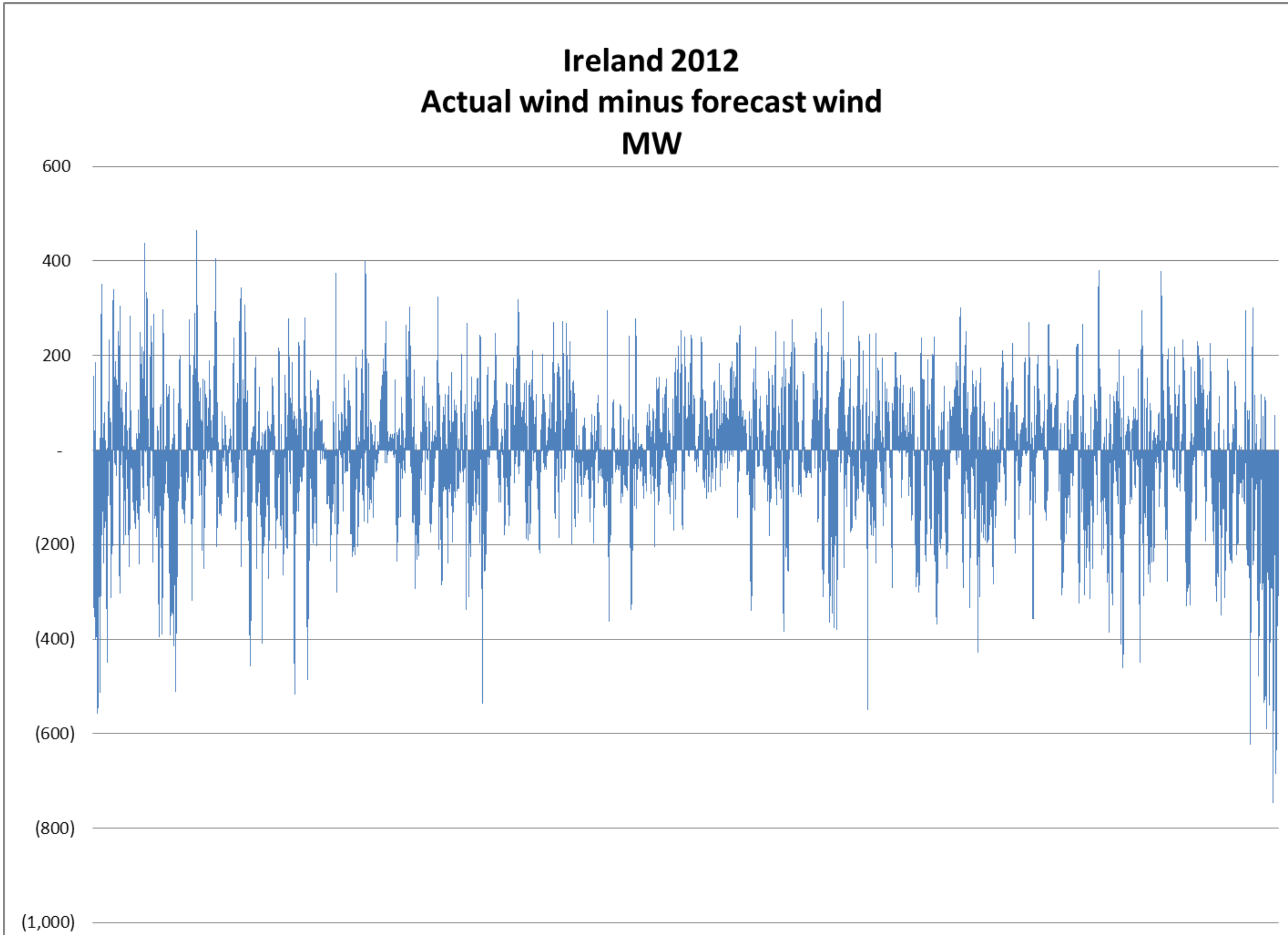
- There are clearly few turbine manufacturers able to offer this feature, so competition will be reduced and capital costs are likely to be higher

Centralized control for curtailment and ramping

- From about 2005, most utility-scale wind turbines have been required to allow local SCADA control to be over-ridden by the TSO from its control room
- In an increasing number of cases, grid-connected turbines can be stopped, started and ramped by the TSO
- In most cases, the cost of grid over-ride is built into the original investment

Who bears the cost of curtailment?

- With the exception of Denmark, as wind capacity and penetration increases, the growing tendency is for generators to bear the risk and loss of being curtailed.
- In Germany, from 2012, new turbines built will not be compensated for any loss of sales ordered by the TSO
  - Stricter methods of calculating the compensation for older turbines are coming into effect for turbines built before 2012
- In Ireland this is the case for all new turbines
- There is a growing realisation in both countries that the loss of volume sales could be partly compensated for the services performed for the TSO by this action


Ireland 2012
Actual wind minus forecast wind
MW
600
400
200
-
(200)
(400)
(600)
(800)
(1,000)