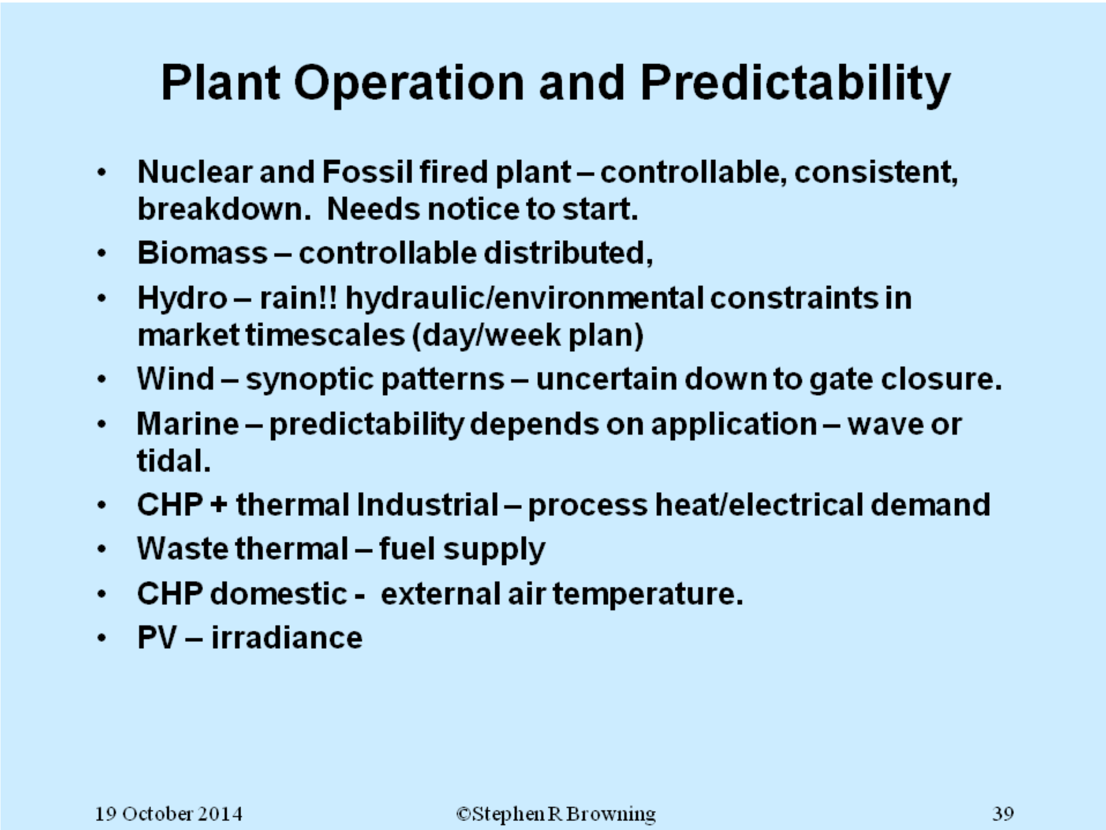
Renewable Generation replaces fossil fuel burn and consequent emissions. Distributed generation is more efficient at providing electricity near the point of consumption and multi-energy generation systems (heat, cooling and power) can provide that energy more efficiently than conventional methods, although still using fossil fuel.

The latest Distributed Generation at premises level comprises micro wind, photovoltaic and combined heat and power (sometimes with cooling) installations. Separate large wind generation is accommodated at higher distribution voltages although with careful rules for operation if the system becomes stressed.

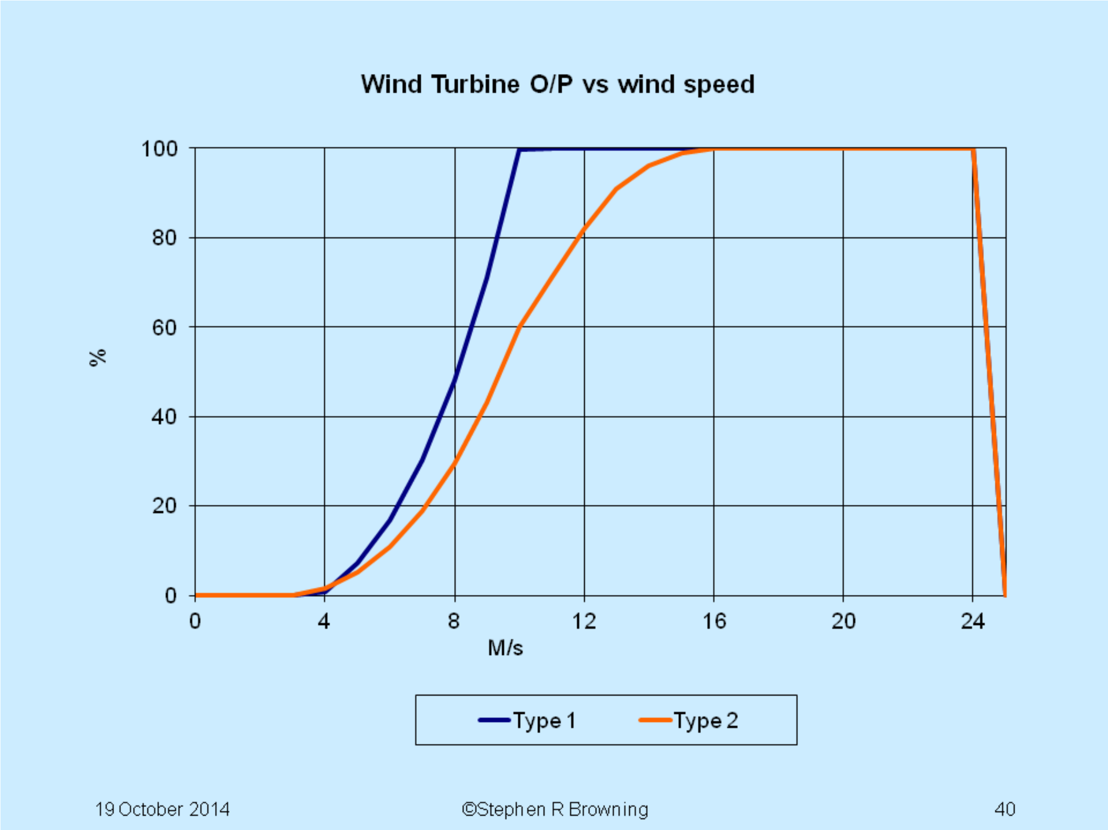
The problem with any renewable generation is predictability and the fact that there is gross variation from day to day. Both irradiance (for PV) and wind speed are difficult to estimate at the lead times relevant to committing main generation.

A quick summary of Generation types, 'drivers' and predictability:

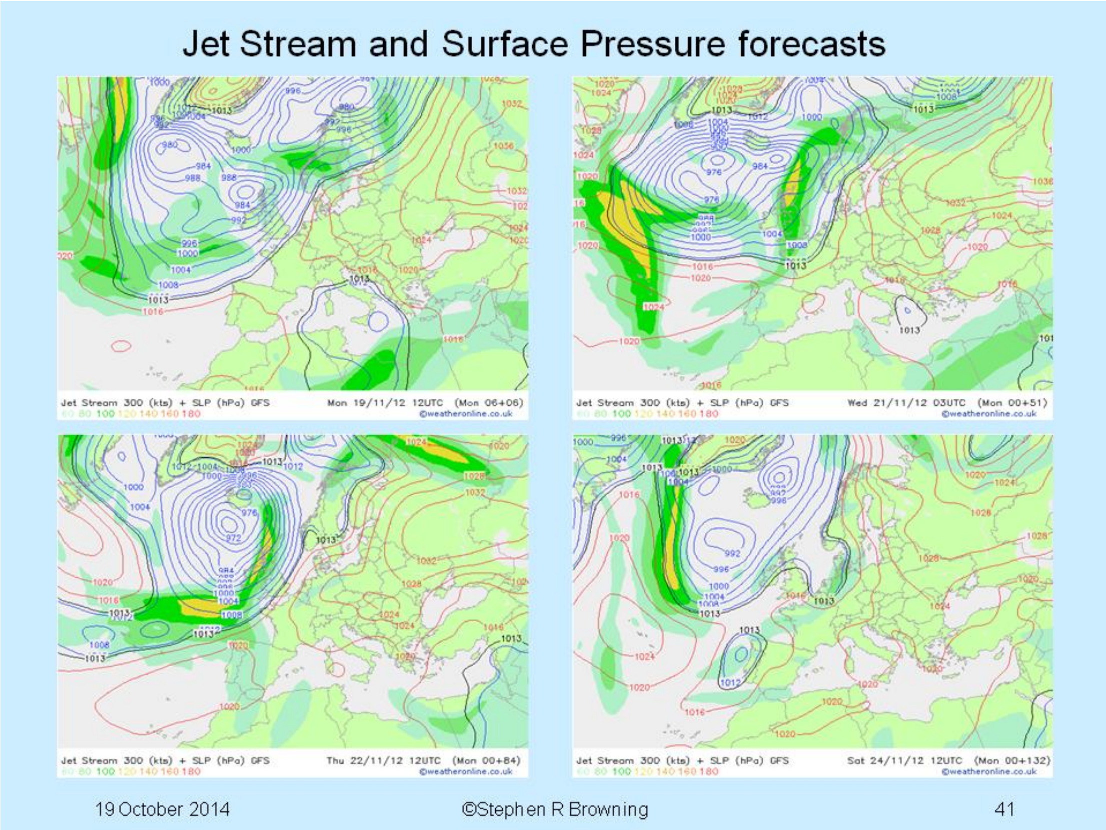


Wind

Wind Turbine output is roughly a cube law characteristic from cut-in speed up to max, then flat at max output up to cut out. Cut in is @4m/s, 8kts and full output is normally achieved at 13m/s, 26kts. Cut out speed is between 25m/s, 50kts for onshore turbines and 30m/s, 60kts for offshore units.



In the UK, the wind is 'synoptic' and thus variable; caused by depressions circling around. Direction, Track and Intensity is 'controlled' by the Jet stream.



The above shows the different wind patterns that can appear over a five day period as systems intensify and then fill. They normally move from west to east although they can be 'held' in a particular position by the Jet Stream. Wind output 'picks up' as the packed isobars cross the turbines.

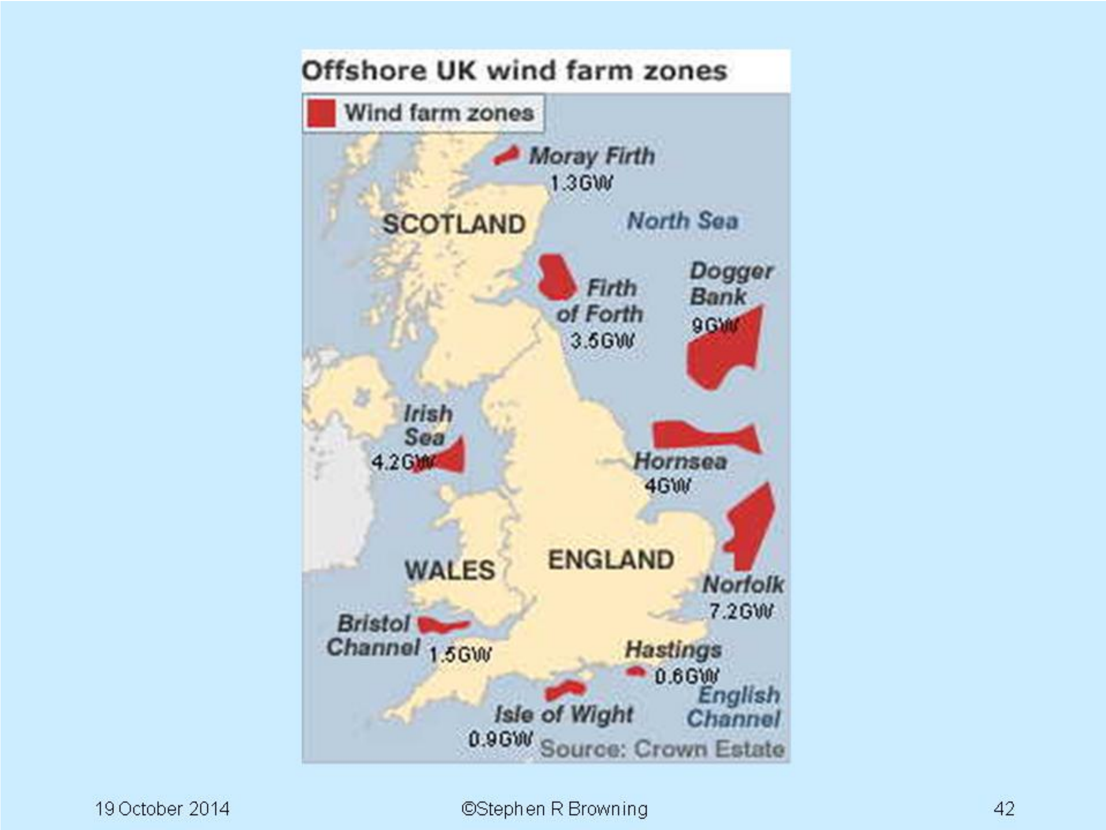
Most of the time when not calm, speeds normally fall within the pickup range. In certain places, higher speeds will occur with gales which will be into the max output plateau or, with high gusts, beyond the cut-out point.

Sets of Turbines are configured in farms. Initially, these were in small dispersed groups with low total output and therefore little impact on the generation requirement.

In 2009, the round 3 UK Offshore wind sites were announced.

There are 9 proposed sites with plans for a total of 6400 towers carrying 5MW heads. This totals to @32GW which is about 40% of the current, conventional installed capacity. Allowing for cutout under high wind conditions, the fleet will probably get up to a max output of @25GW.

Here is a map of the locations


Offshore UK wind farm zones
Wind farm zones
Moray Firth
1.3GW
SCOTLAND
North Sea
Firth of Forth
3.5GW
Dogger Bank
9GW
Irish Sea
4.2GW
Hornsea
4GW
WALES
ENGLAND
Norfolk
7.2GW
Bristol Channel
1.5GW
Hastings
0.6GW
English Channel
Isle of Wight
0.9GW
Source: Crown Estate
19 October 2014
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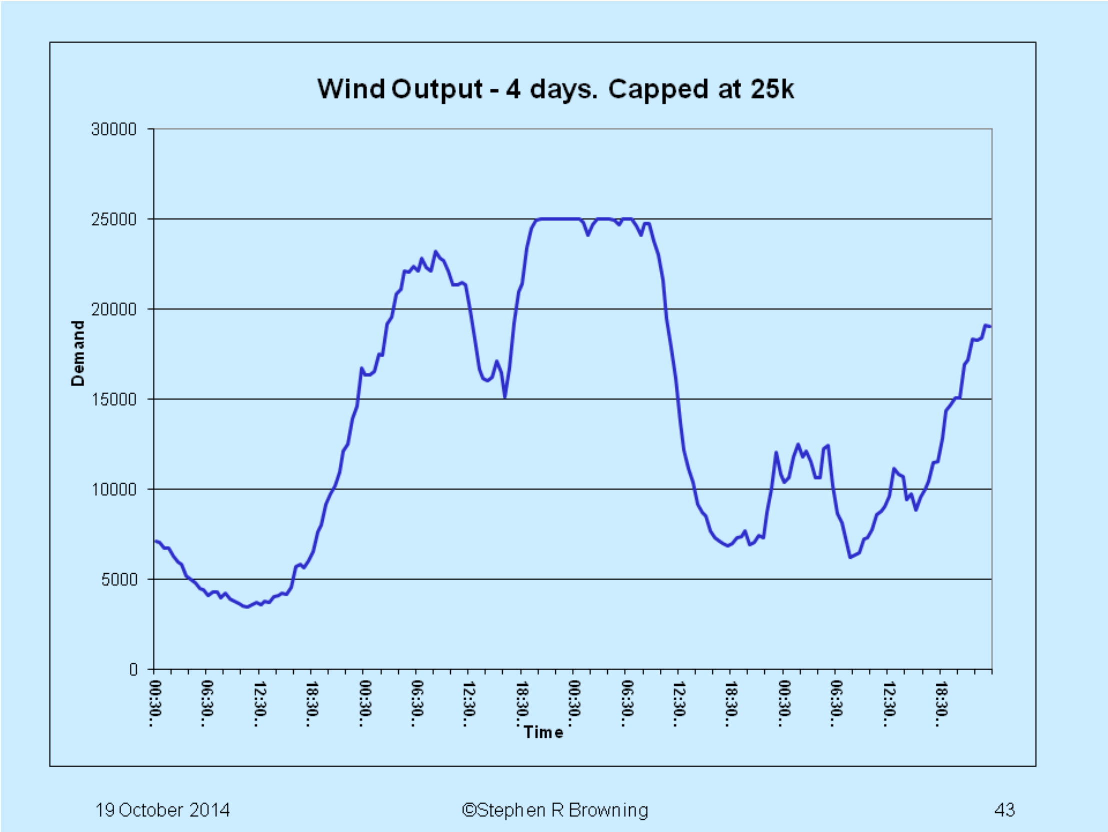
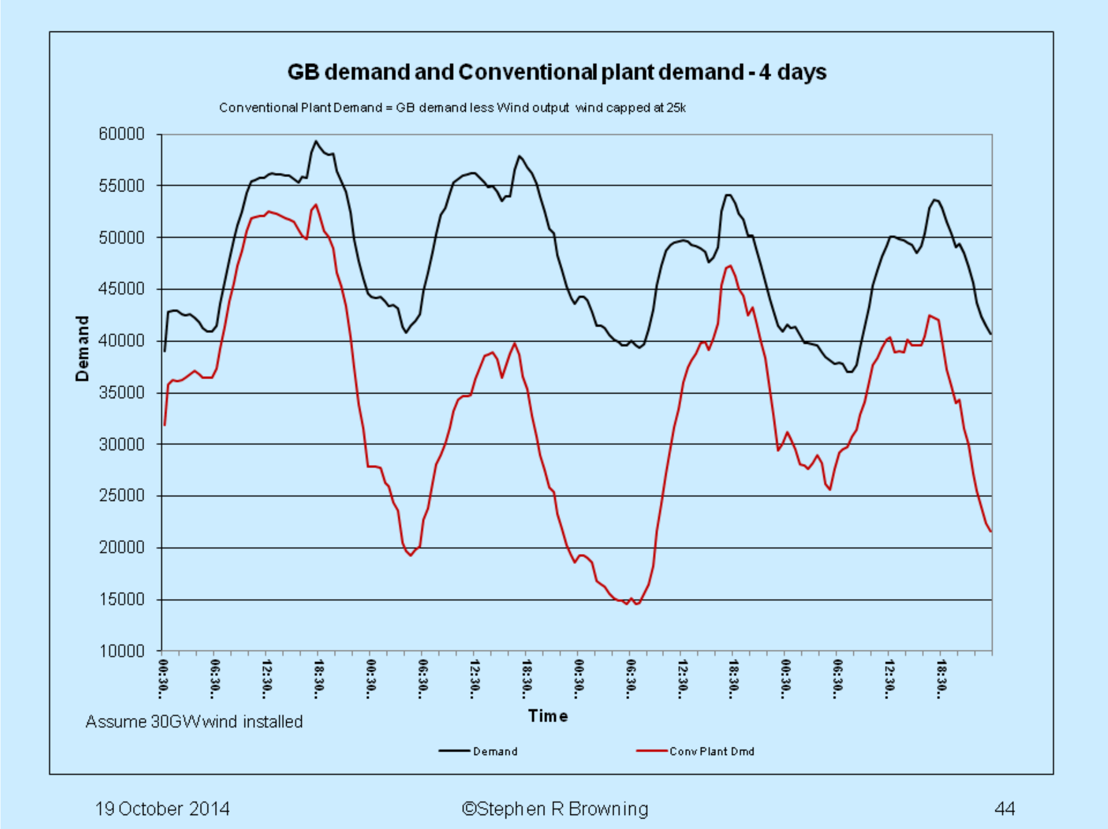
Analysis of actual wind speeds has been used to determine the likely output profile of the whole offshore fleet by ratioing. Wind output over a 4 day period can look like this.



If we subtract actual wind speed from demand over a 4 day period (Thursday through Sunday in this case), the remaining curve, being the demand on other installed plant (Nuclear, conventional steam, Hydro, etc), can look like this.



As you can see, the timing and levels of the 'other plant' Peaks, Troughs and ramps have been considerably altered. The maximum ramp up has changed from @14GW in 4 hours on the Day 2 (Thursday) morning to @25GW in 5.5 hours on Day 4 (Saturday) morning. Wind penetration by Power is varying from 6% to 63%, the latter at the demand minimum on the third day. At that time we have 25GW of Wind and less than 15GW of Nuclear and Conventional plant; stable operation of the system will not be possible especially with extra short timescale wind output variation.

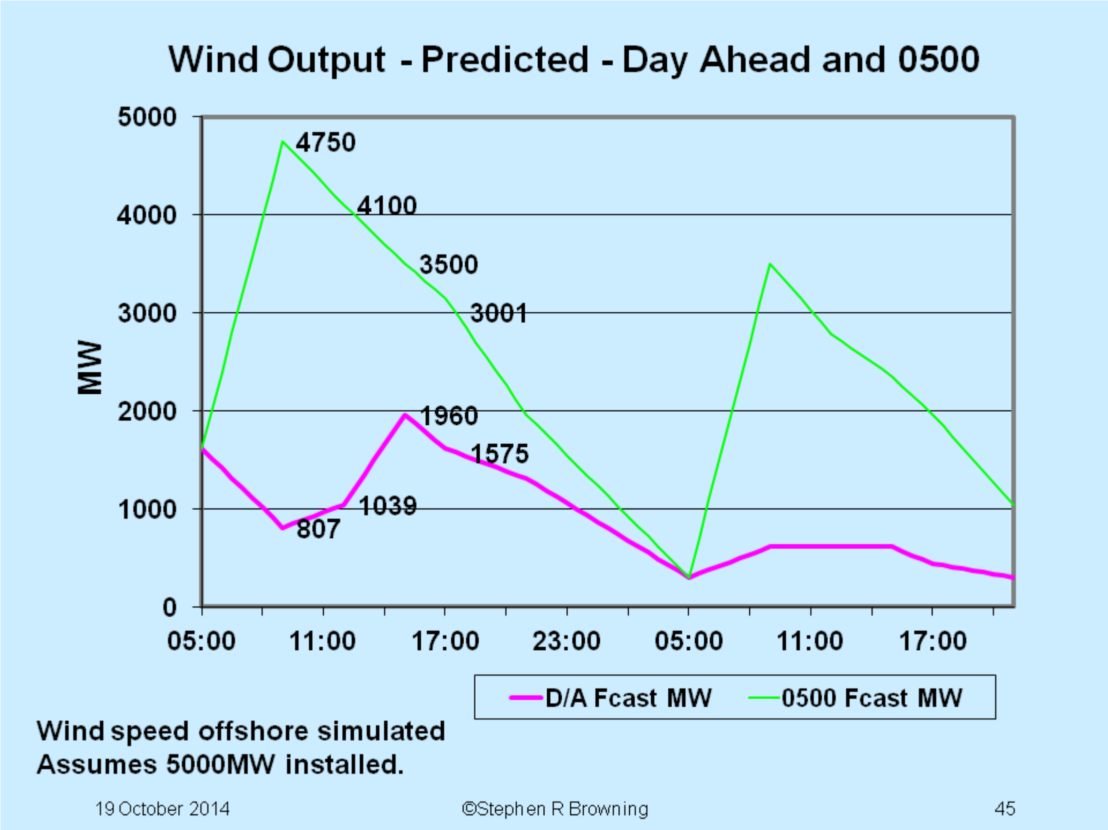
And this is the of course the impact assuming perfect forecasting of wind output.

Wind can be difficult to predict, being mainly caused by the passage of cyclonic weather systems. As these farms are clustered in discrete locations, the passage of a depression will hit them in order, depending on track. Getting the track and timing right is difficult but crucial to output prediction accuracy.

My earlier analysis of forecast versus actual data for a particular location now follows.. This is based on definitive forecasting and more modern ensemble and other methods are improving the accuracy.Here is an example of wind predictability for one area and the effect on the residual requirement for main generation in Great Britain.

For this example we have installed 5000MW in the sea to the Northwest of Manchester and used that city's forecast and actual data over two days.

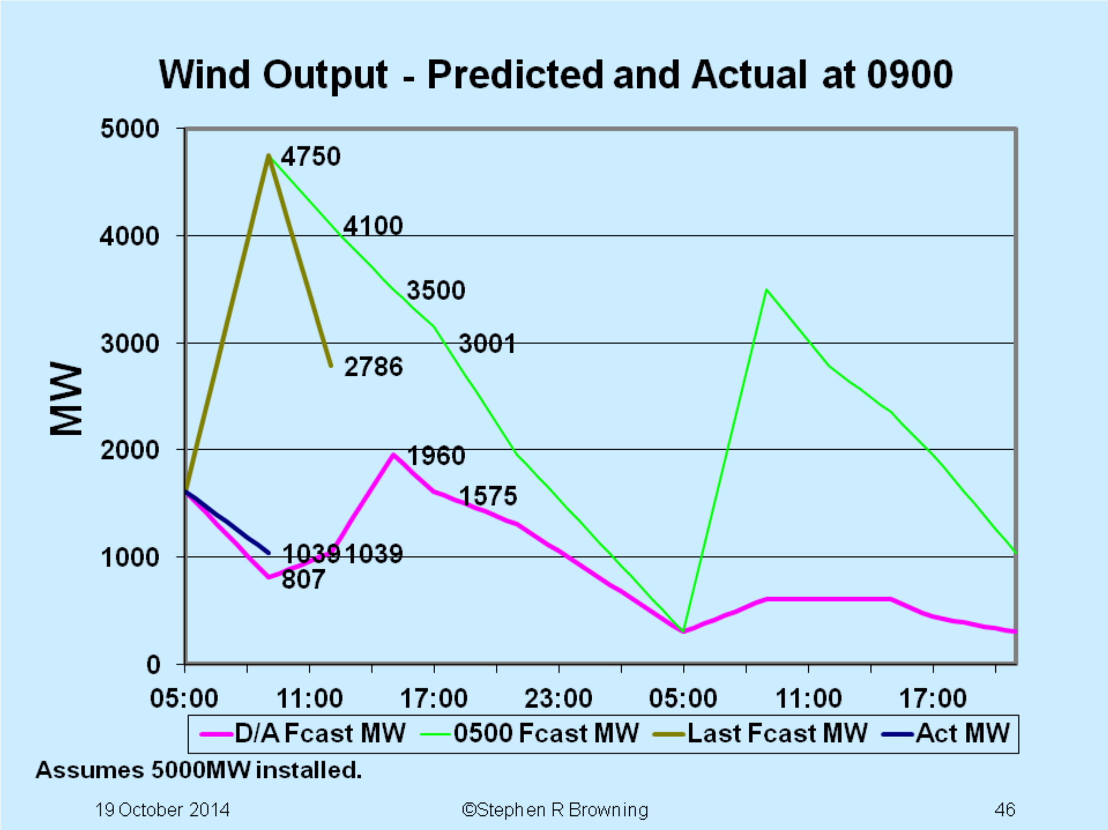
First here are the Day Ahead and 0500 forecasts.



At Day ahead, the wind speed prediction was pessimistic – 4-8 m/s which is wind turbine cut-in. Wind farm operators would have given low estimates to suppliers who would in turn have purchased extra conventional plant.

The 0500 forecasts show very different profiles; it looks like a weather system has now been identified as 'incoming'.

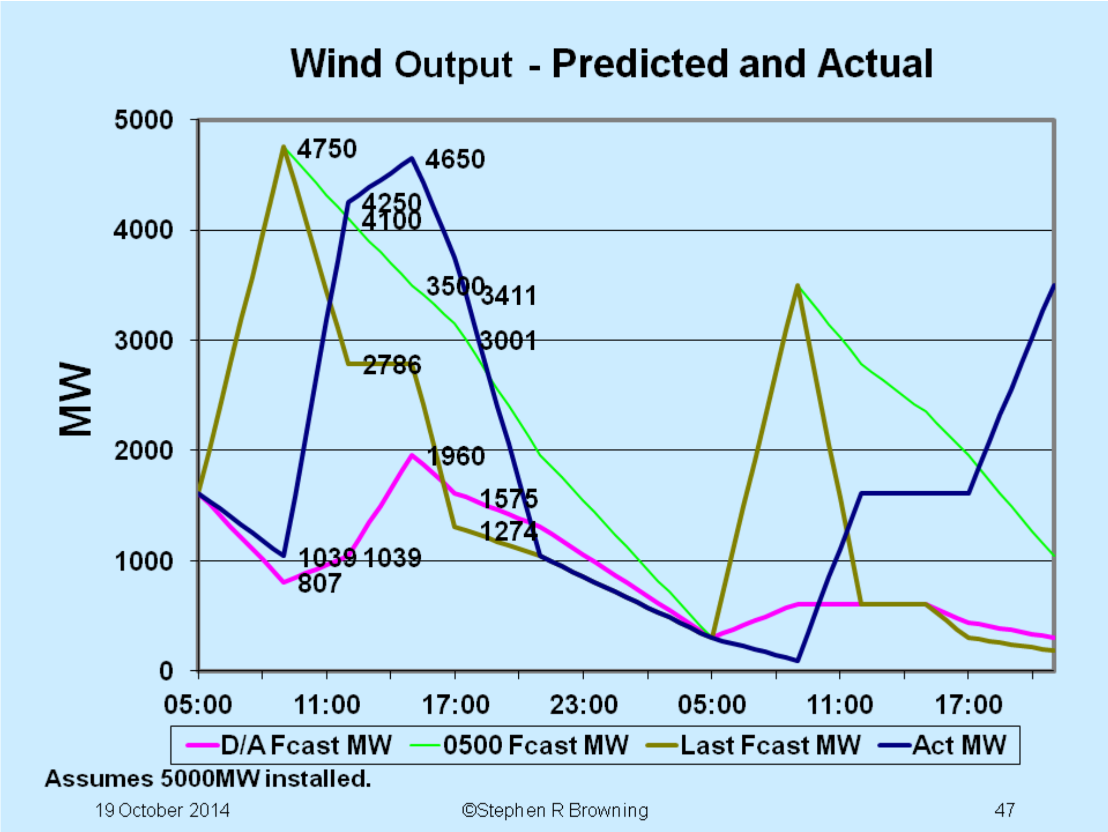
Now we move on to 0900 and add the actual wind speed based outputs



Oh dear, it looks like the wind didnt arrive (the low dark blue value is the actual)

And a new forecast appears (Last fcast red line); and prediction for 1200 is revised downwards.

Now let's see what happened at 1200 and thereafter!!



The wind arrived with a vengeance!! In fact, for the 1700 Daily demand peak the forecast still stayed at @50% assuming a drop off whereas the speed actually increased; the system came through later than expected!!

In tabular form here are the Forecasts and Actuals for each demand Peak and Trough time

	Wind Percentage Outputs - Day 1			
	Forecasts			
Time	Day Ahead	0500	Last	Actual
Peak 0900	16.15	95.00	95.00	20.79
Peak 1200	20.79	82.00	55.71	85.00
Trough 1500	39.20	70.00	55.71	93.00
Peak 1700	32.26	63.00	26.14	75.00

For the first day, the day ahead forecast predicted low output levels of 20% in the moring and 40% for the evening Peak. The 0500 forecast then predicted 96% at the 0900 Peak, reducing to 80% at the 1200 Peak then 72% at 1500 and 65% at the 1700 Daily peak. This is evidence that a depression was now expected to sweep across the area and move on.

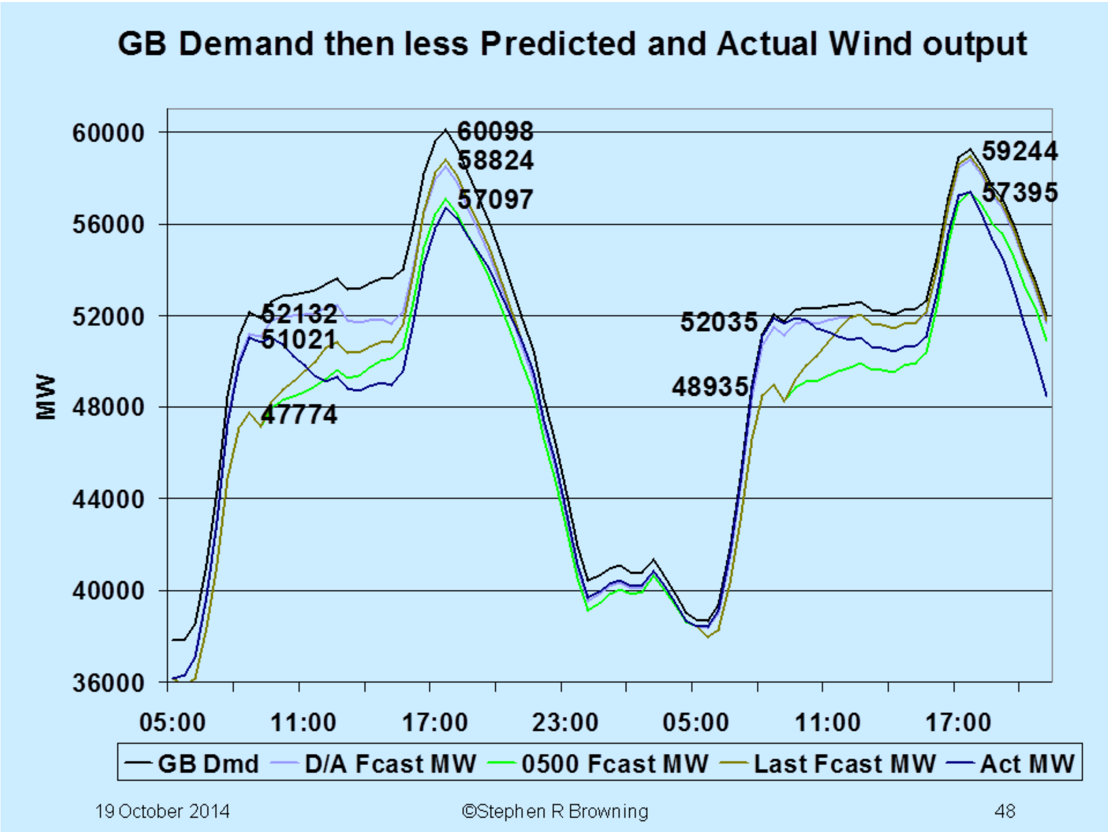
However, at 0900 the actual output was in fact 20%!! The final forecast for 1200 was then revised down to @55%.

But then the depression hit the fans – Actual output at 1200 was 86%. The final estimate for 1500 was set at at 55%.

However, by 1500 the wind reached max strength giving 96% output. The final estimate for the 1700 Daily Peak was set at 55%.

And at the 1700 Daily Peak, the wind was still at 72%

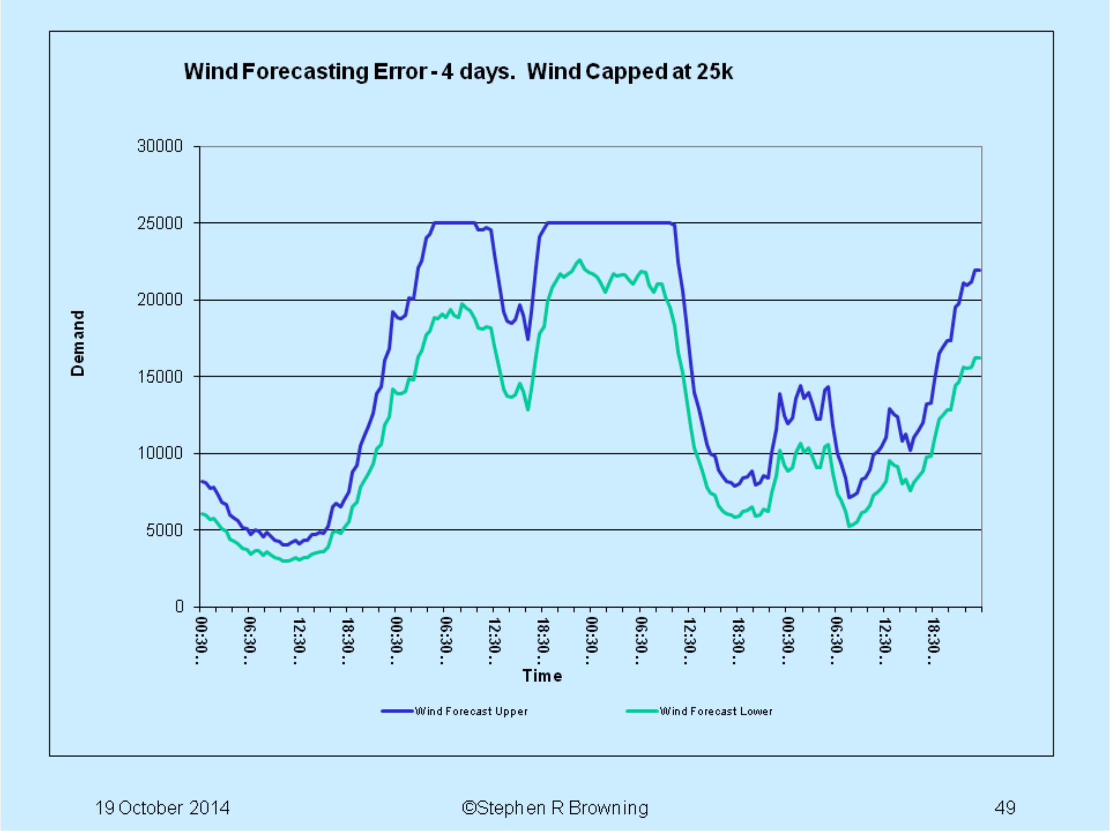
This magnitude of difference between the forecasts and the error to the actual makes the job of committing, scheduling and dispatching the other generation to match the remaining demand both difficult and inefficient. It is also difficult to ensure Transmission operates in a stable state.



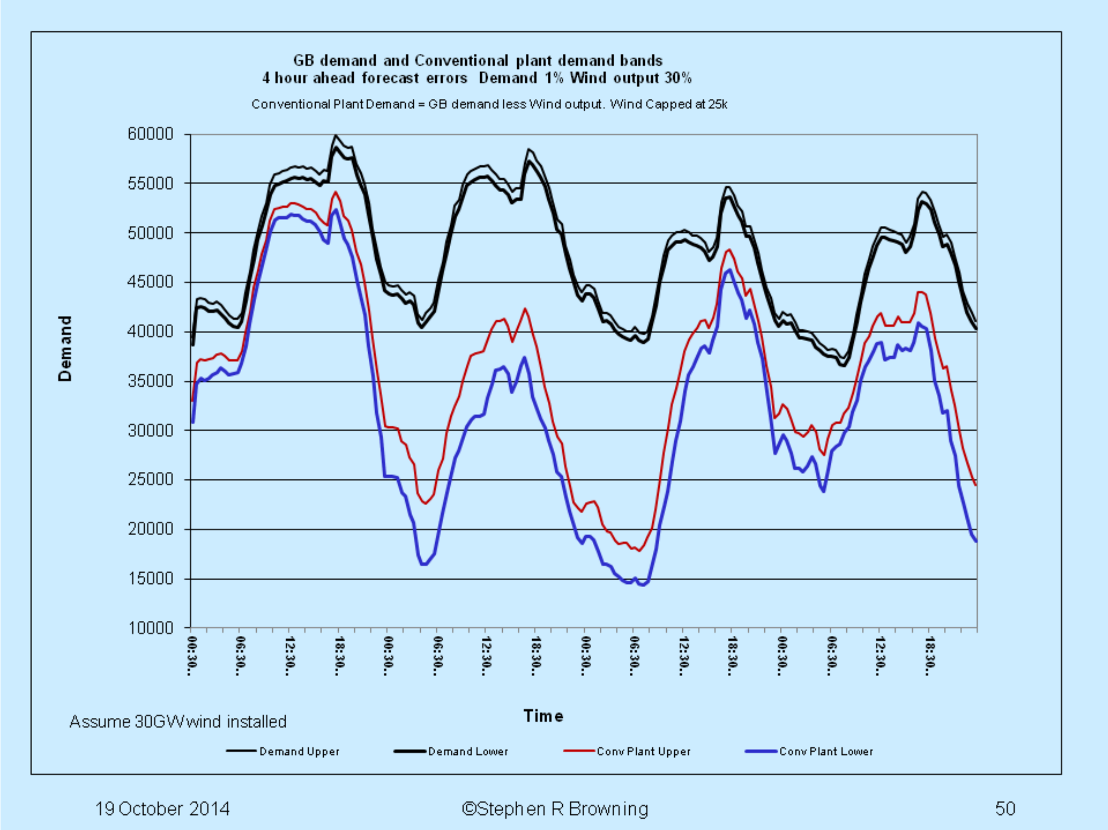
This is just the uncertainty due to one 5MW site; in all we have 9 proposed sites with a total of @32GW of Wind Generation. However I was using 'definitive' which give the large errors. More modern forecasting methods, including Ensemble forecasting and better wind speed to turbine output models, plus the effects of geographical 'distribution' will reduce the error range. However, accuracy of only 50% at 4 hours ahead is currently assumed but it is expected that better modelling and location diversity should reduce the error to 30%.

As we showed earlier, new fast ramps will appear in the residual conventional plant demand. Although we currently cope with fast pickups and dropoffs in normal demand, the timing and magnitude of those events is always predictable. For example, as 'Day follows Night' the GB morning weekday pickup always starts @0530 and is mainly complete by finishes by 0815. Thus conventional plant commitment, scheduling and dispatch is always taking place over the same time period and at the same rate. Across the demand rise, 10 large units (or equivalent capacity) will always be ramping up at their maximum rate to maintain the Generation to Demand match.

The new ramps introduced by wind variation will also have a large degree of uncertainty as regards magnitude and timing. If we superimpose a wind forecasting error of +/-15% (lower end of the 4 hour ahead error band as stated above) on the big (32GW) fleet wind output data and cap max output to 25000MW this is the result.



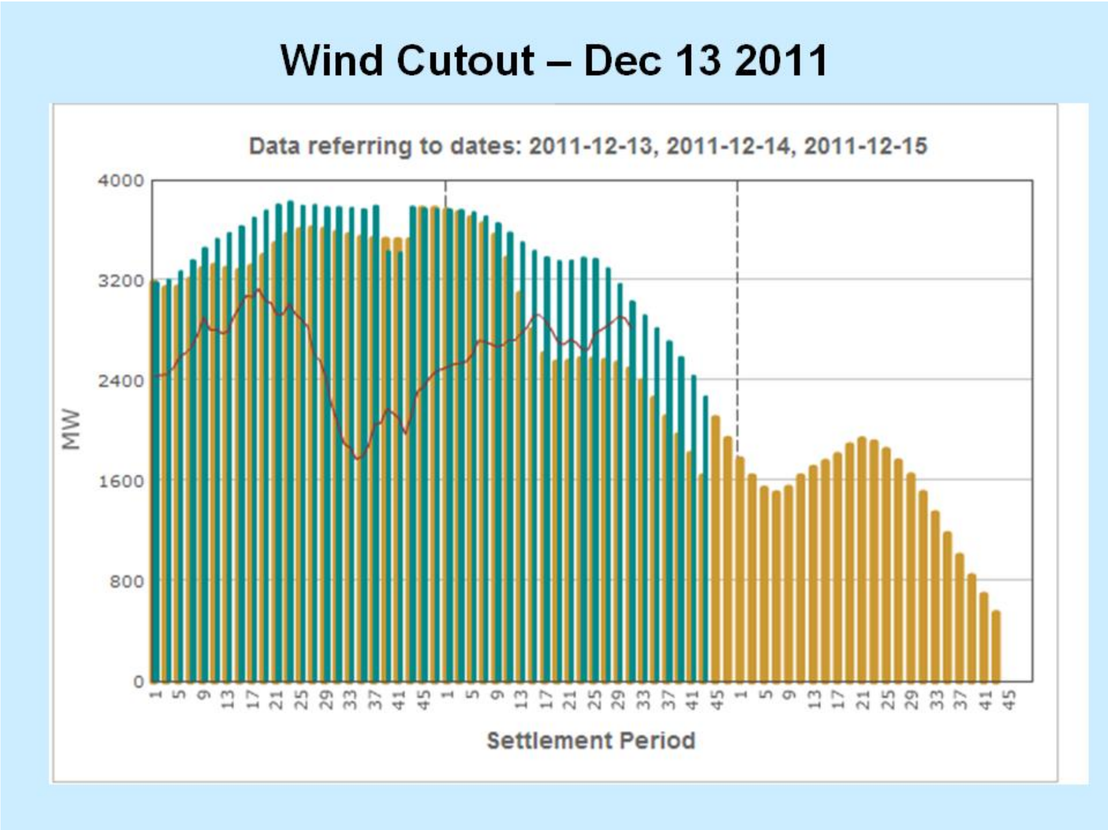
And here is the resulting uncertainty in the residual conventional plant demand. The normal Demand forecasting error range is also shown, being 1% at 4 hours ahead.



It will be difficult to commit, schedule and dispatch conventional plant effectively or efficiently against such a 'moving uncertain target'.

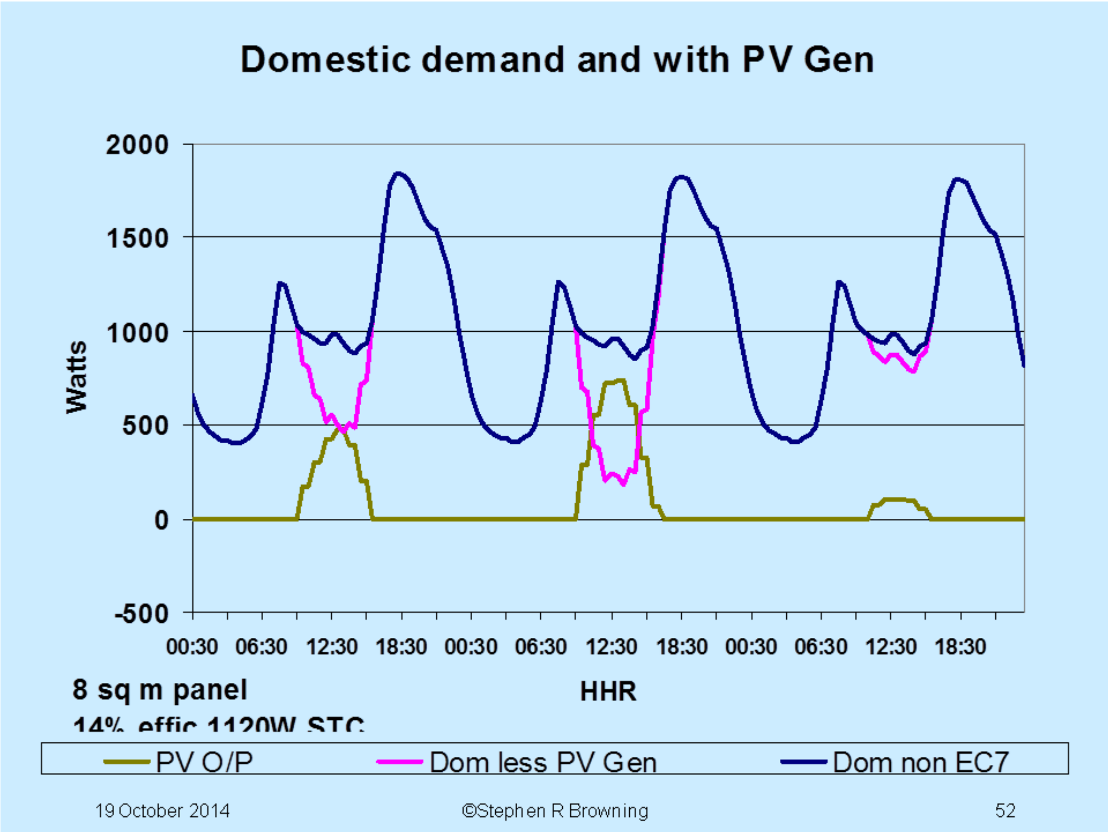
It is now recognised that high speed bulk storage is required to enable large wind penetration. The question is, however, whether this will be able to sufficiently 'smooth' the variability and buffer the uncertainty. There is also the issue of steady state stability of the Transmission system if storage is not co-located with the generation, as has been mooted by the proponents of Customer Demand reaction and the Electric Vehicle charge/discharge strategy. Big swings of Wind Generation in offshore locations and onshore compensatory storage could put Transmission into 'Unsteady State' instability.

Note that the above example shows the wind upper error range with a cutout cap. With diverse location of the farms the fleet is unlikely to get up to full output (32GW). When some farms are at full load the wind speed at other farms will be above cutout (25-30m/s). Here is an example of 'cutout' with the current GB fleet. The line shows actual output and the bars are predicted output.



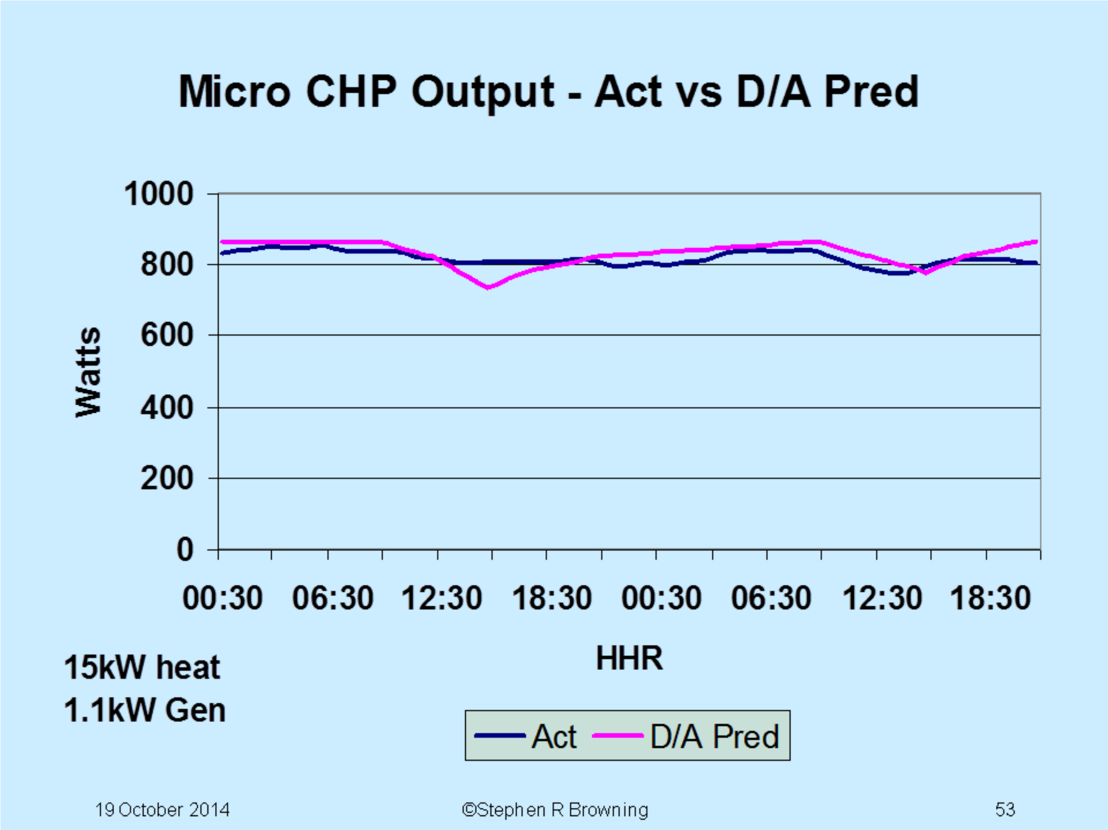
Photovoltaics

Here is an example of 3 days of PV output superimposed on an 'average' domestic load curve.

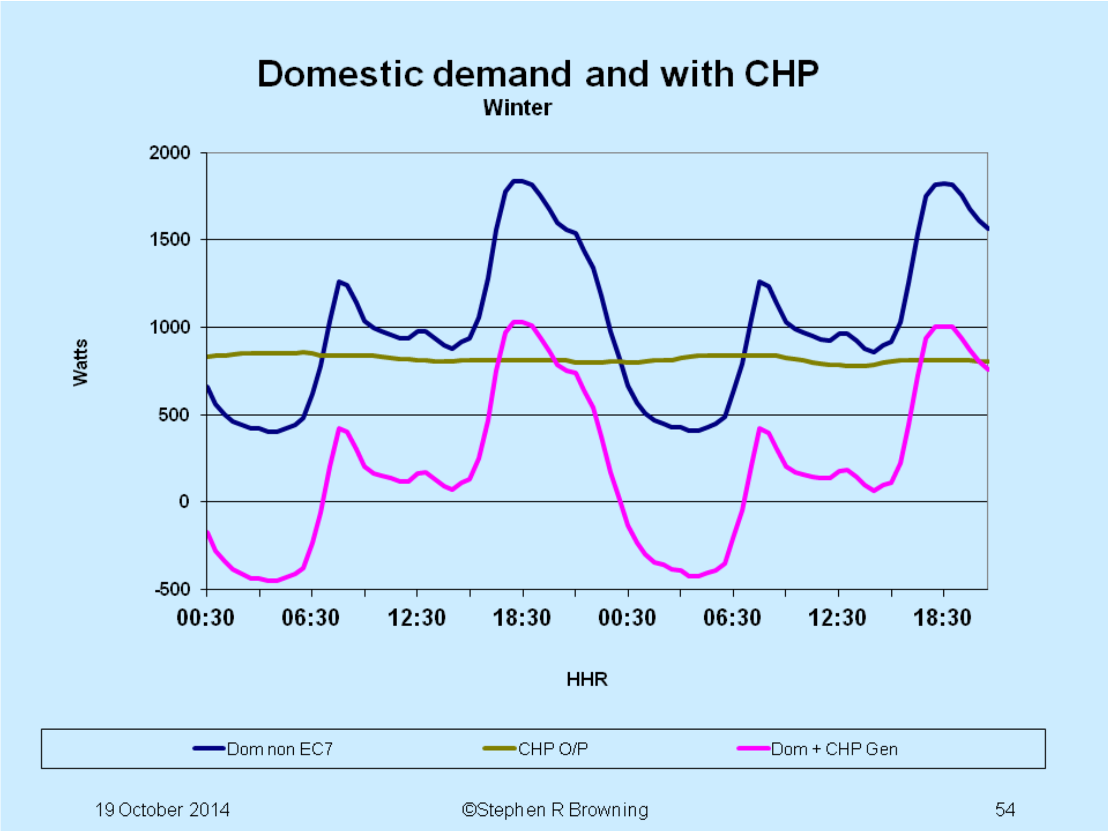


Micro CHP and CCHP

In general, CHP and CCHP systems are driven by the heating or cooling requirements of the premises, or the process for which the thermal energy is required. Temperature fluctuates less frequently than other weather variables and plant output is more in tune with demand, which increases with low and high temperatures.



Also, assuming the CHP runs continuously when the weather is cold, the domestic premises profile might appear as follows:



Note that both the PV and CHP systems may tend to export at times of low premises demand.

Within the current operational framework, it is assumed that more spare and reserve output on conventional generation will need to be carried to meet the increased level of uncertainty introduced by renewable and other distributed generation.

Operational Overview - Observation, Prediction and Control

- Keep Generation and Demand separate – metering and prediction.
- Distributed Generation prediction – process control driven (industrial CHP)
- Distributed Generation prediction – weather variable driven.
  maintain capacity register by plant type by area (PV, wind, marine, CHP).
  Monitor area weather variables and prediction – widespread continuous.
- Distributed Generation prediction - Controllable sites (CHP).
  Metering of control elements and trading interface.
- Site control and observation elements
- Electrical Storage.
- Site and micro-grid – demand/gen/storage - Import/Export control.
- Cheap communications and 'distributed aggregated' trading – energy and reserve.

Operational Issues

- Operation is all about 'Timing' – deliver it 'Now'
  (not a second more, not a second less).
- Observation, Predictability, and Reliability is the key to efficiency minimising market imbalance and unnecessary reserve/spare plant.
- ROCs do not encourage improved forecasting techniques.
- Reducing renewable generation output to improve predictability reduces already low Load Factor.
- Improve Demand Efficiency – reduce variation
  Change the tarriff attitude from 'one price at any time'.
- Storage – the great issue – Low loss
  Buffer variable Export and Import. Can we make a breakthrough???
- Cheap advanced ICT systems to monitor/control distributed systems and communicate dynamic tariffs or trading data automatically.