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working with the weather

Measuring the value of ensemble forecasts to renewable energy: so much more than the ensemble mean

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with thanks to ARPA Bologna and Bethany

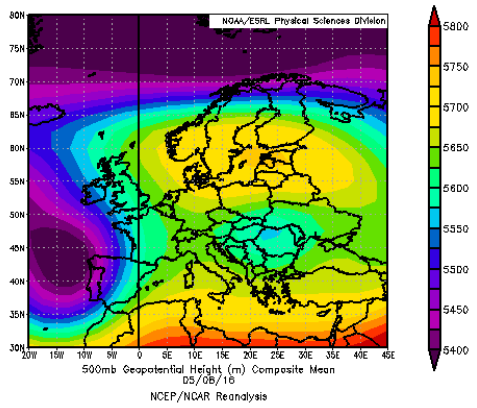
June 9th 2016

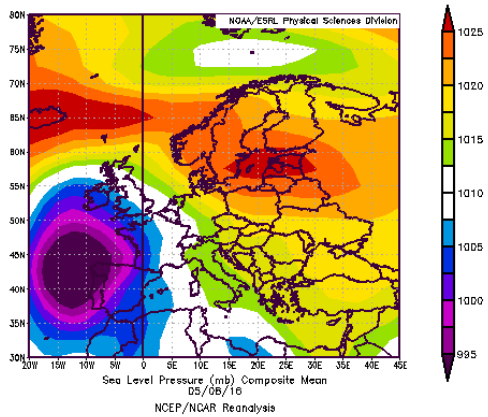
Overview

- Growth of renewables => weather forecast even more important
  - Environmental benefits
  - Brief explanation why
- Forecast skill: moderate cases vs calm or windy extremes
- Ensemble forecasts: so much more than the ensemble mean
  - But without a single ens member harder to correct for model error
- A simplified approach at valuing weather forecasts

> 95% electricity supplied by renewables: good news?

- Sun 8th May
  - DE wind delivered around 25GW (daily avg)
  - Solar also high
  - At 2pm, ~45.5GW of renewables and 45.8GW of demand => >95% renewable
  - Good news and an environmental success, right?





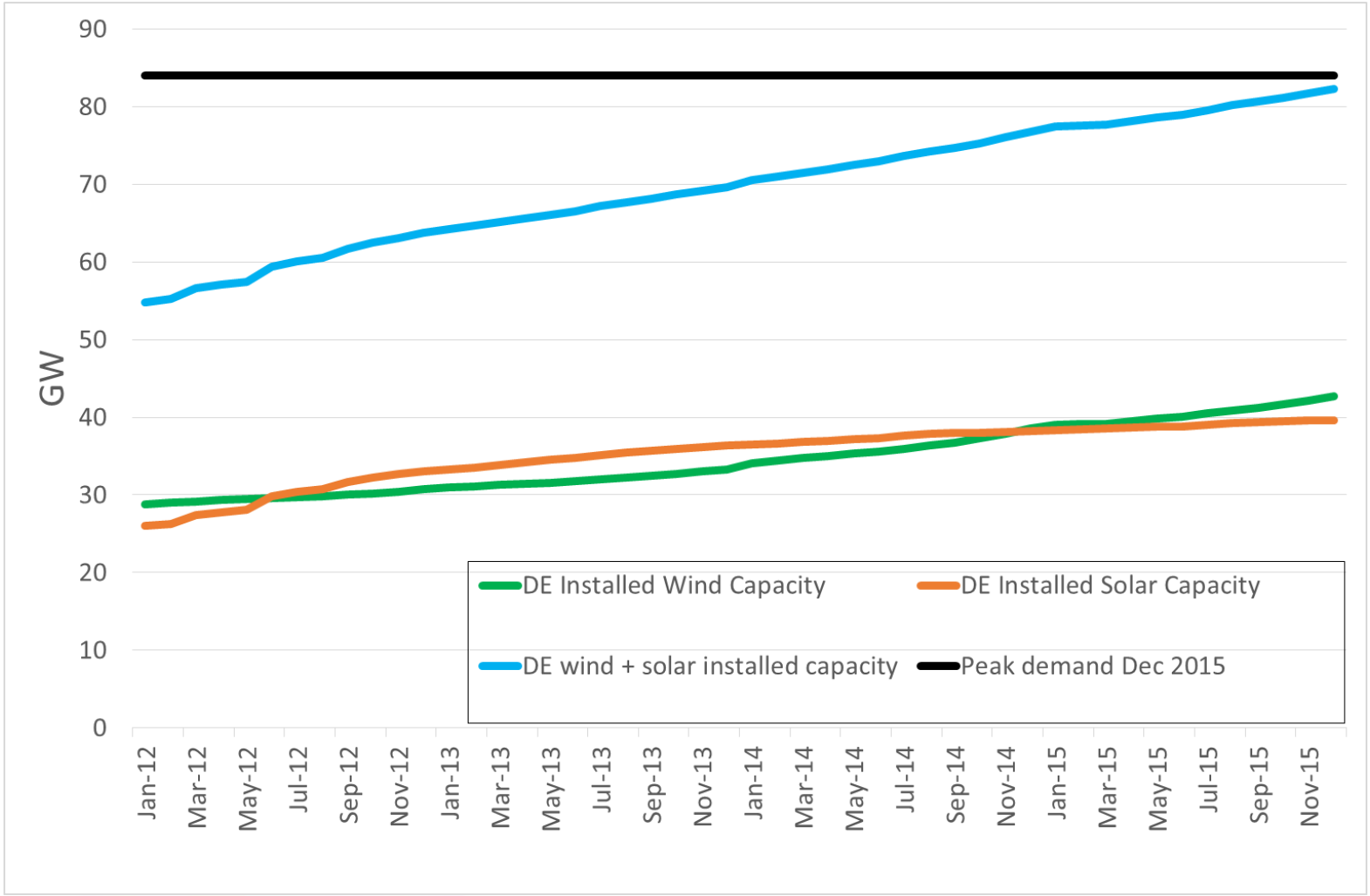
Source: NOAA

> 95% electricity supplied by renewables: good news... only if fcst

- Sun 8th May
  - DE wind fcst around 14GW (daily avg) on Friday
  - DE wind delivered around 25GW (daily avg). Solar also high (fcst)
  - At 2pm, ~45.5GW of renewables and 45.8GW of demand => >95% renewable
  - Conventional plant had been scheduled to generate due to forecast. Due to limited flexibility it could only reduce output a little – impact worse since Sun
  - Prices went negative
    - supply companies were paid to consume electricity, then pass cost to end-user
    - -13 €/MWh daily average, -130 €/MWh for 2-3pm. 'Normal' ~+10 €/MWh
  - Better forecast would have meant better scheduling

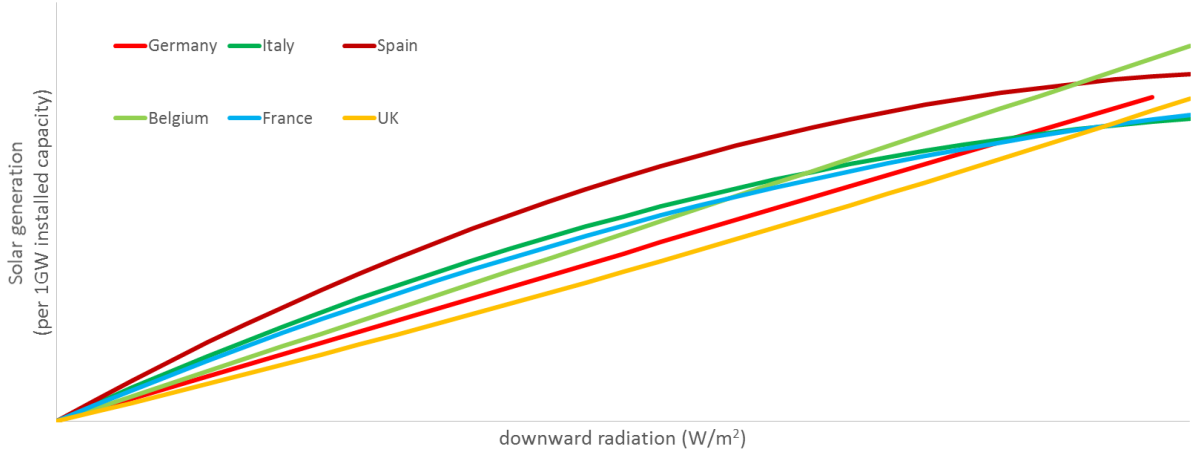
    => less carbon emissions, more efficient use of renewable output, lower end-user prices

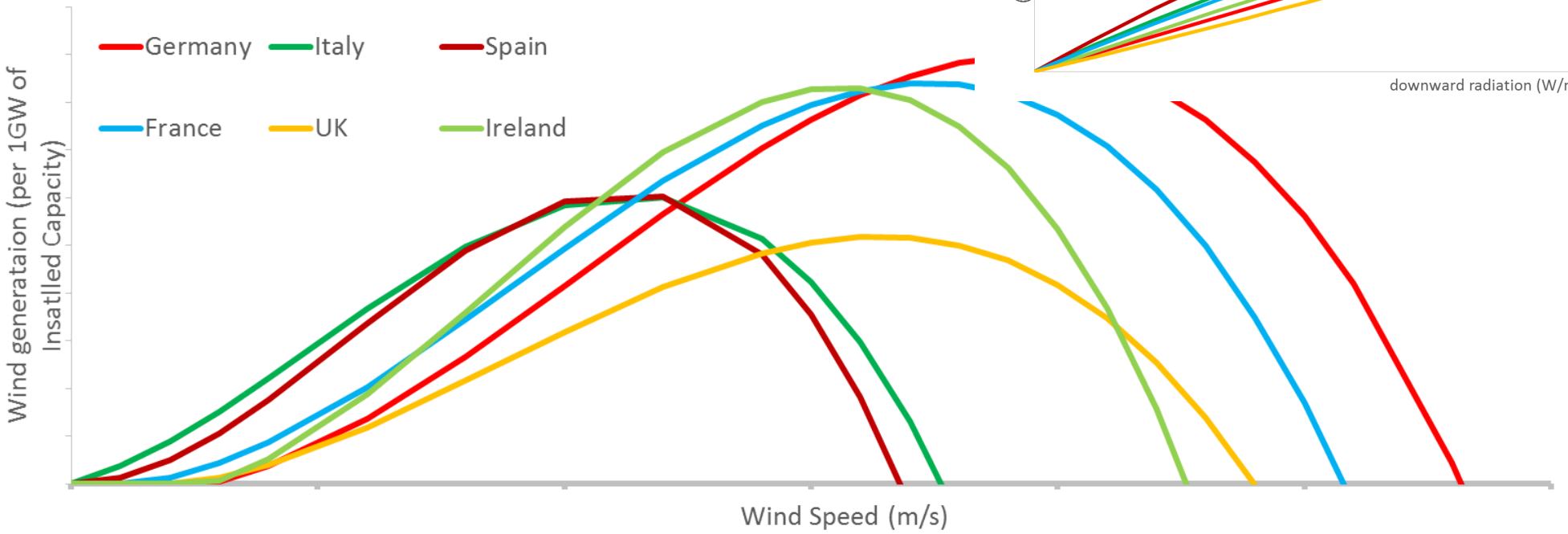
DE renewable growth



- Note: Installed capacity not actual generation

Nonlinear generation curves





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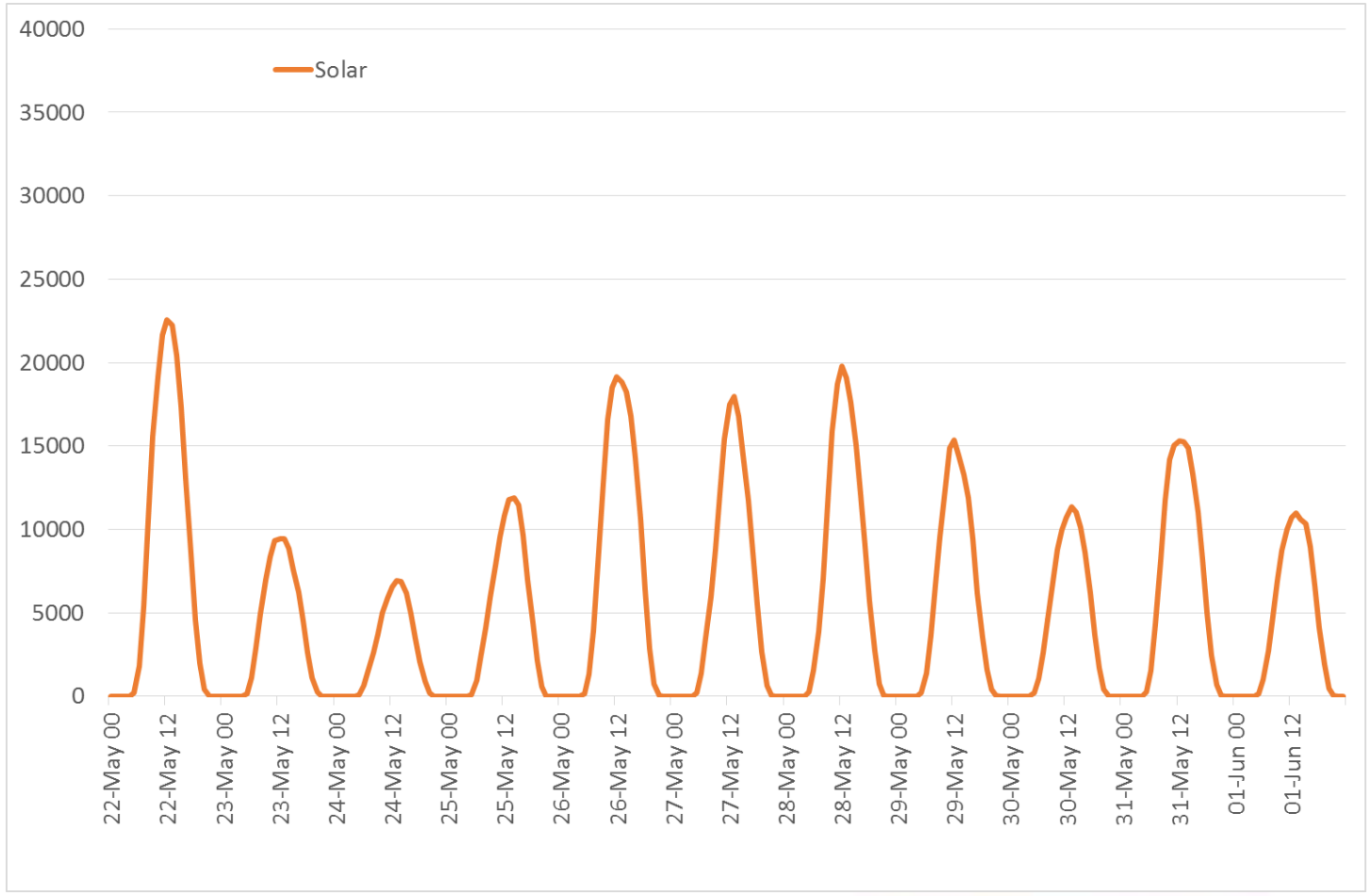
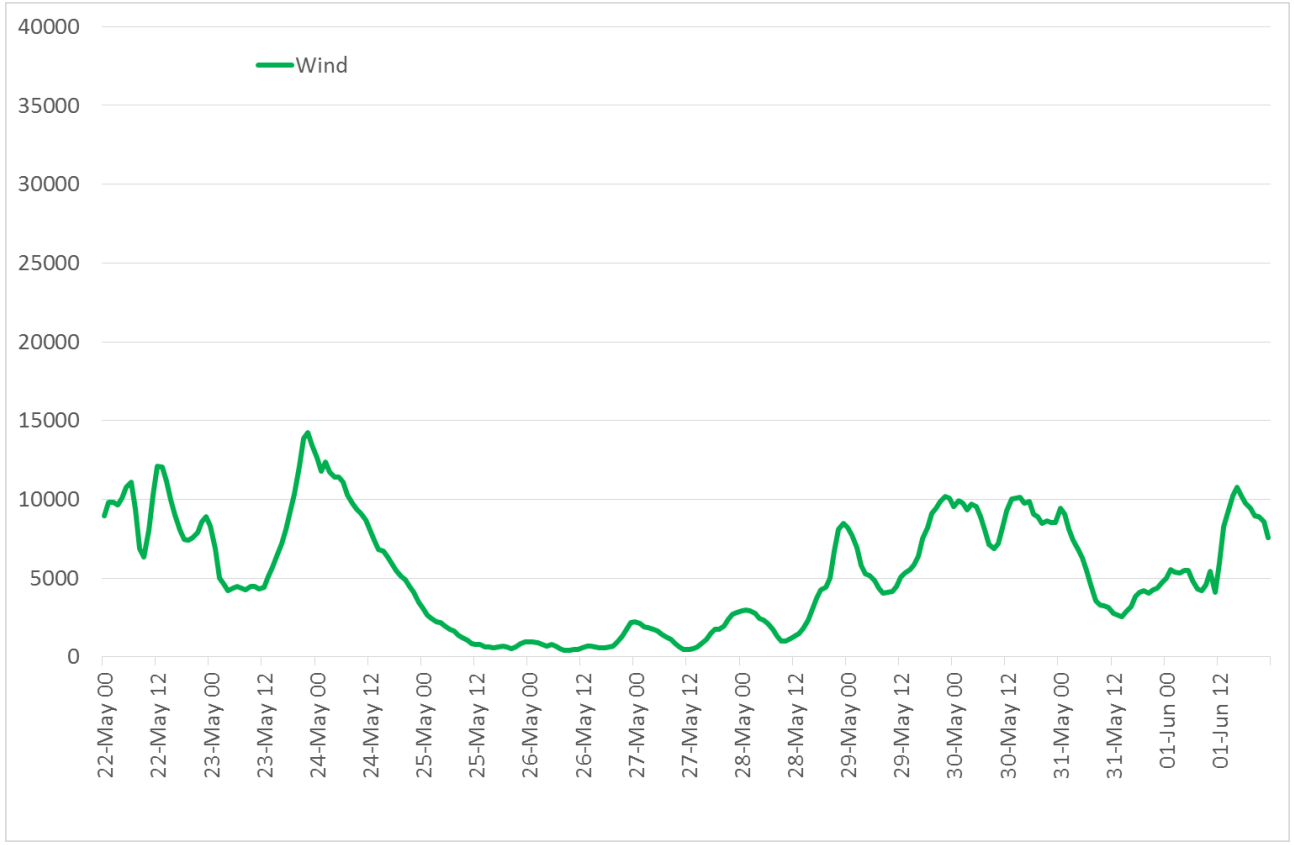
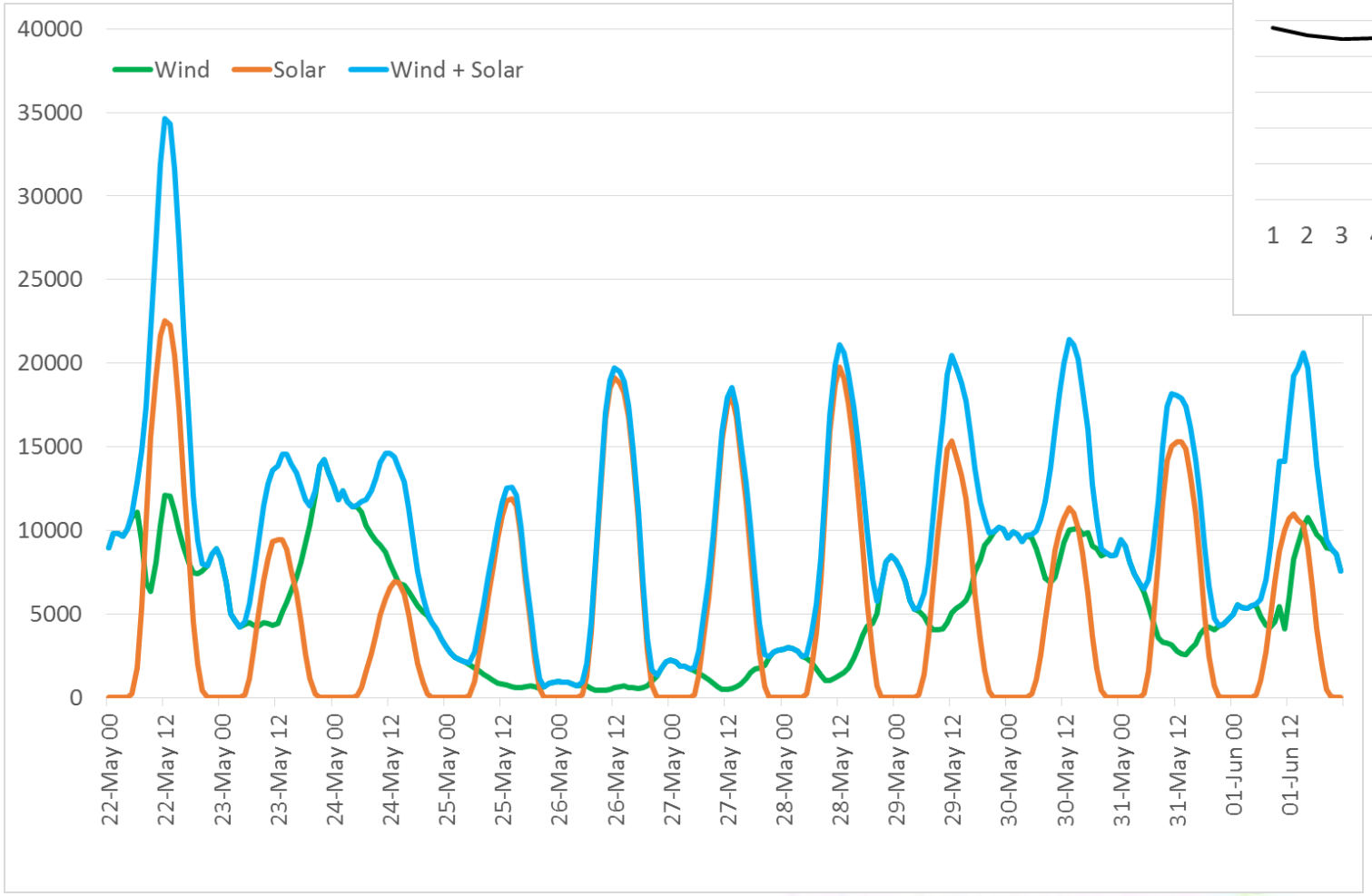
Variability of renewables: DE solar

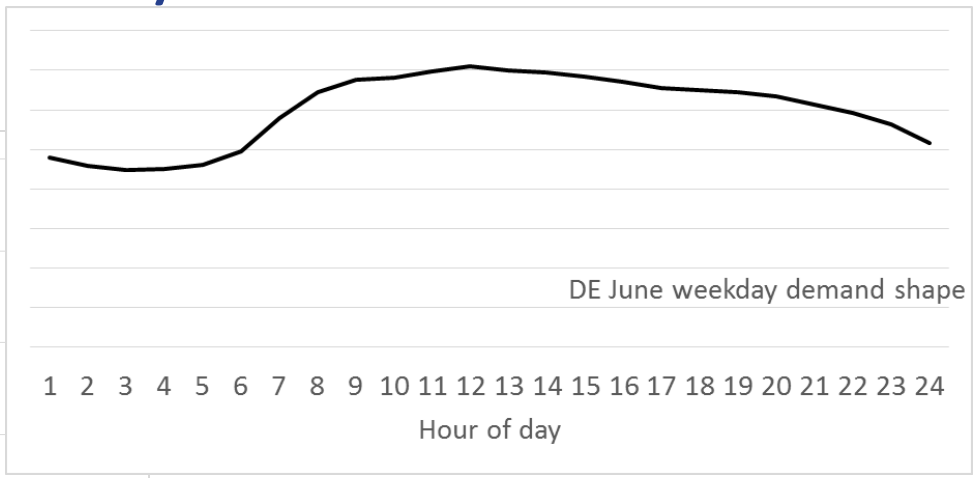


Variability of renewables: DE wind



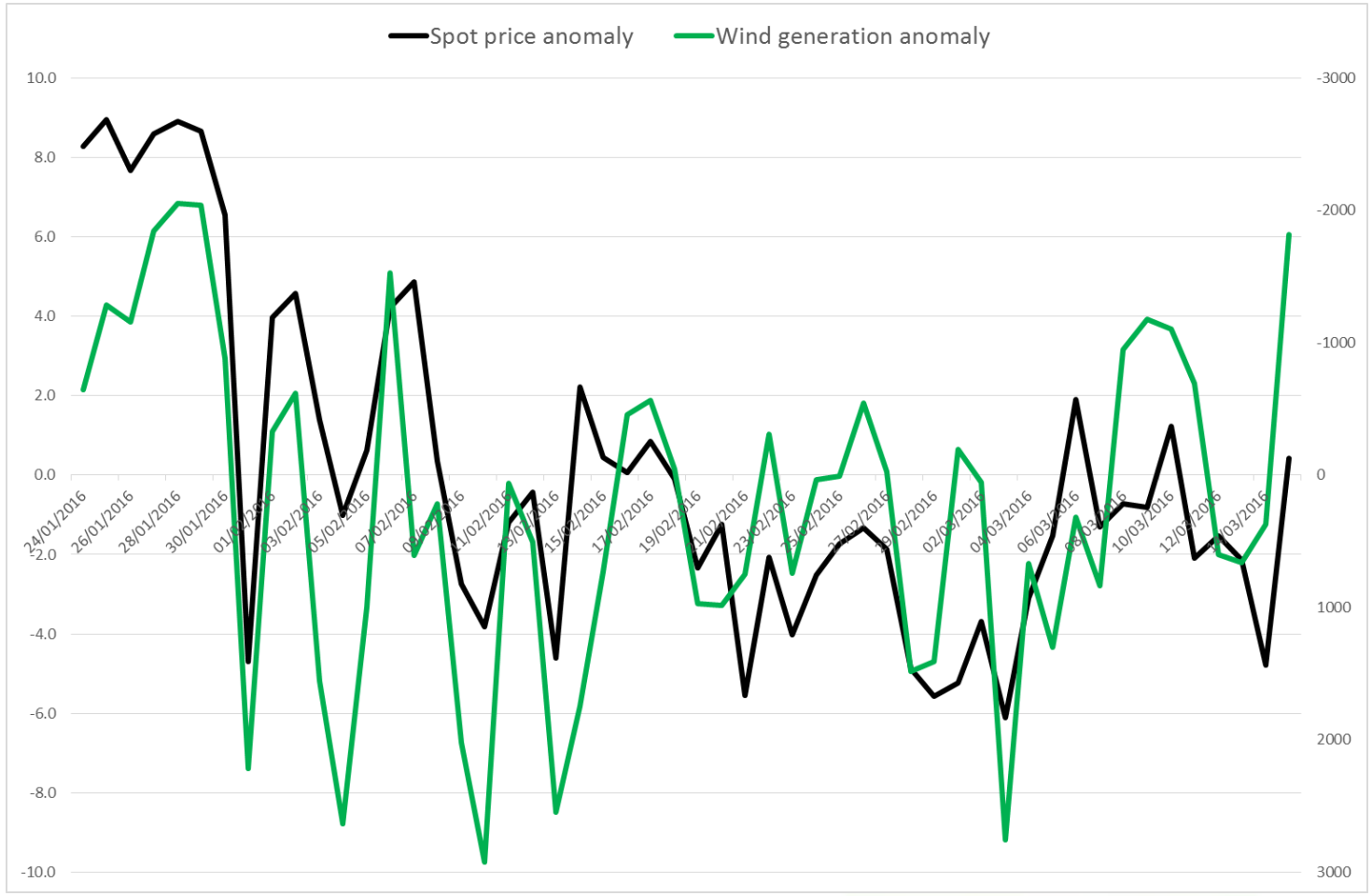
Variability of renewables

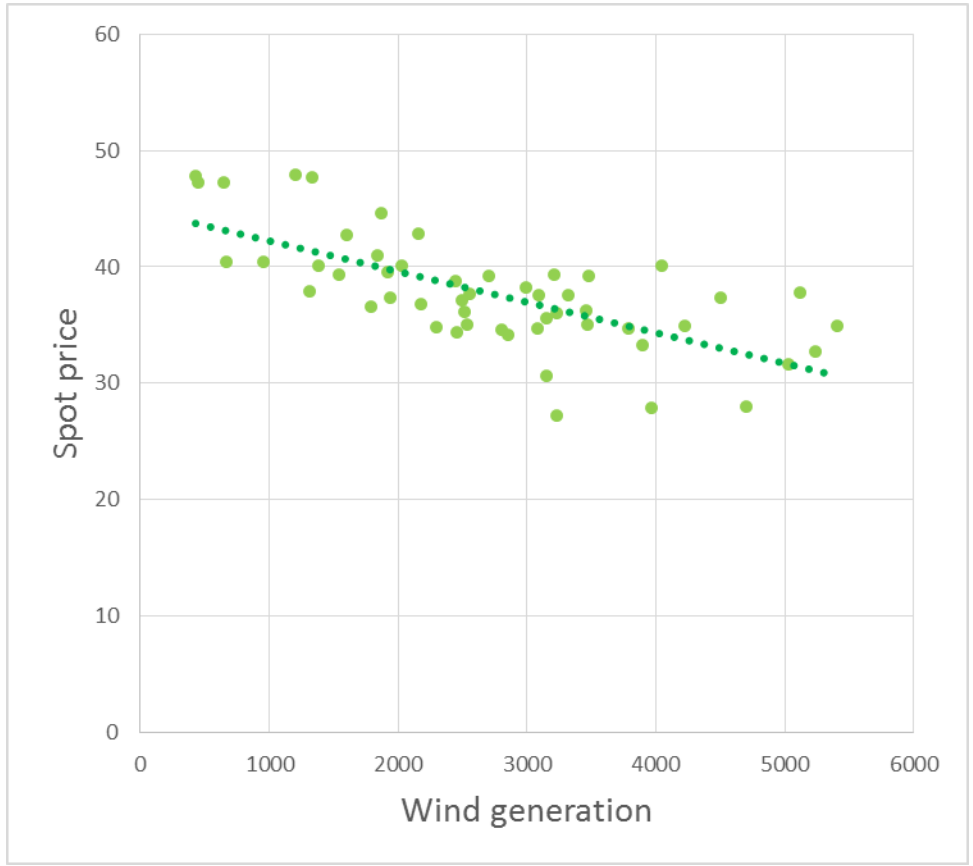




- Conventional (thermal) plant generation makes up the difference
- How much it varies within day impacts price

Italy Feb/Mar: price is wind sensitive





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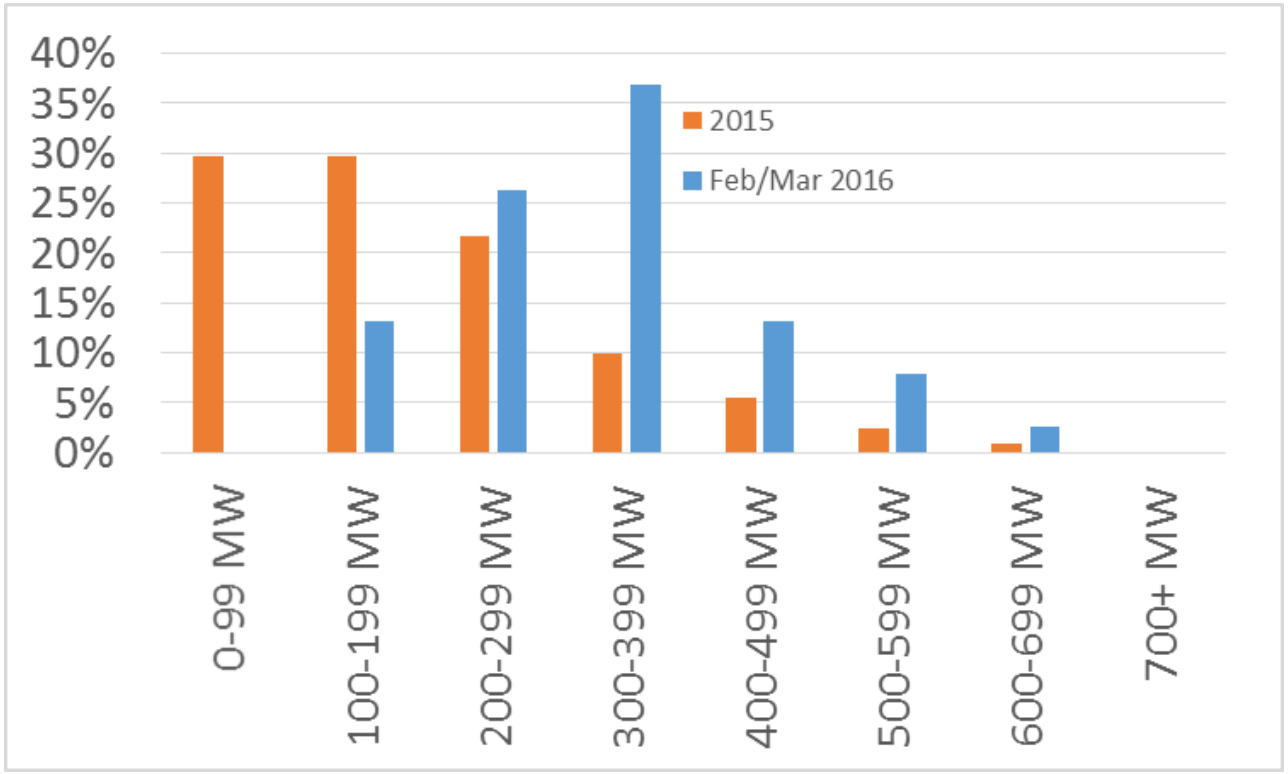
Italian wind power Feb/Mar 2016

- MW per 1GW installed capacity
- Enables comparisons across time
- Frequency of actual generation



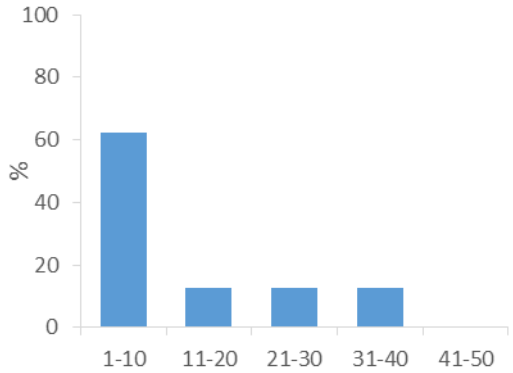
Rank histograms @ 96h lead time

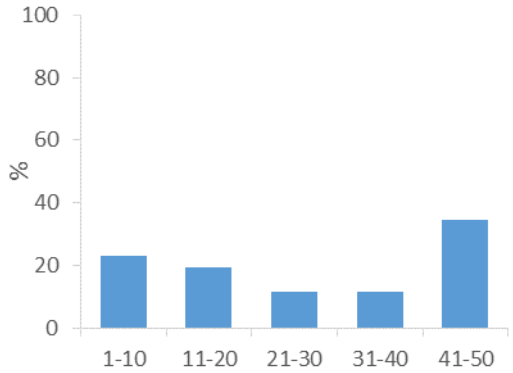
Actual generation < 249MW

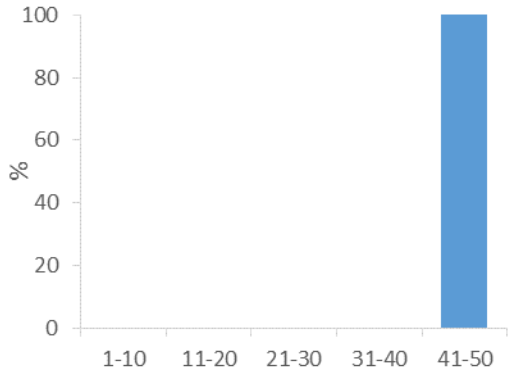
250-499MW

>500MW

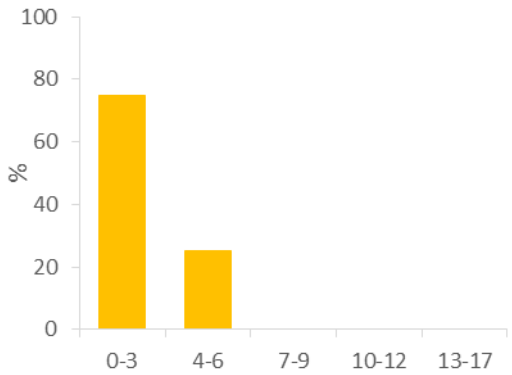
EC ens

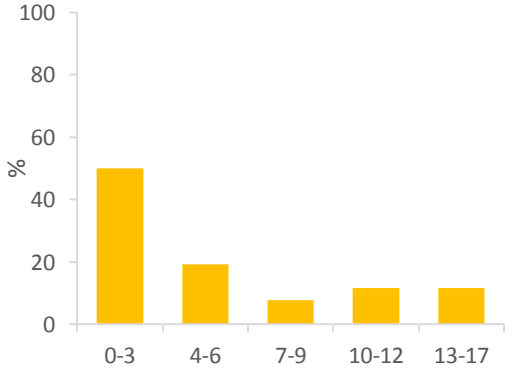


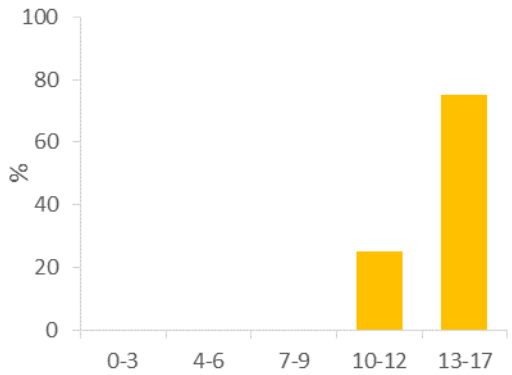




COSMO-LEPS ens*







*COSMO-LEPS ens using EC ens based wind curve, so at a disadvantage

Forecast improvement/adaptation

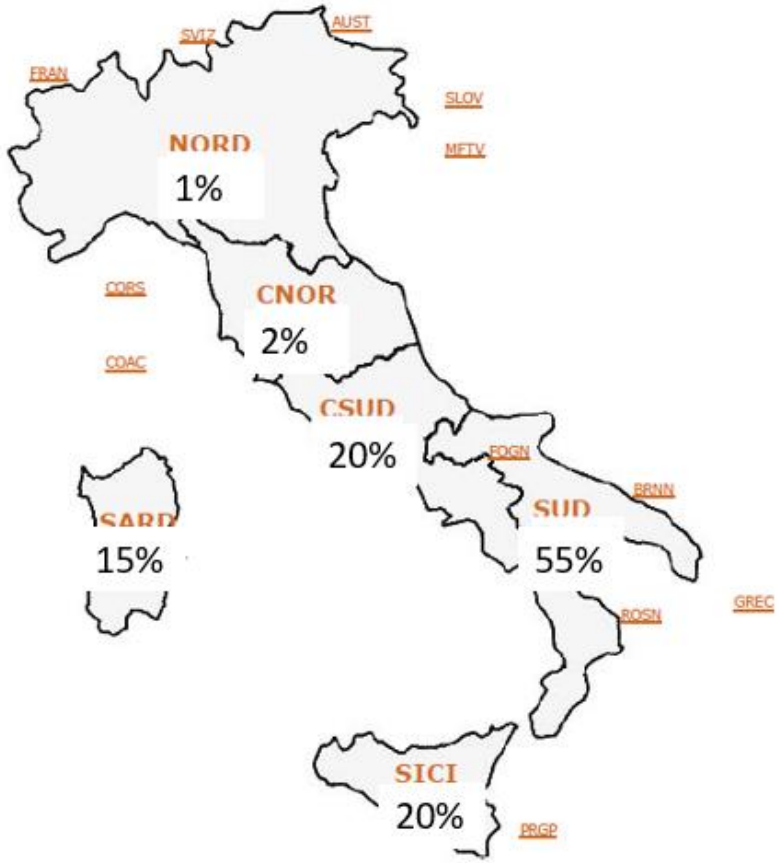
- Regime transitions
  - known increase in uncertainty but often clear biases
    - eg Atl Ridge set up and under-forecasting winds for DE
- Forecast 'busts' – not in large scale pattern but localised detail
  - If even single ens member with pattern change, something to work with
  - Else, if enough analogs to be a bias, something to work with
    - Depends if a consistent bias or a frequency correction
  - Harder... if model missing mechanism of intensification (topological or otherwise)
    - Look to LAM... If no improvement these are the ones that cause most issues.

Ensemble members provide a lot of scope for improvement,

but do have limits

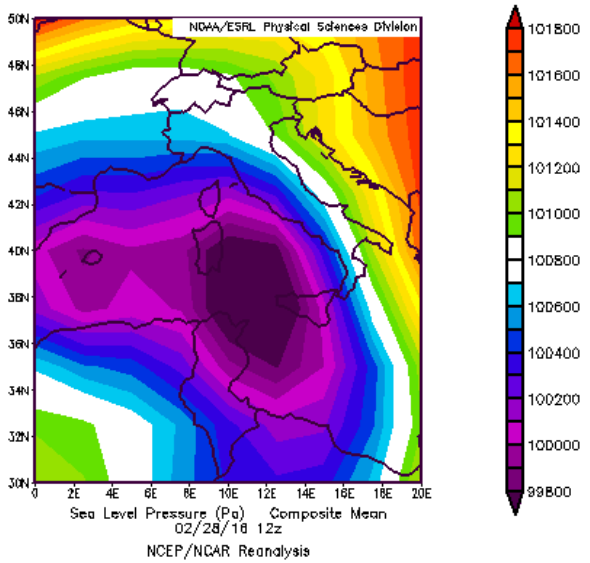
IT wind generation capacity

- Rough estimate
- Wind in south “more valuable” than wind in north



Source of background map: GME

Feb 28th: actual 435MW

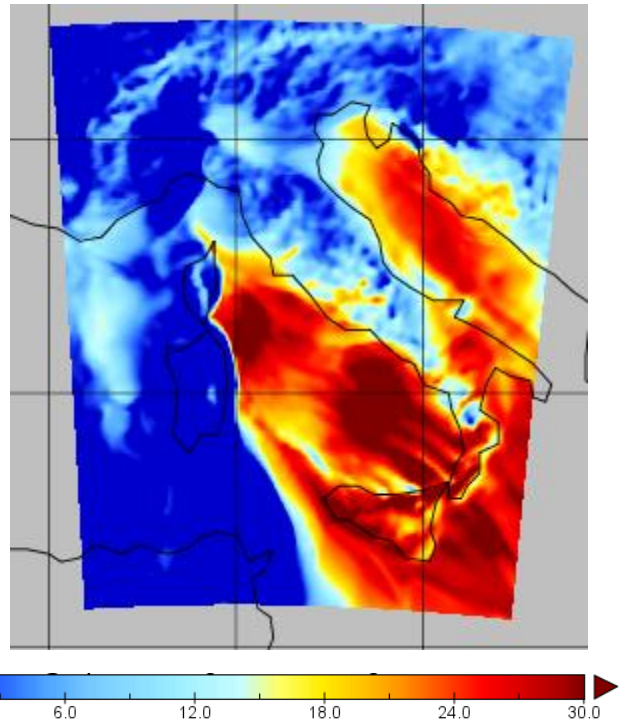


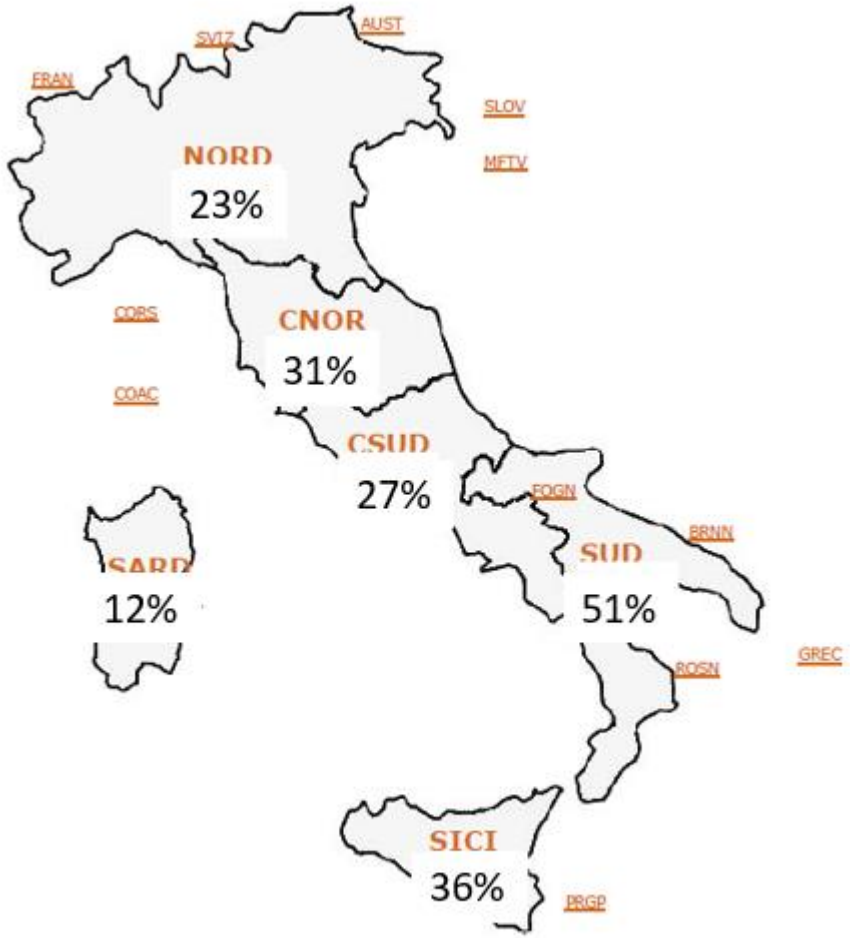
Source: NOAA

- EC forecast keeps low centred too far west, model error.
- COSMO-LEPS ensembles span the solution & have good location for low

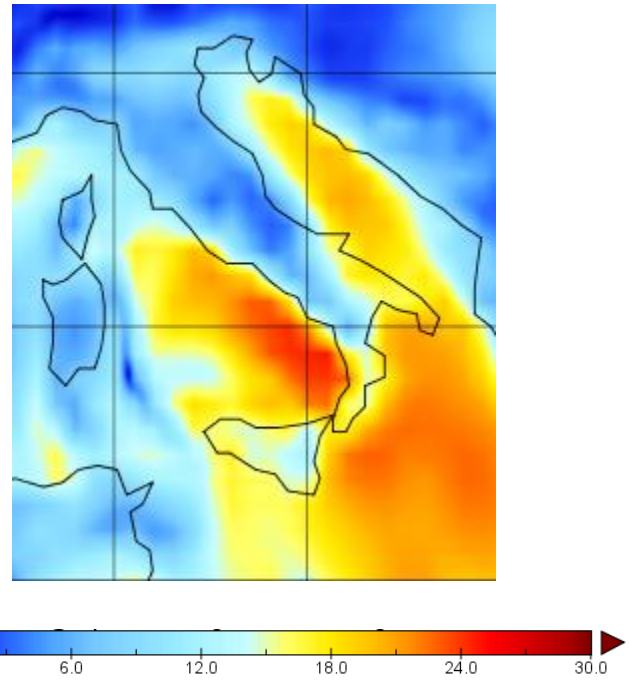
Feb 28th

ARPA5 12z 24h fcst





ECMWF 12z 24h fcst



Sources: GME; GISS, NOAA; ARPA; ECMWF

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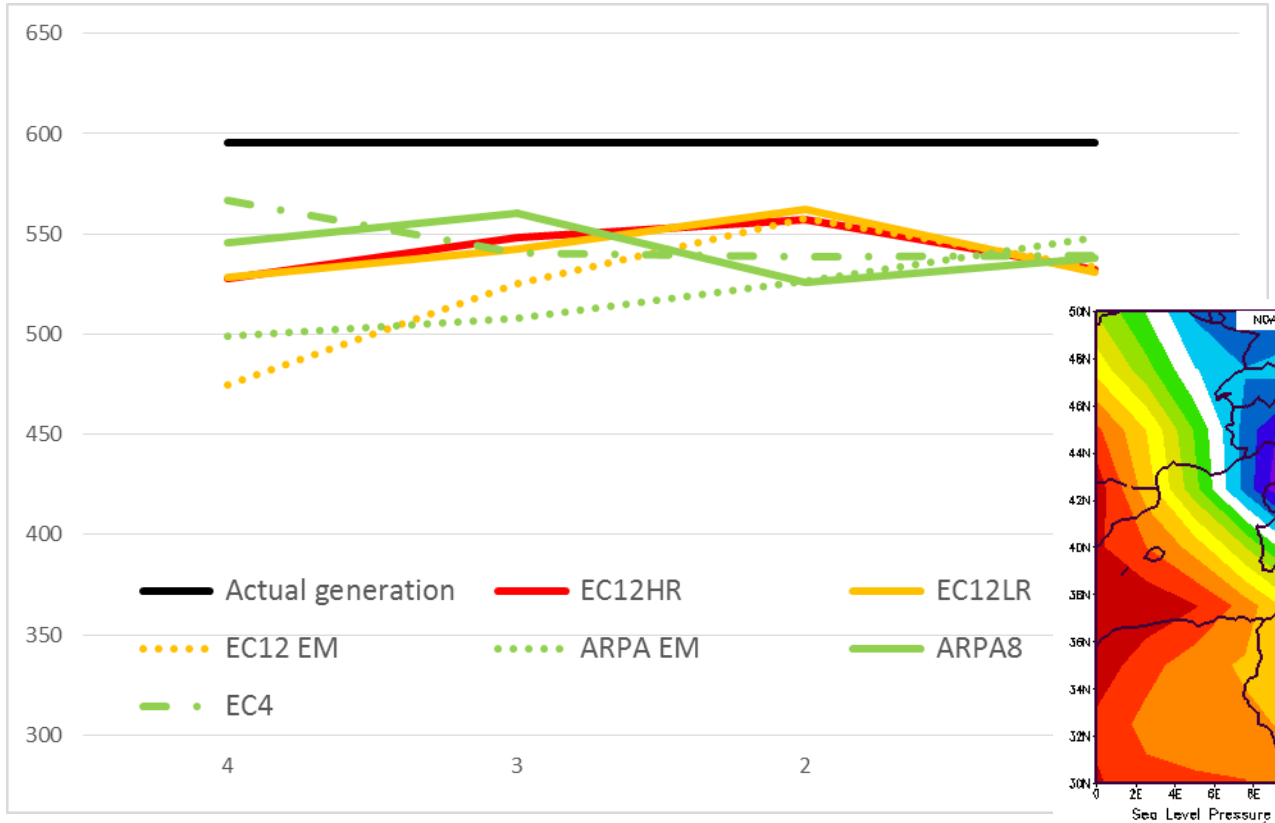
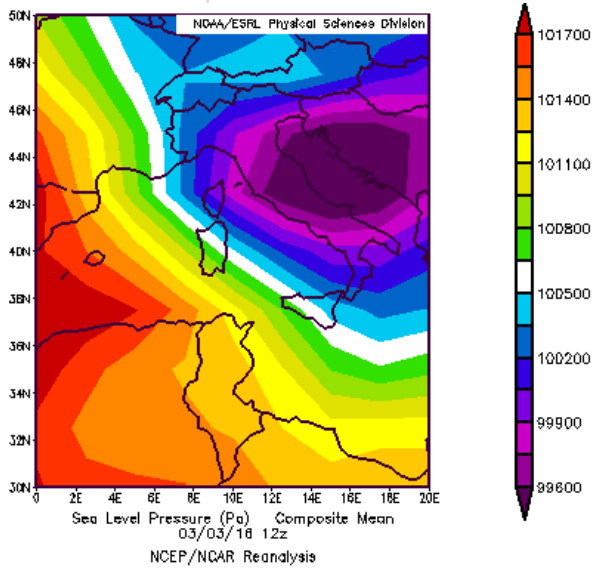
Mar 3rd: actual 595MW

- EC winds too low for south/Sardegna. Some systematic bias, some not

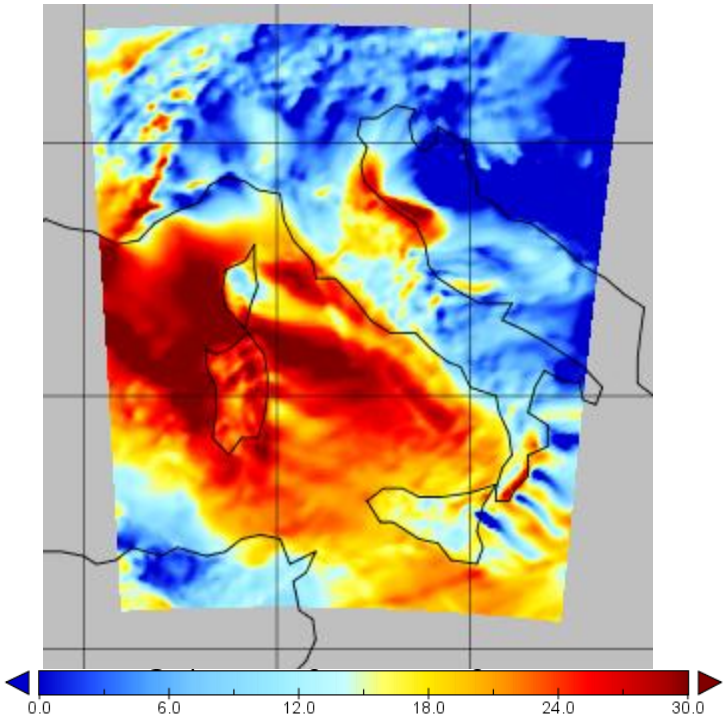


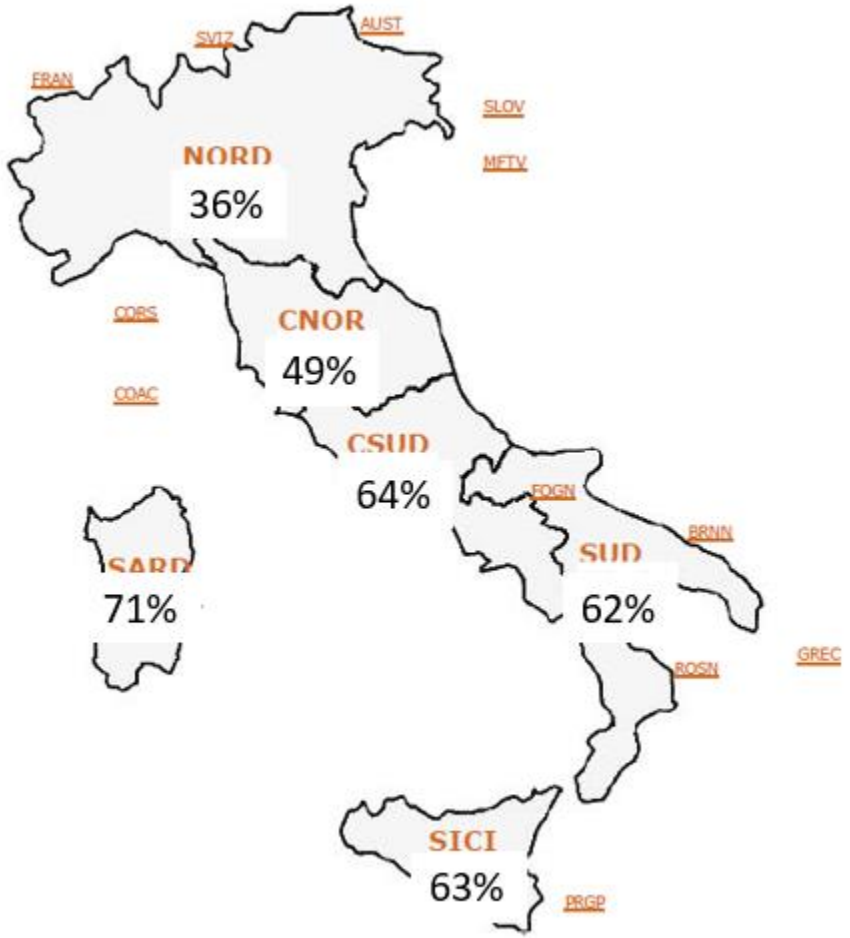


Source: NOAA

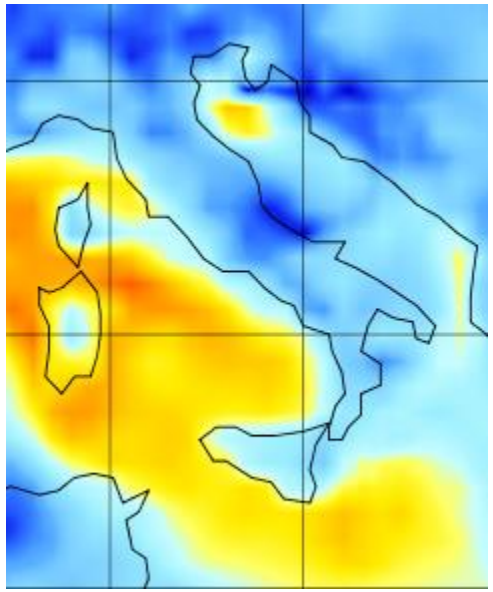
Mar 3rd

ARPA8 12z 24h fcst





ECMWF 12z 24h fcst



Sources: GME; GISS, NOAA; ARPA; ECMWF

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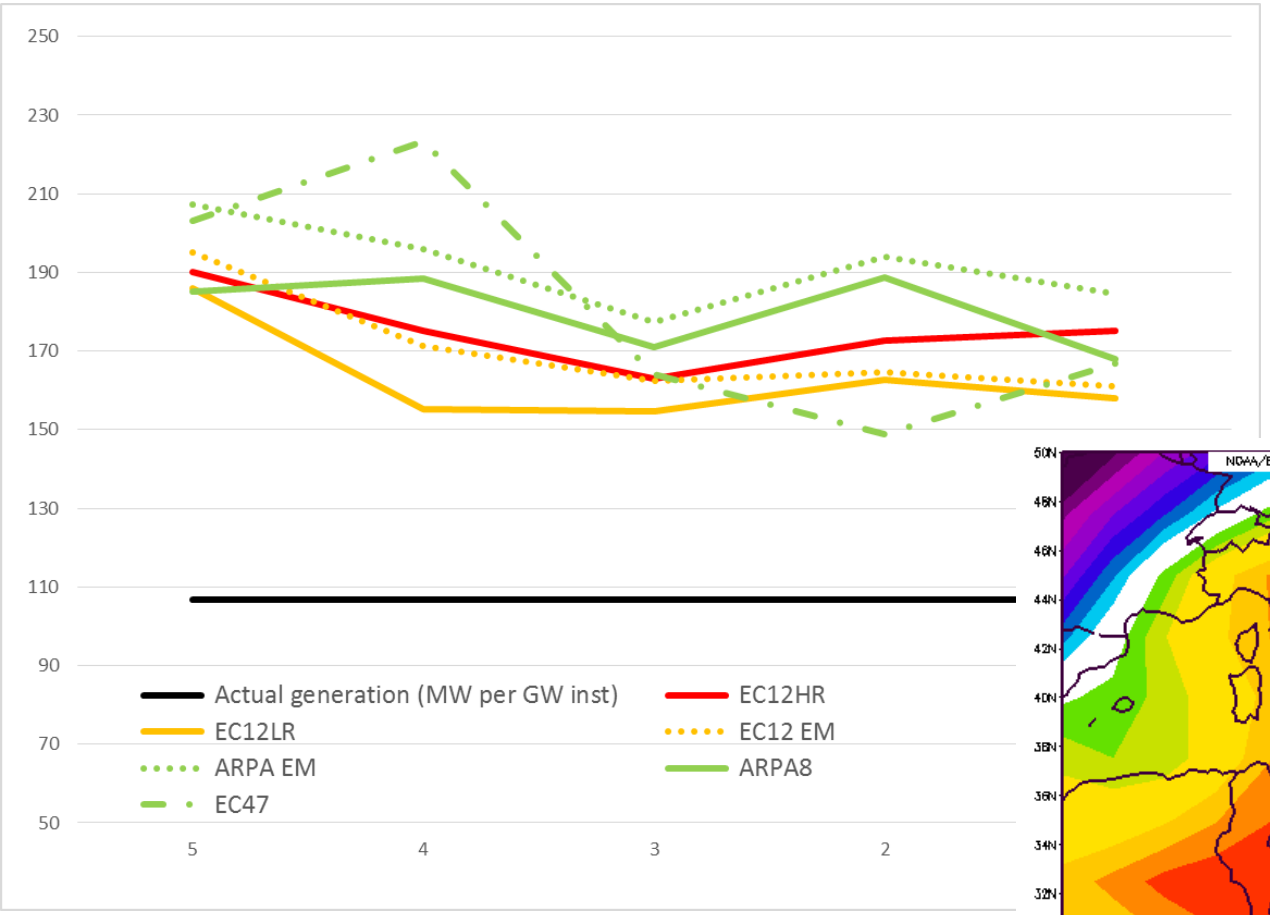
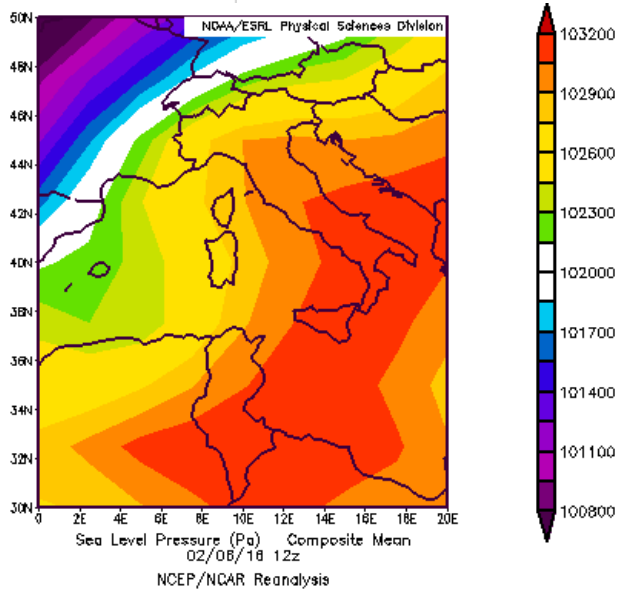
Feb 6th: actual 107MW



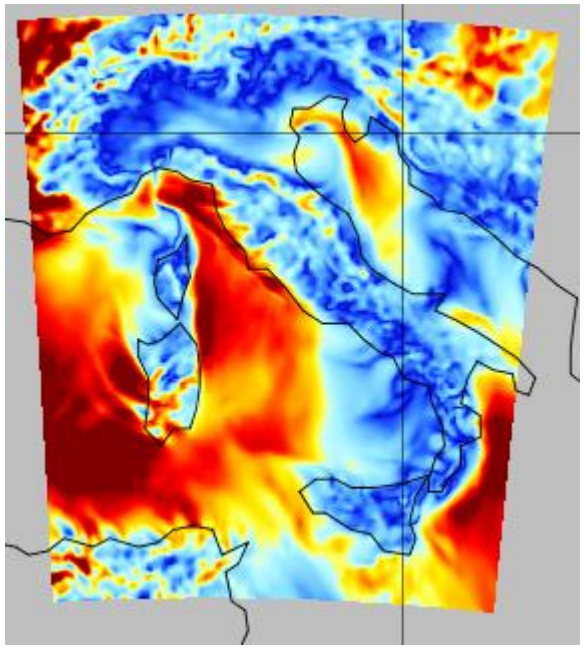


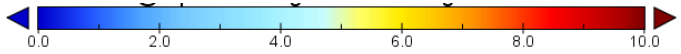
- Forecasts good, with clusters clumped from 96h
- EC and COSMO-LEPS forecast too high wind speed.
- Other patterns where calm forecast well
- Hard to correct for

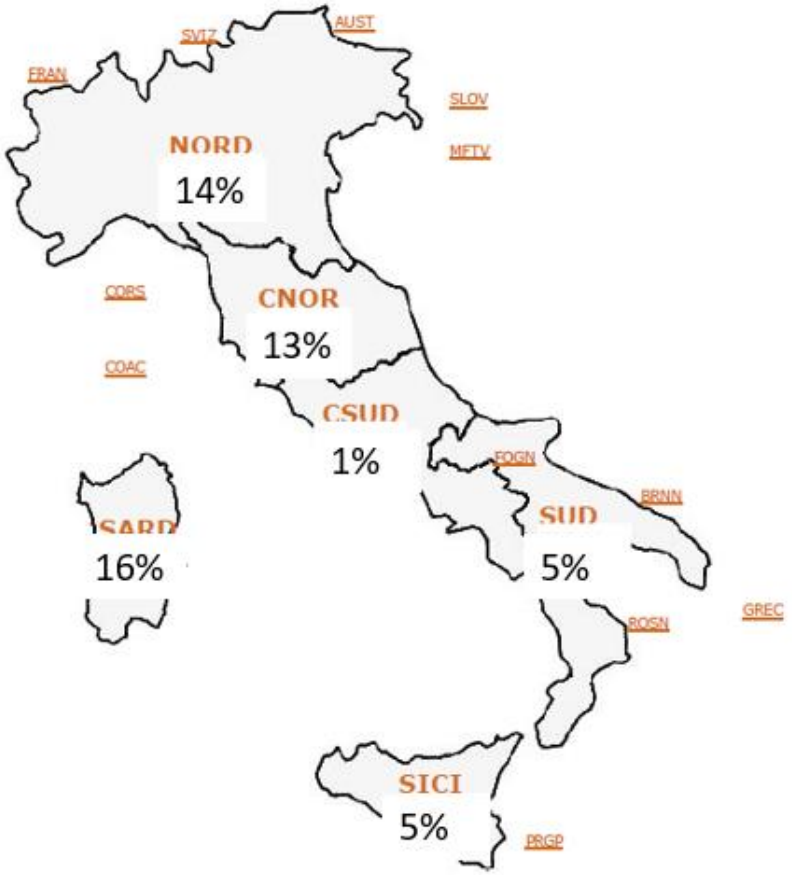
Source: NOAA

Feb 6th

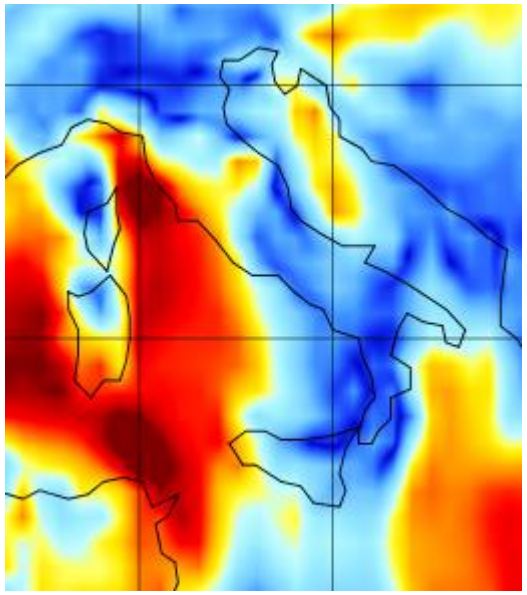
ARPA5 12z 24h fcst

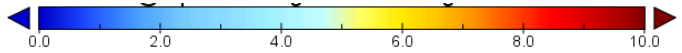






ECMWF 12z 24h fcst





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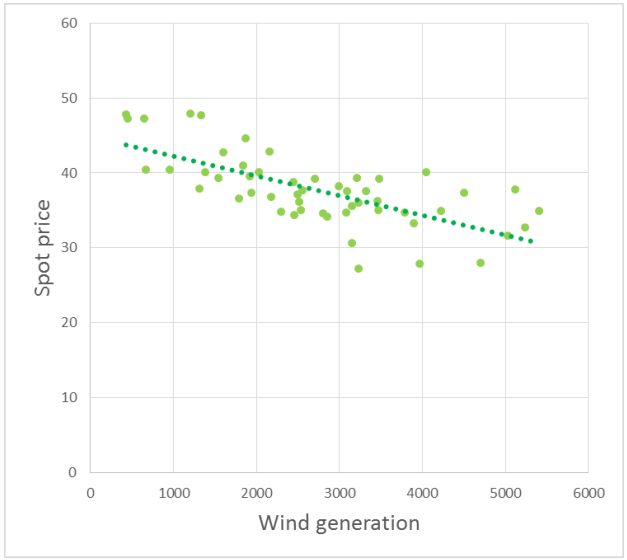
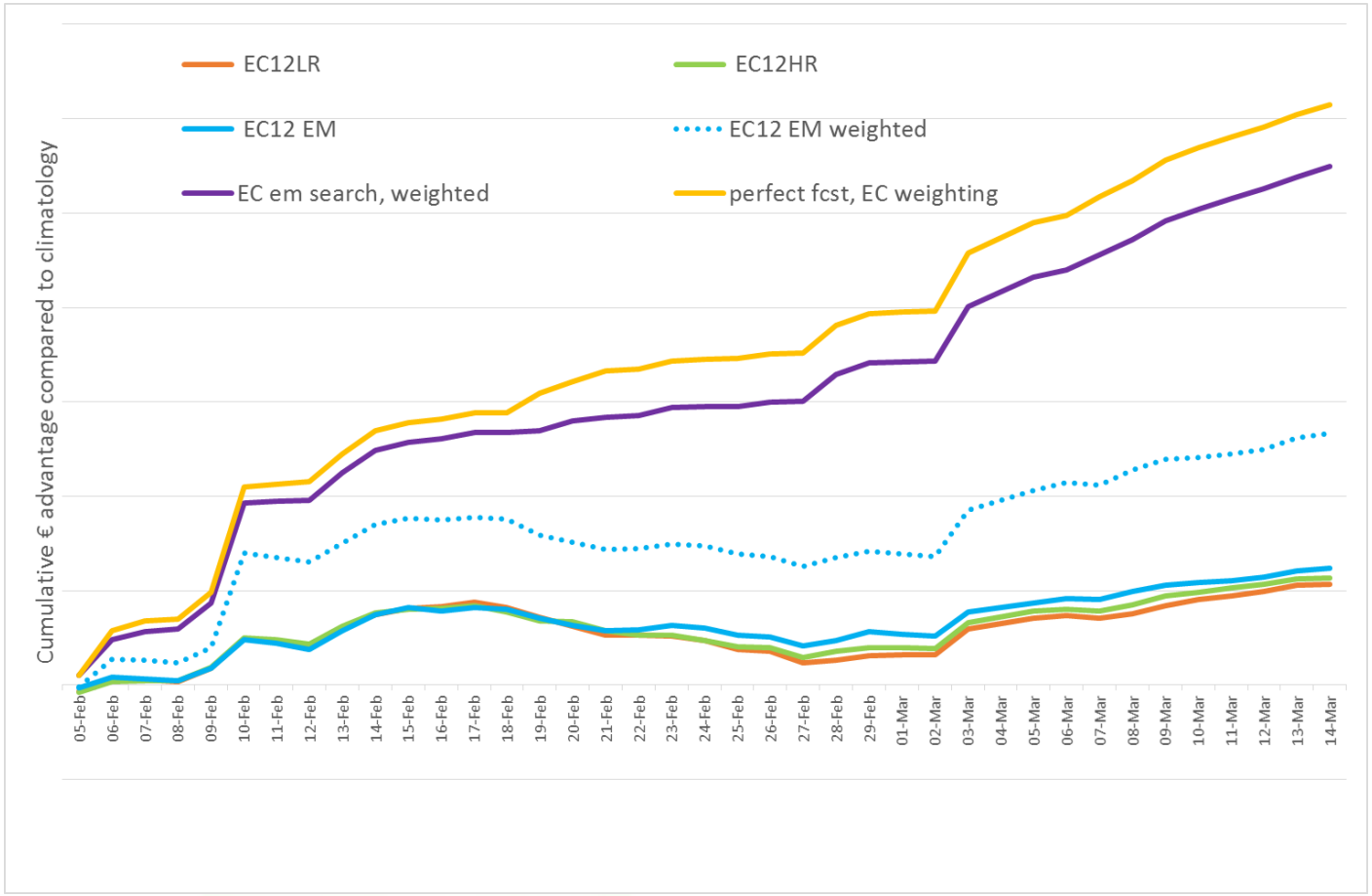
Sources: GME; GISS, NOAA; ARPA; ECMWF

Forecast value

- Assume perfect weather forecast = exact spot price
- Theoretical approach
  - Supply demand balance will vary with forecast, but assume fixed
  - Calculate supply and demand from forecast and look up implied spot price
  - Repeat with climatology
  - See what contribution forecast has made if eg 1GW plant
  - Data intensive!
- First step is to contrast climo and forecast on daily average spot price at set lead time eg 96h, using average sensitivity

96h forecast value for IT wind generation





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Looking forwards

- Many improvements in hi-res and ensembles forecasts over the last 10 yrs
- Regime transitions continue to present a forecast challenge
- Other significant errors seem to be due to model processes/dynamics being 'wrong'
  - If an ensemble member exists which hints at a change, easier to post-process
    - How high does resolution need to be before these will be addressed?
    - Meantime, is there an alternative ensemble initialisation method which could increase the dispersion of the ensembles to sample more of the actual phase space?
- Improved forecasts can reduce carbon emissions

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