DNV·GL

ENERGY

Balancing and Scheduling of Renewable Energy with other sources

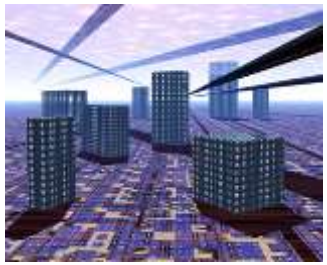
Jonathan Collins

5th May 2014

DNV GL - Energy

- We assist customers in delivering a safe, reliable, efficient, and sustainable energy supply around the globe
- Our expertise spans renewable and conventional power generation, onshore and offshore, transmission and distribution, smart grids, super grids and sustainable energy use
- Renewables Advisory brings together over 800 renewable energy experts from GL Garrad Hassan and DNV KEMA



Policy & Strategy | Power Generation | Trading | Transmission & Distribution | Use

Private and confidential

DNV GL Short Term Forecasting

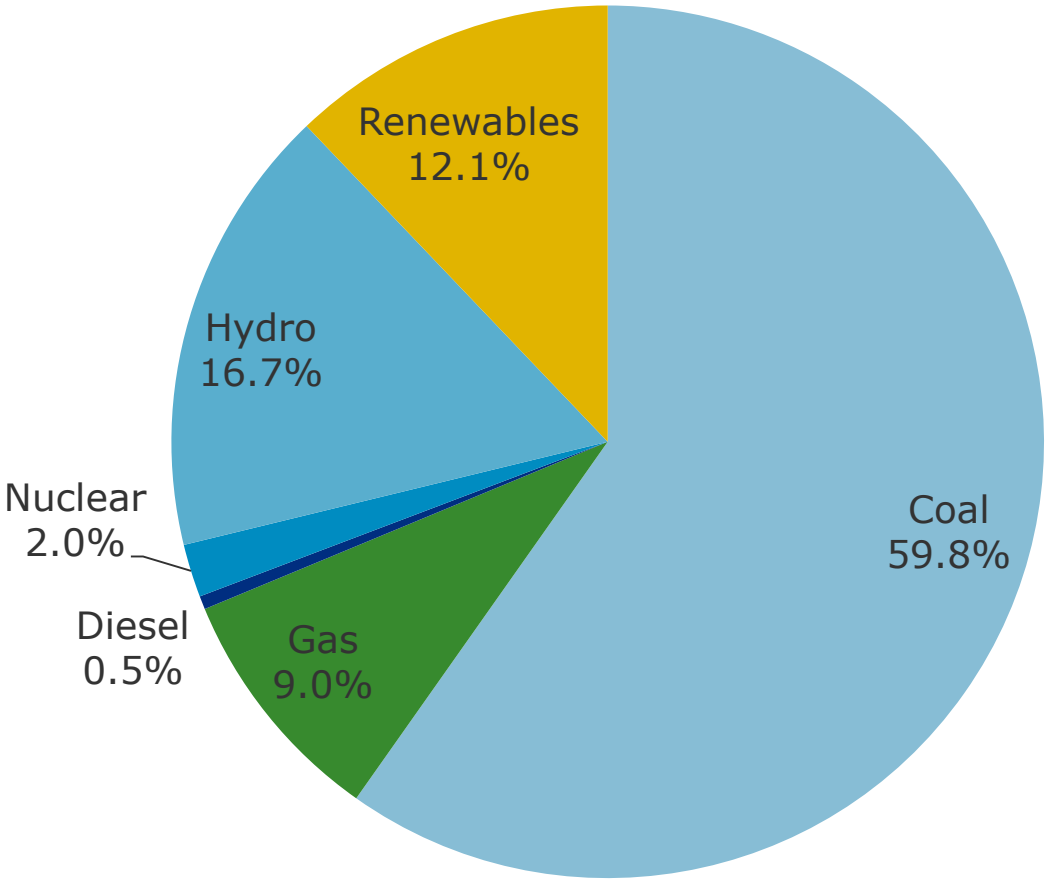
- Operational since 2003 (formerly within GL Garrad Hassan)
- Wind, Solar and Demand forecasts
- Delivering forecasts in 16 countries for over **33GW** installed capacity

Aruba	Argentina	Australia	Canada
China	Greece	Hungary	India
Italy	Japan	Poland	Romania
Spain	Turkey	UK	USA

- Deliver market-leading accuracy and reliability
- Clients include Site Owners, Utilities and Grid Operators

Renewable Generation in India – A Summary of Current Status

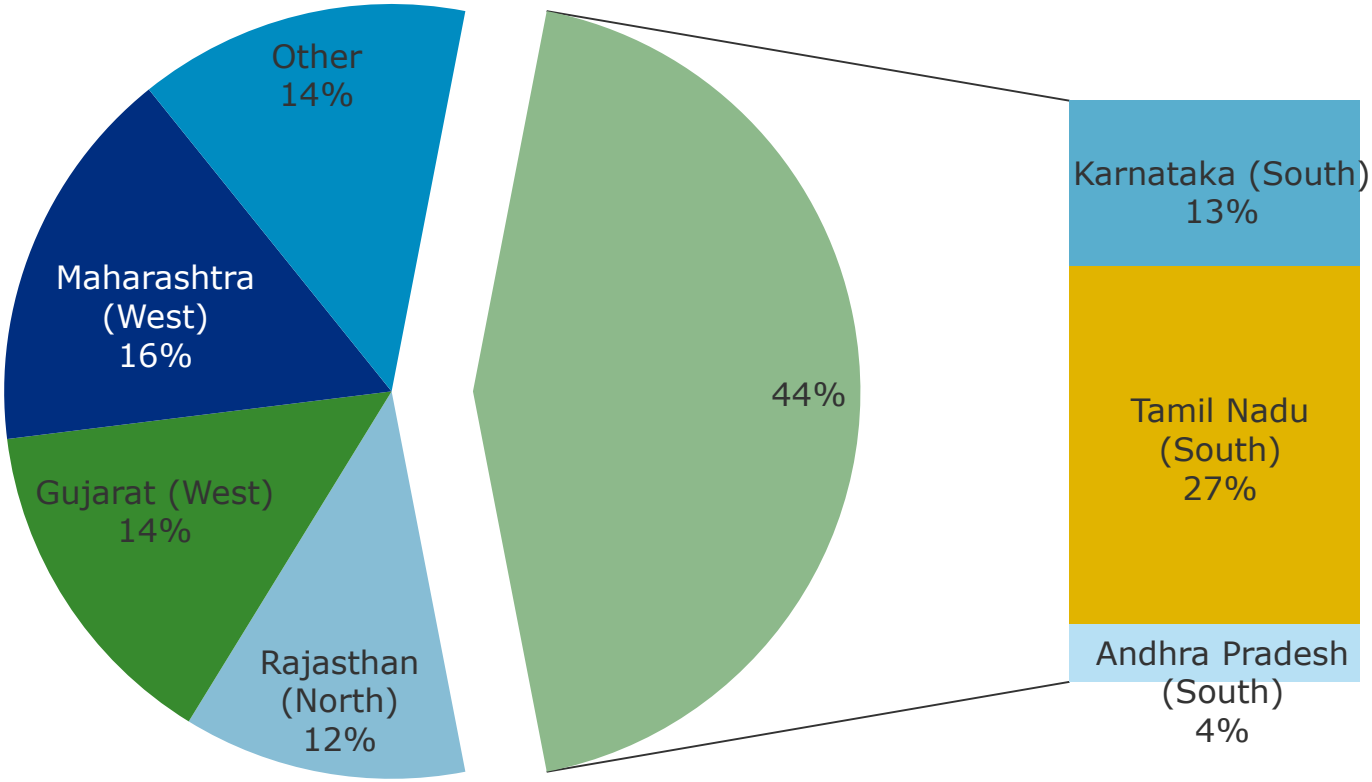
All India Current Energy Mix (31/03/14)



Source: CEA

Installed Renewables Capacity By State

- Six states contain 86% of India's renewable generation capacity
- 44% is concentrated in just three Southern states



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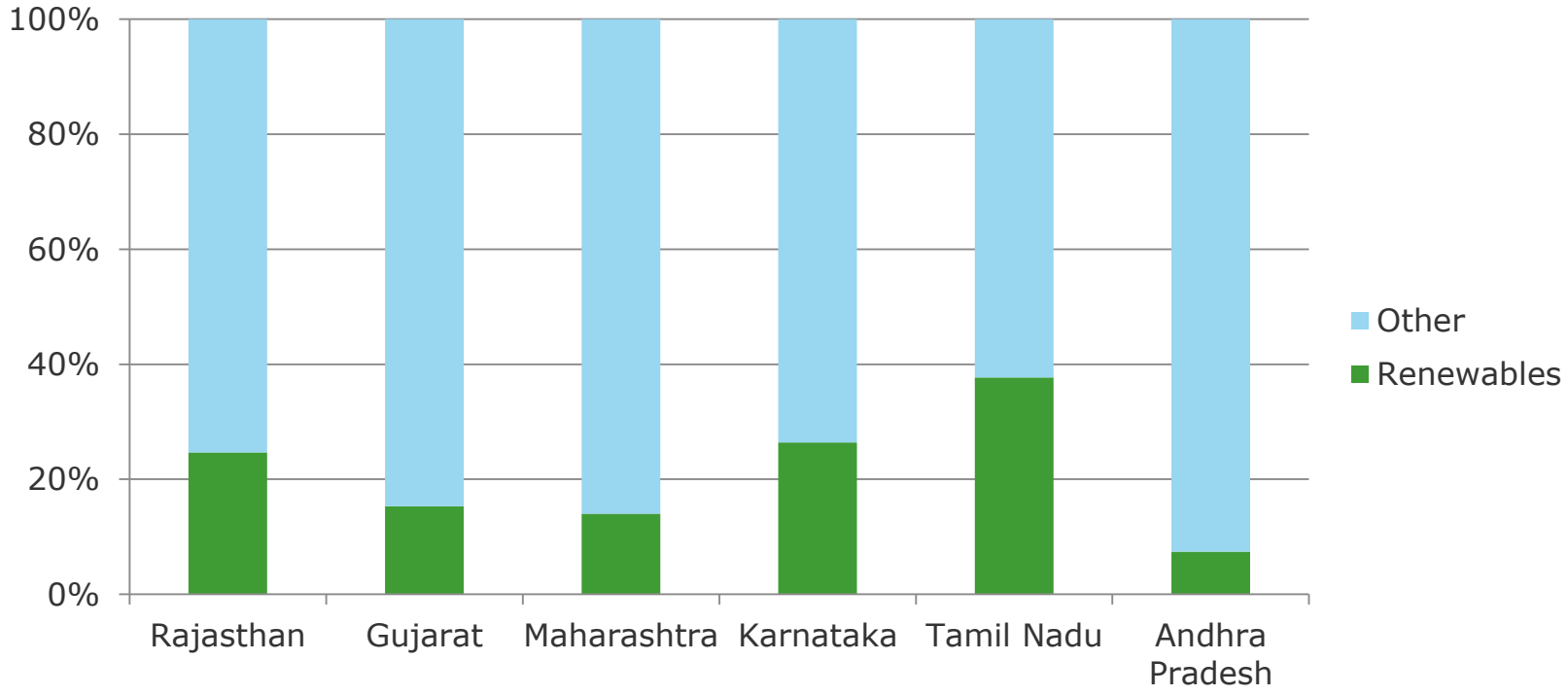
Renewable Capacity vs Other Generation

- In these 6 states, renewables make up an average of 20% of total capacity (Up to 38% in Tamil Nadu)

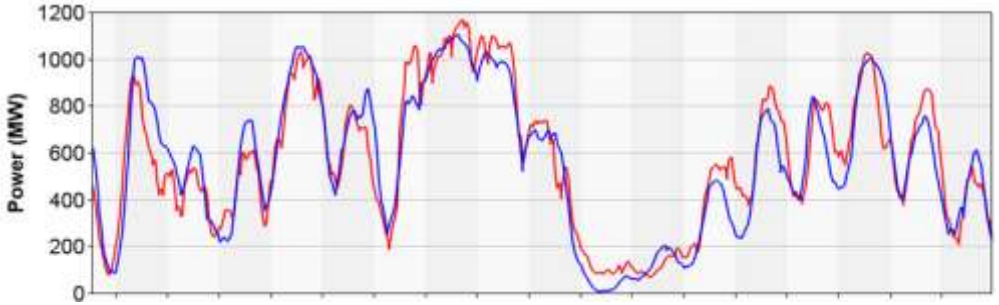


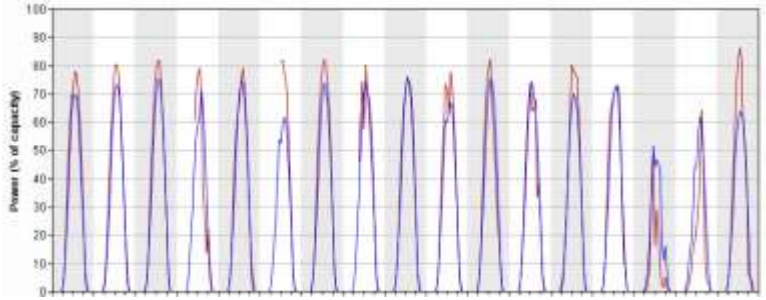
Source: CEA (31/03/2014)

Knowledge gives the power to plan

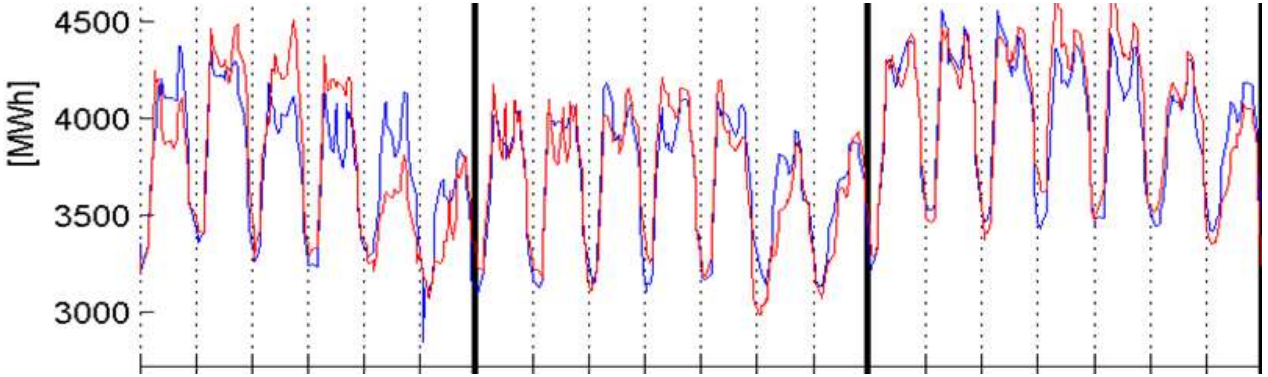
Forecasting

- The first step in balancing RE on the system is to know what's coming…
  - Plant availability: Renewables and conventional
  - Wind / Solar Generation Forecasting





  - Demand (Load) Forecasting



Counting the Cost of Forecasting

- Wind and solar generation is variable but not unpredictable

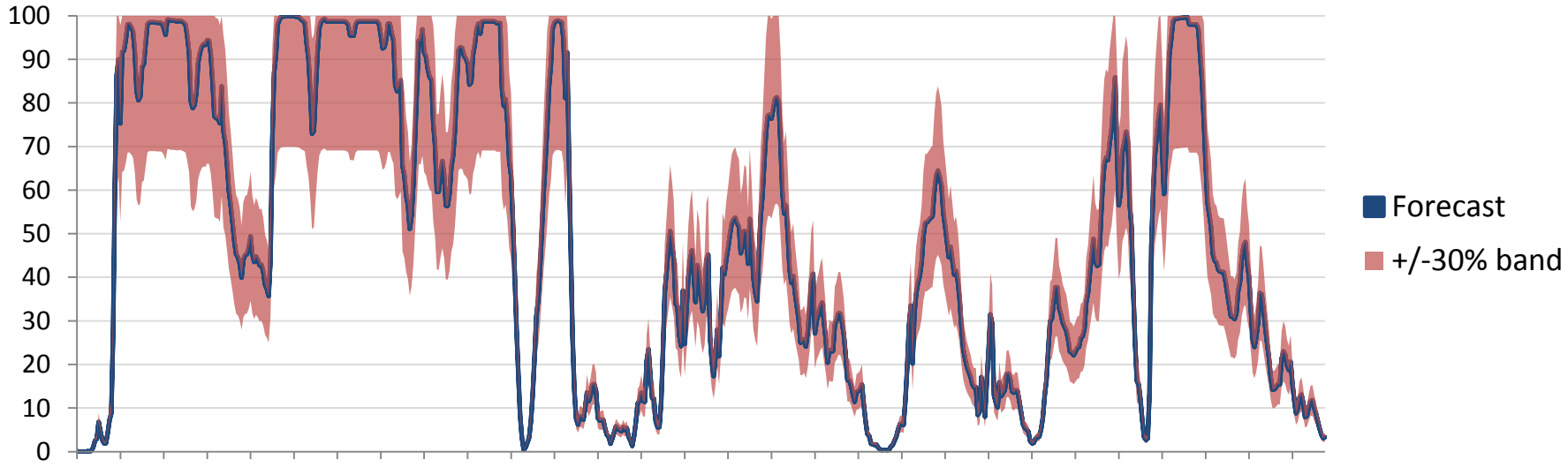
- Forecasting is used in many countries with high RE penetration (20%+) to incorporate renewables successfully:
  - Centralized forecasts to manage grid
  - Site forecasts to trade onto open energy market
  - Or a combination of both (eg Germany, UK, Texas)

- Accurate forecasting will be essential in India with planned RE capacity

- DNV GL experience shows forecast accuracy achievable in India is comparable to the best accuracy levels globally
  - NMAE 12% of capacity or lower

RRF Mechanism

- Current proposed structure for RE forecasting in India
- All wind farms of >10MW capacity
- UI Charges applied if actual production outside +/- 30% of forecast



Counting the Cost of Forecasting

- Is evaluating forecast errors based on "percentage of forecast" representative of real cost incurred?

Errors are treated asymmetrically…

Same MW error, different % error

Forecast Power (MW)	Actual Power (MW)	Absolute Error MW	Error - % of Forecast
70	50	20	29%
50	70	20	40%

…and skewed…

Different MW error, same % error

Forecast Power (MW)	Actual Power (MW)	Absolute Error MW	Error - % of Forecast
3	4	1	33%
30	40	10	33%

Counting the Cost of Forecasting

- The cost of balancing each 1MW of forecasting error is less dependent on the original forecasted value but on other factors (demand, available capacity, etc)

- Industry standard accuracy measure in most countries is NMAE – mean absolute error normalised by the installed capacity of the site

$$NMAE = \frac{|ForecastPower - ActualPower|}{Capacity}$$

Counting the Cost of Forecasting

$$NMAE = \frac{|ForecastPower - ActualPower|}{Capacity}$$

- Assume a 100MW wind farm:

Forecast Power (MW)	Actual Power (MW)	Absolute Error MW	Error - % of Forecast	NMAE (% capacity)
70	50	20	29%	20%
50	70	20	40%	20%
3	4	1	33%	1%
30	40	10	33%	10%
30	38	8	27%	8%

Counting the Cost of Forecasting

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- Assume a 100MW wind farm:

Errors treated symmetrically

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Counting the Cost of Forecasting

$$NMAE = \frac{|ForecastPower - ActualPower|}{Capacity}$$

- Assume a 100MW wind farm:

No skew:
larger MW error = larger NMAE

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Risk of "Gaming"

- Asymmetry in forecast accuracy evaluation will encourage intentional over or under prediction in order to minimise error statistics and maximise revenue

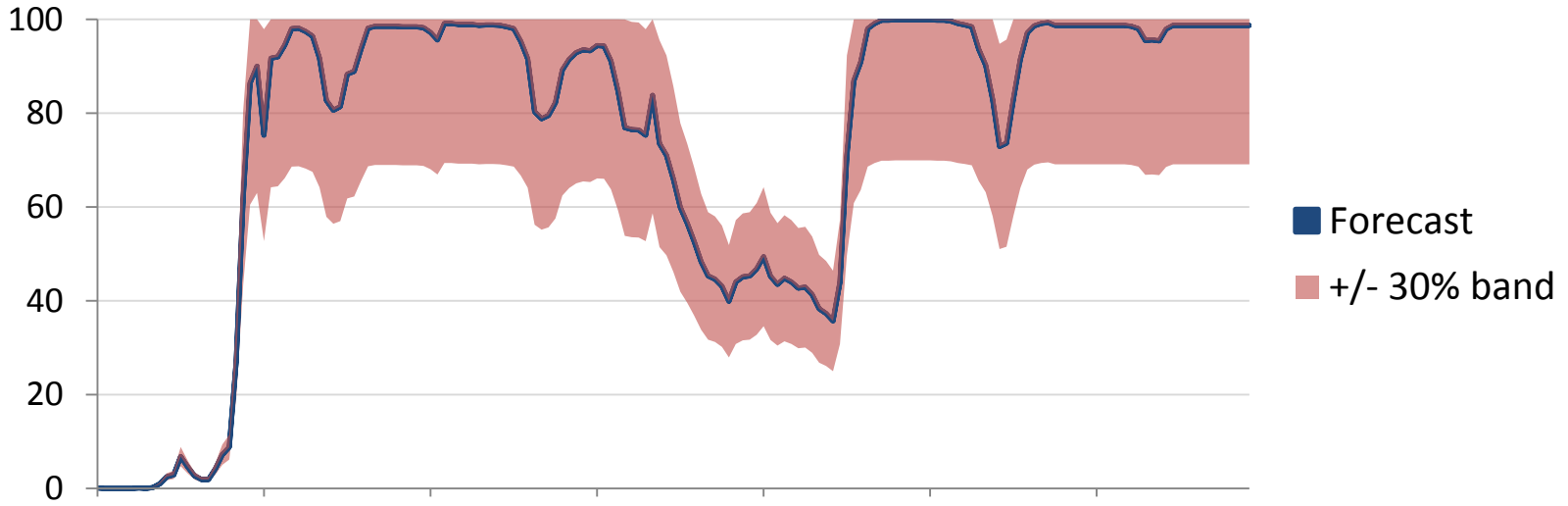
- Same MW error, different penalty – much better to over-predict:

Forecast Power (MW)	Actual Power (MW)	Absolute Error MW	Error - % of Forecast
70	50	20	29%
30	50	20	66.7%

- Encourages adding a bias to all forecasts

Risk of "Gaming"

- To minimise risk of charges, should never forecast > 77% of capacity
- Any actual power generation between 54% and 100% will not incur UI Charges (+/- 30% of 77%)
- Forecasting > 77% reduces protection from over-prediction for no benefit



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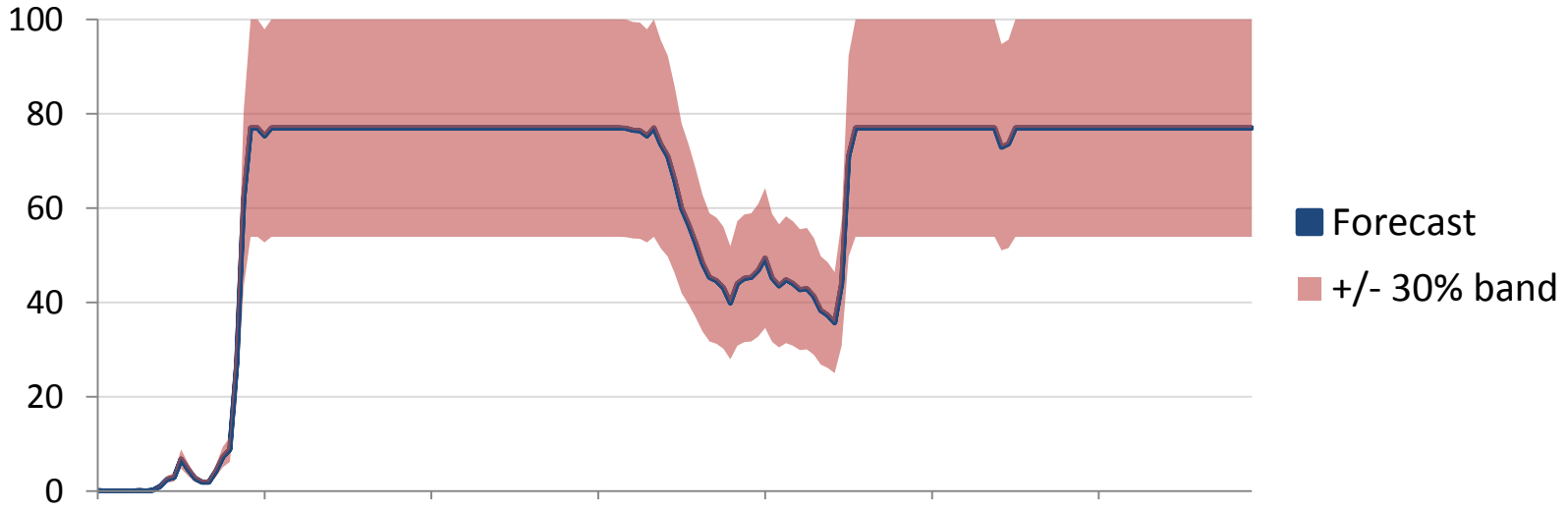

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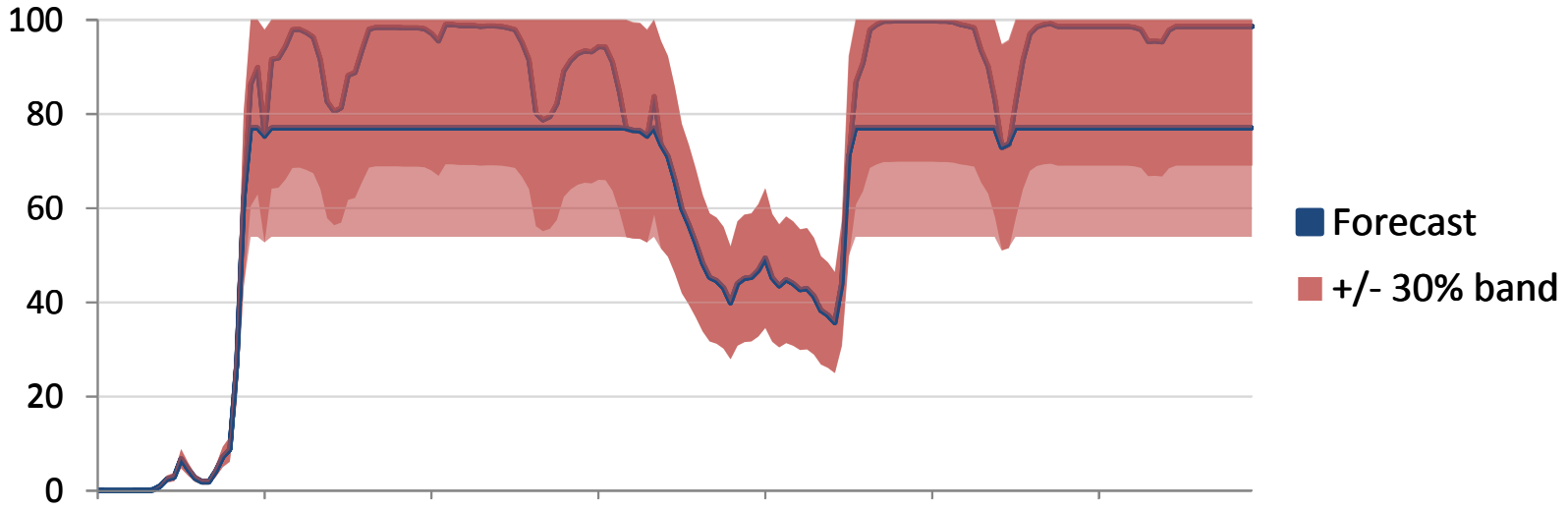

Risk of "Gaming"

- Linking UI Charges to grid frequency may also promote gaming
  - Frequency is to some extent predictable day-ahead
  - The regulations may financially reward over-prediction based on expected grid frequency
  - DNV GL work shows that in extreme cases the most revenue can be made with a constant forecast of 100% of capacity irrespective of actual expected generation

Counting the Cost of Forecasting

- Regulations should reward provision of the most accurate forecast possible:
  - Accuracy measure should not be asymmetrical or skewed if the real cost of balancing forecasting errors is not
  - Incentives should be linked only to forecast accuracy (not grid frequency, etc)
  - It should not be possible to "game" the system
  - The structure should drive towards the most efficient incorporation of RE onto the grid rather than penalizing renewables for their variability (This encourages R&D into best forecasts and best use of forecasts)

Counting the Cost of Forecasting

- Overall forecasting saves money!

  (Significantly more than it costs)

  For RE generators / grid operators / both

  But only if structured correctly

Taking Action

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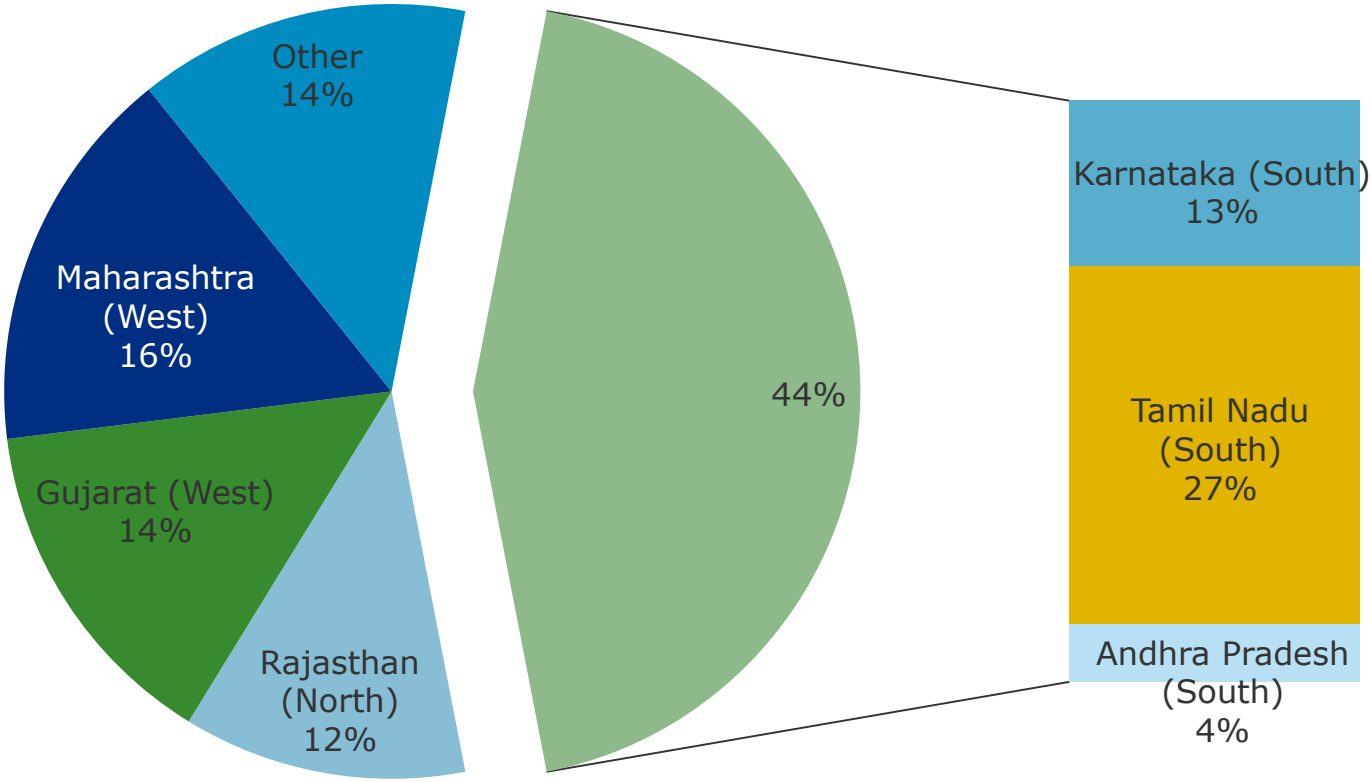


Source: CEA
(31/03/2014)

Strengthening the Grid

- Need to bridge the distance between generation and demand
- Development of transmission infrastructure can take significantly longer than development of the wind/solar sites that want to connect to it
- Therefore require:
  - Clarity of renewable capacity targets (at state and country level)
  - Long-term view in providing sufficient transmission infrastructure (eg "Green Energy Corridor")

Curtailment of Renewable Generation

- Renewables are treated as “must-run” under IEGC regulation
  - But with provision for curtailment

- **Curtailment should always be a last resort!**
  - Renewables displace other sources in supply mix due to near-zero marginal cost of generation

- Used in Europe when necessary – producers are usually paid for “lost” generation

Widening the Grid - Interconnection

- A more isolated network will find it harder to integrate renewables and will experience problems at a lower level of RE penetration

- Mitigated by:
  - Diversity of generation type
  - Geographic spread of RE capacity
  - Interconnection across networks (eg Nord Pool)

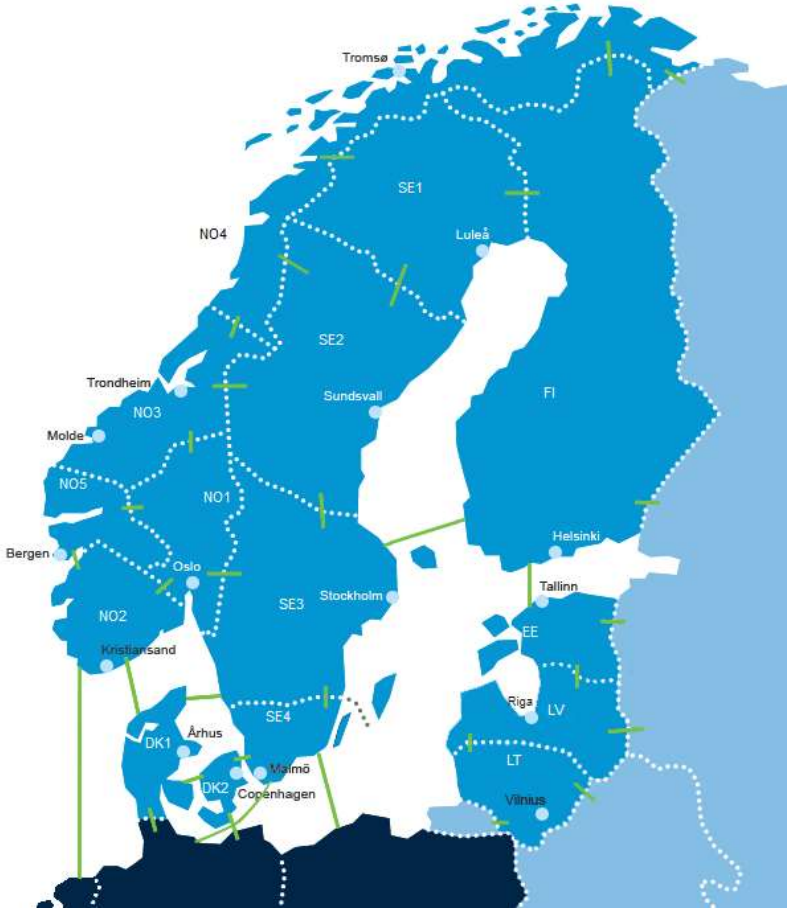
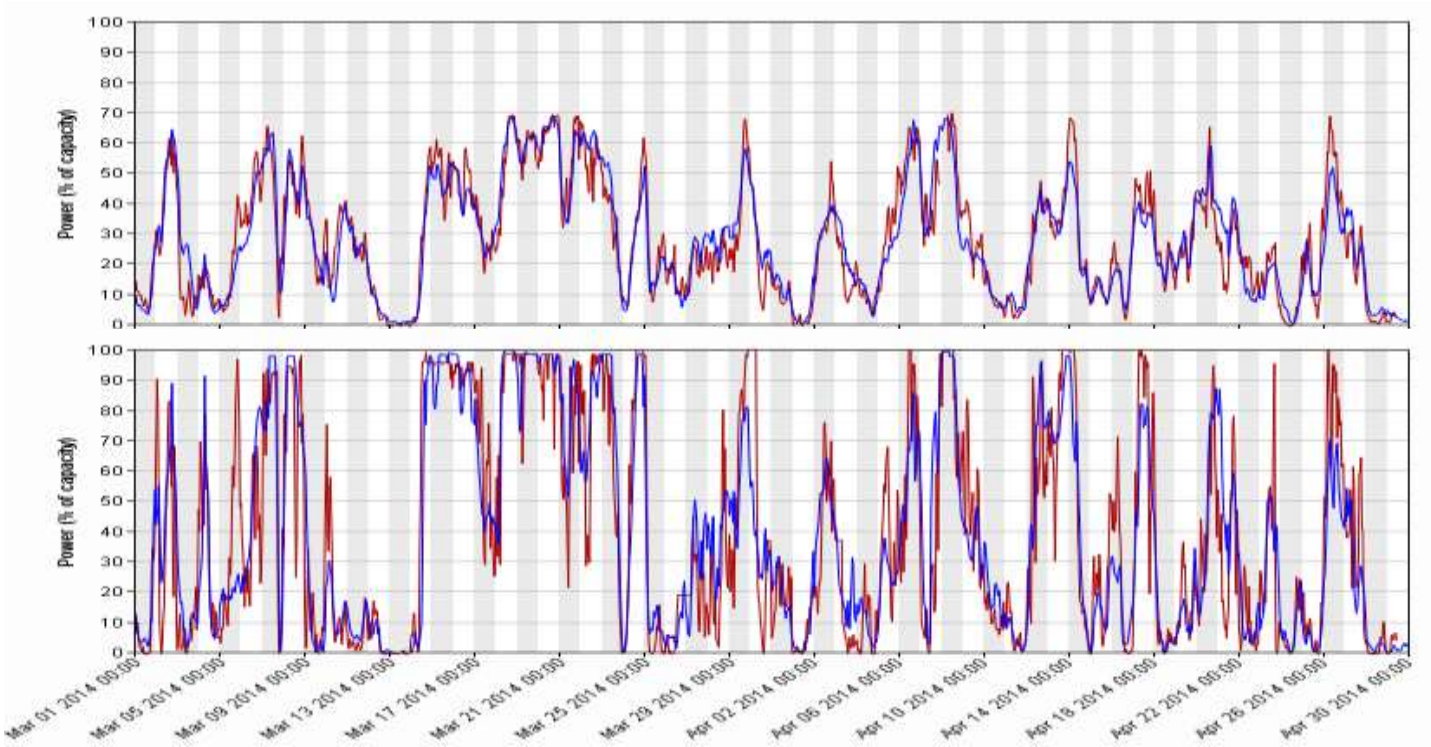


Image source: http://www.nordpoolspot.com/

Widening the Grid - Interconnection

- RE generation forecasts for geographically diverse sites show lower variability and better average accuracy than individual site forecasts



Portfolio

24 hour ahead

NMAE = 5.0%

Single Site

24 hour ahead

NMAE = 11.2%

- Centralised forecasting at state or country level may be beneficial

Reserves & Demand Side Management

- Daily variations in RE generation change the net demand (total demand minus RE generation) from day to day
- Incentivise non-RE generation to behave in a RE-friendly manner to aid efficient grid operation
  - E.g. operate at <100% in order to provide reserve capacity
- Good market design reduces the amount of reserve needed
- Demand side management (eg Smart Grids)
- Added complexity can make finding efficient market equilibrium harder

Conclusions

Conclusions

- Best possible forecasts of within-day and day-ahead+ situation essential
- Market structure / incentives need careful consideration
- Infrastructure development is crucial but needs time
- Long-term policy view is important
- No one solution – optimal operation will be found with a combination of strategies

Thank you

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