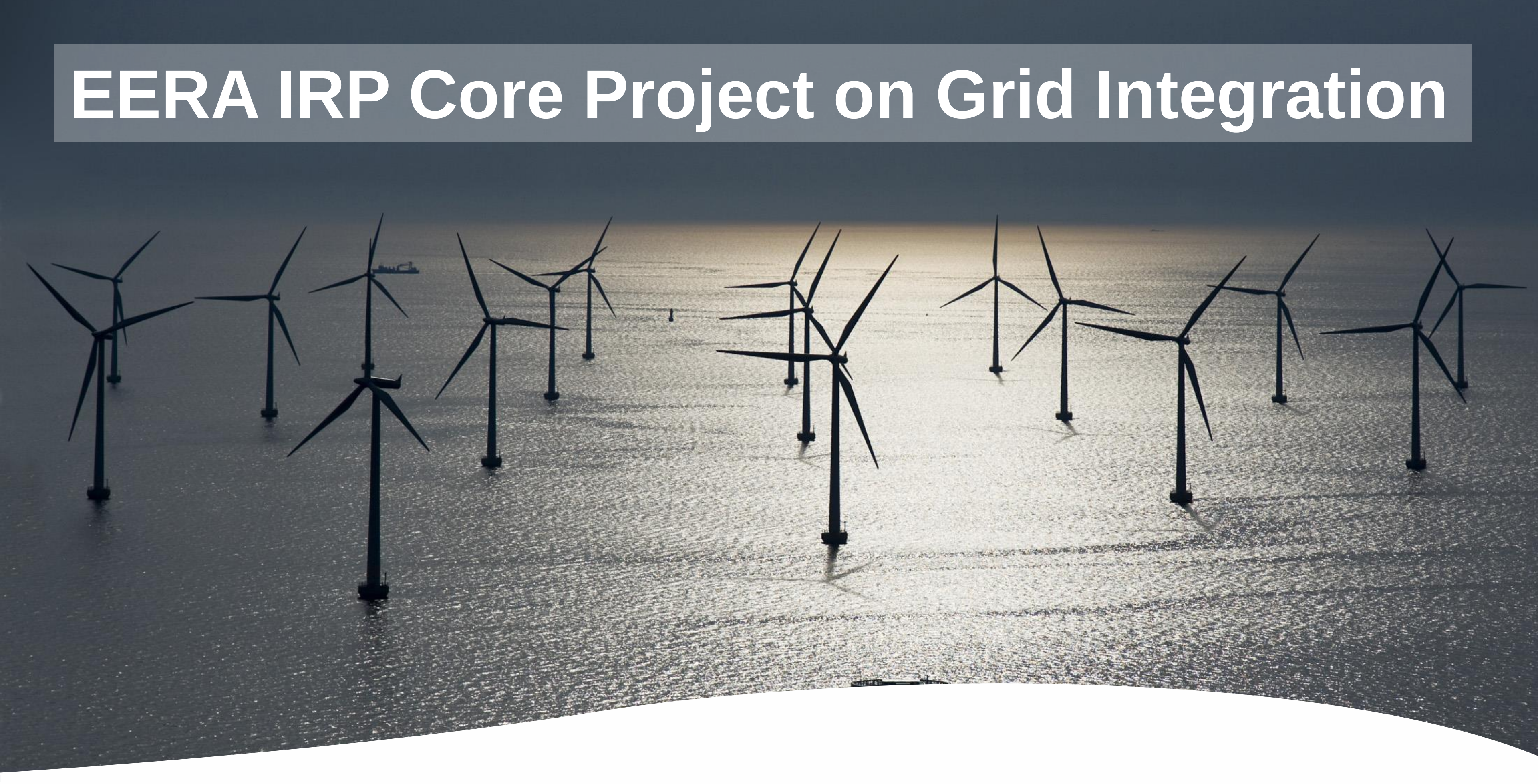
EERA IRP Core Project on Grid Integration



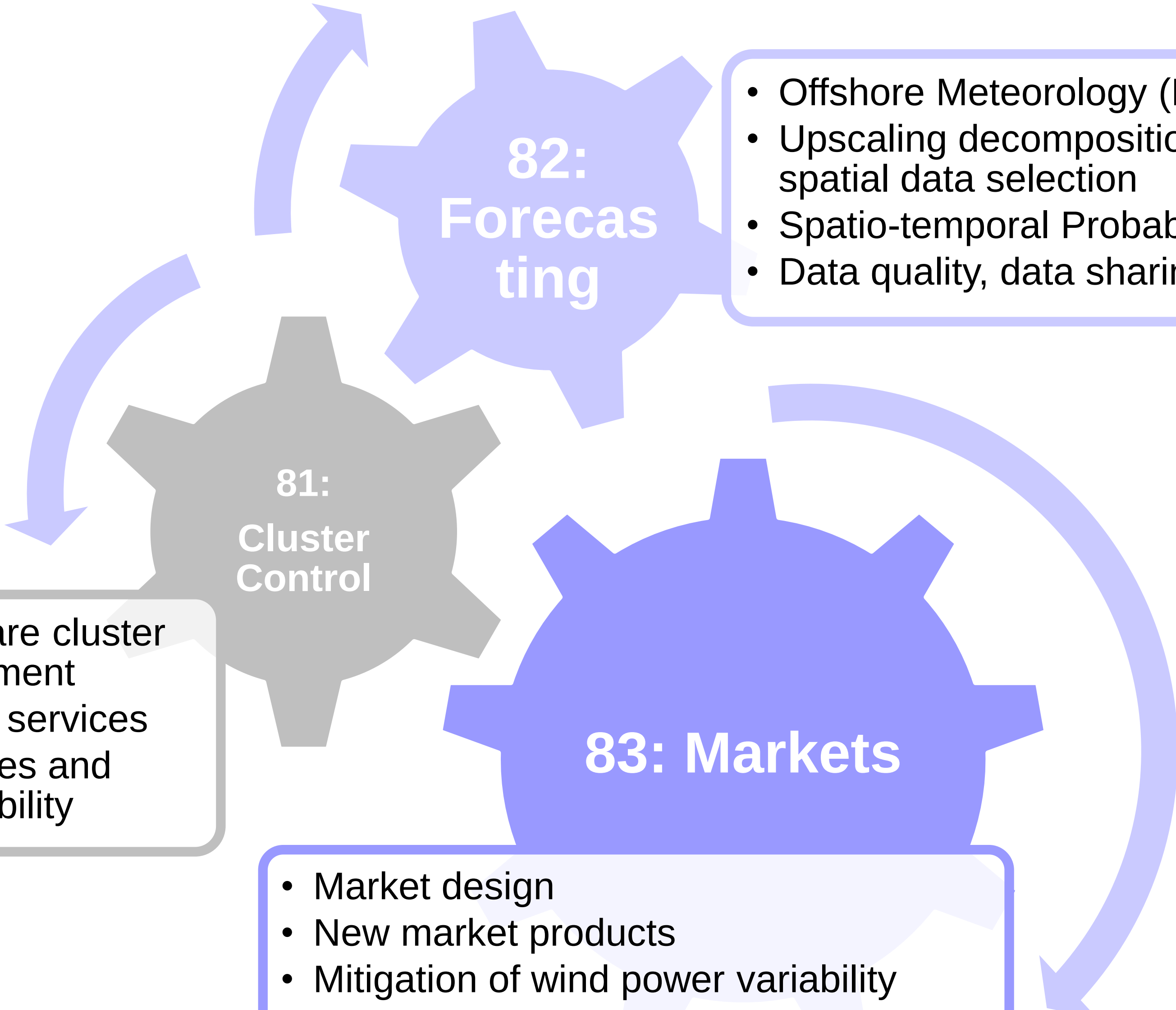
IRPWIND: WP8

Grid Planning and Operation

Kurt Rohrig
Fraunhofer IWES

European Energy Research Alliance

EERA
European Energy Research Alliance



- Offshore Meteorology (MBL)
- Upscaling decompositions, spatial data selection
- Spatio-temporal Probabilistic
- Data quality, data sharing

- Grid-aware cluster management
- Ancillary services
- Grid codes and controllability

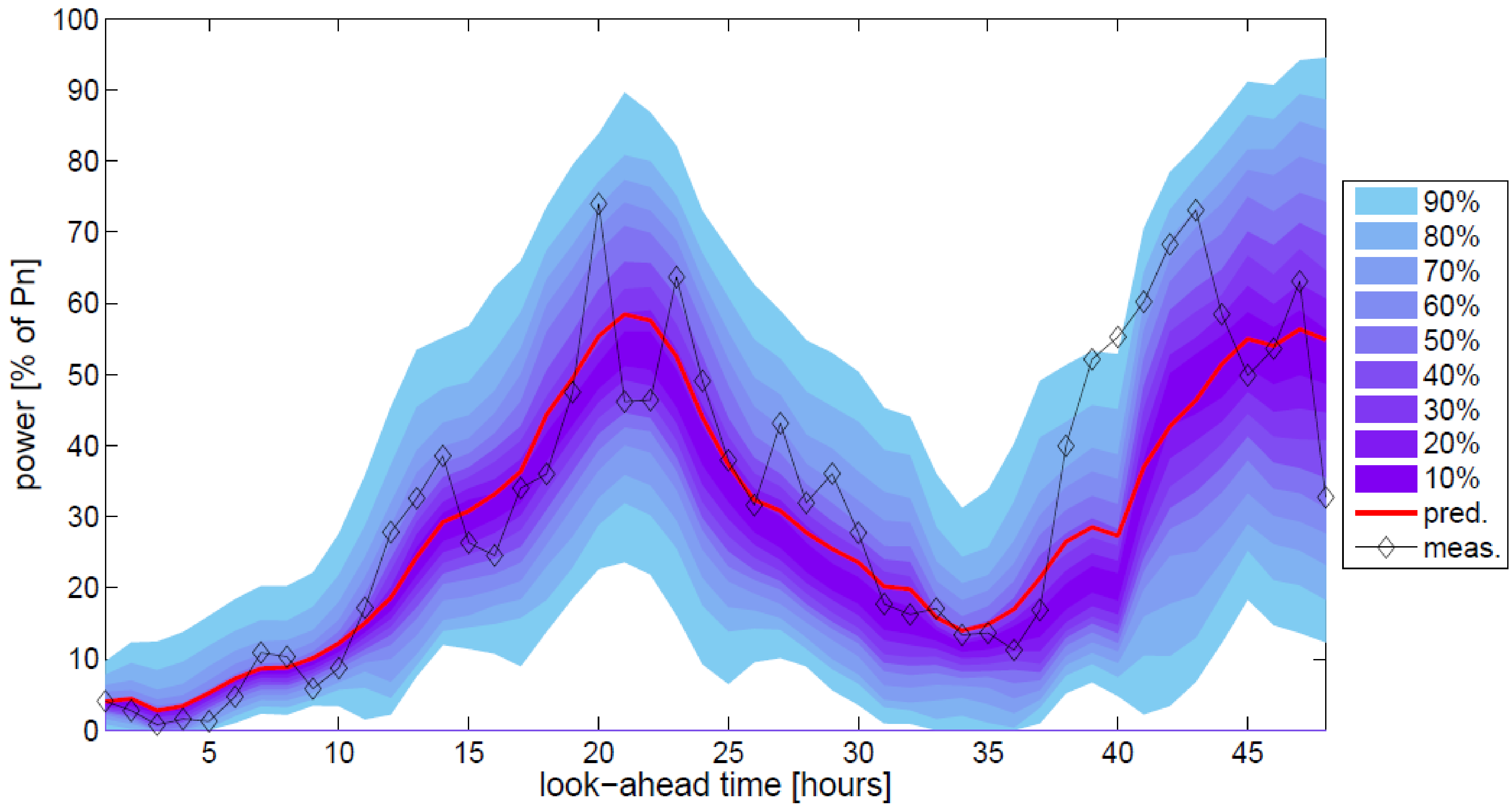
- Market design
- New market products
- Mitigation of wind power variability
- Market modelling with an offshore grid

Objectives

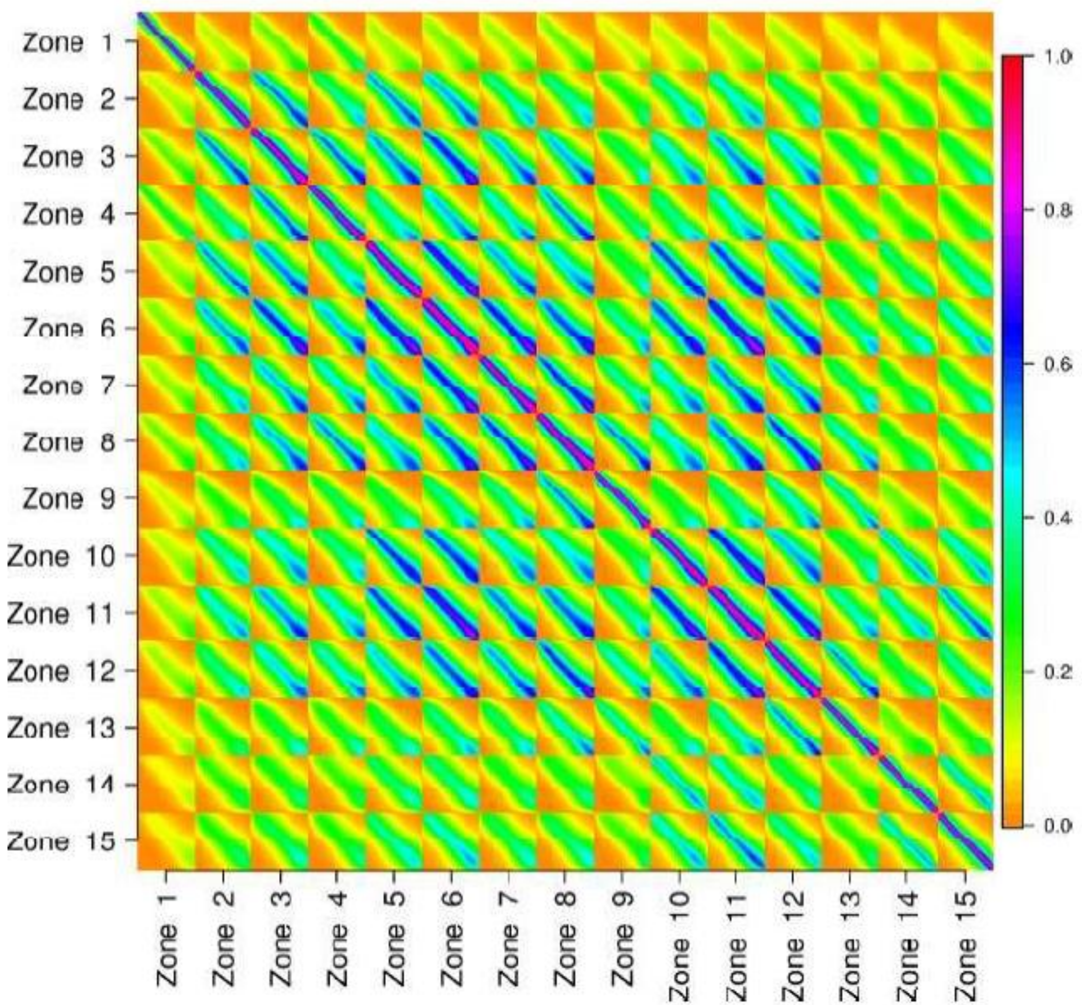
1. **New wind power up-scaling**: demonstrate improvement over existing methods
2. **New Probabilistic forecasts: aimed towards a TSO use case**
3. **Spatio-temporal forecast scenarios: show day-ahead and regulation market benefits.**
4. **Data: type, quantity and quality requirements for wind power forecasting**

European Energy Research Alliance

Probabilistic Forecasting

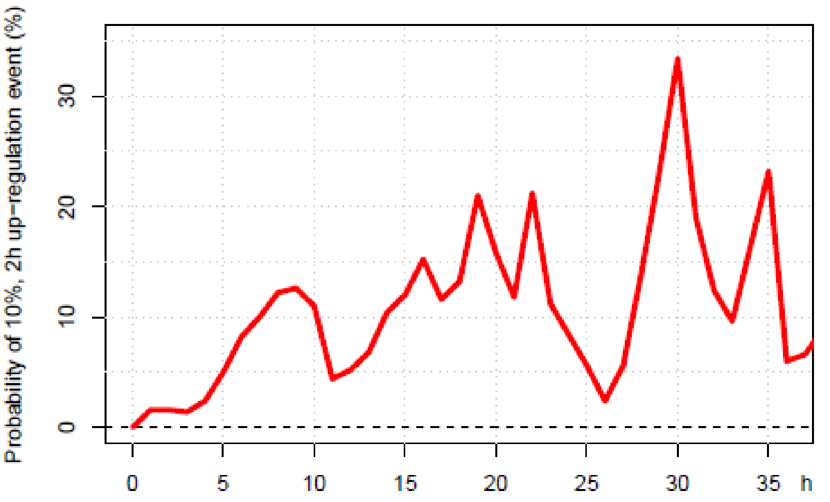


Space Time Correlations

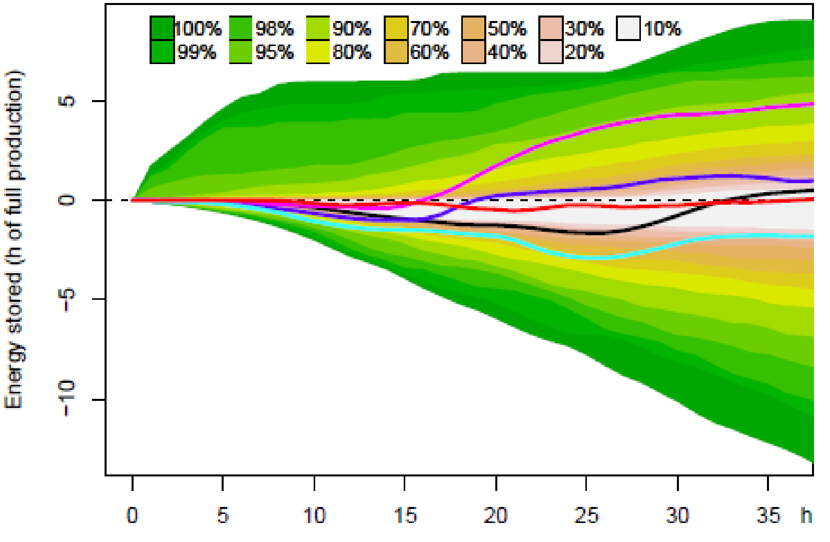


Space time scenario example uses

Probabilistic Ramp Forecast



Storage sizing



Forecasts for a Successful Market Integration of Wind Power

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Windenergie und Energiesystemtechnik Kassel

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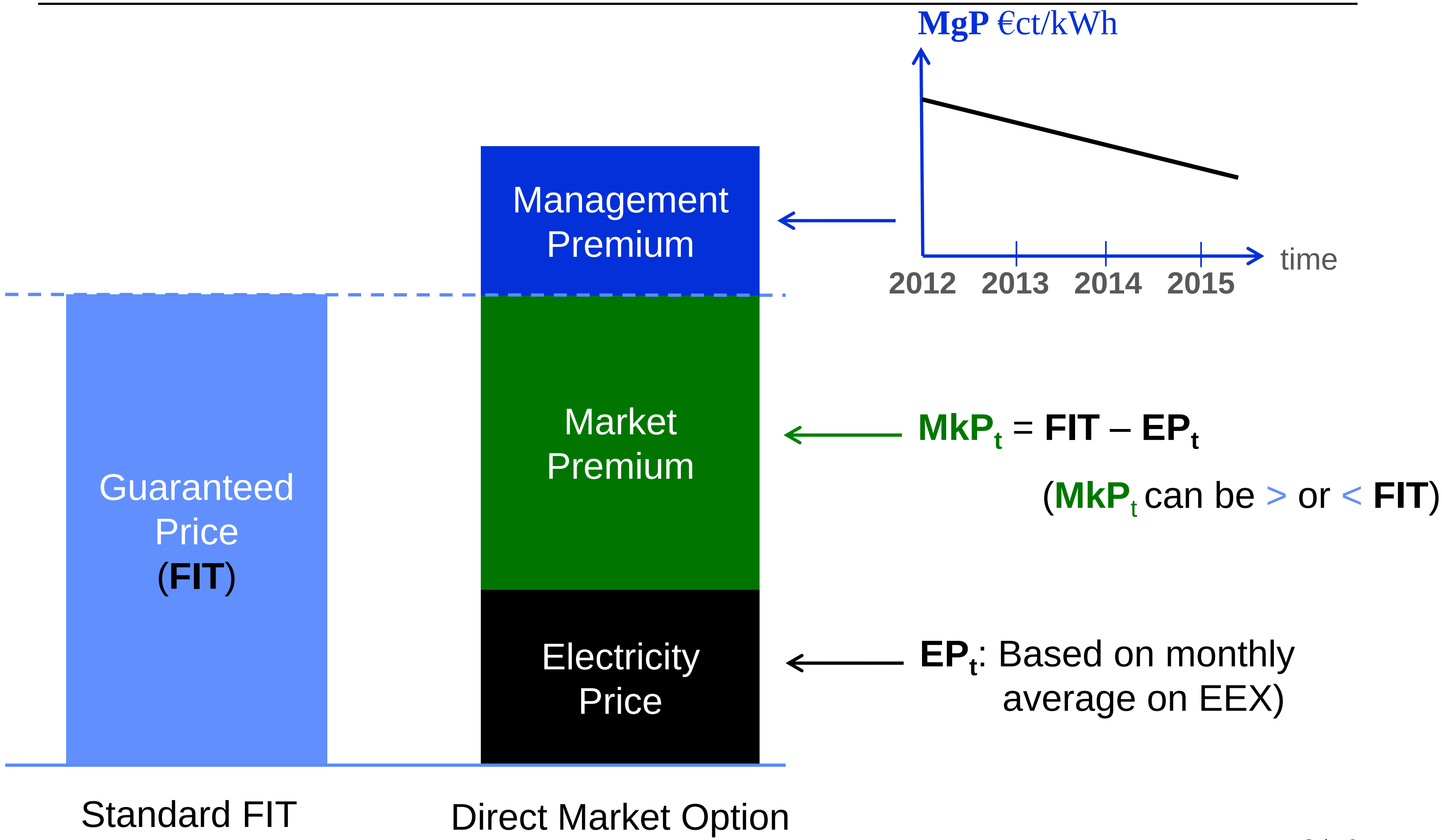
Fraunhofer IWES

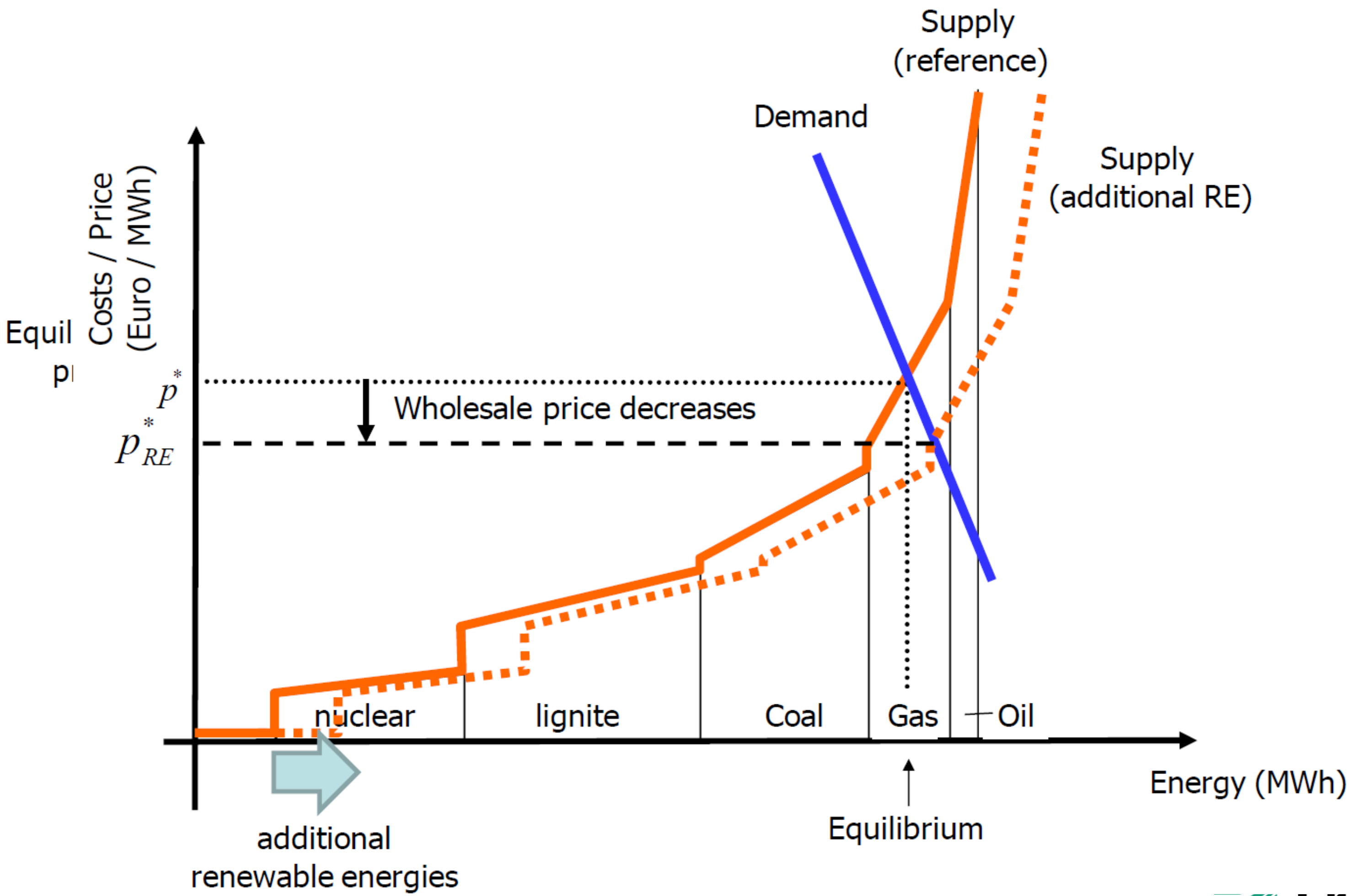
From German FIT to Direct Market



Wind Power is traded on the spot market

Source: Renewable Energies Sources Act 2012

Adding more RE reduces spot price



Source: "The Impact of PV on the German Power Market –
Or Why the Debate on PV Feed-In Tariffs Needs to be Reopened" Arrhenius Institute. 2010

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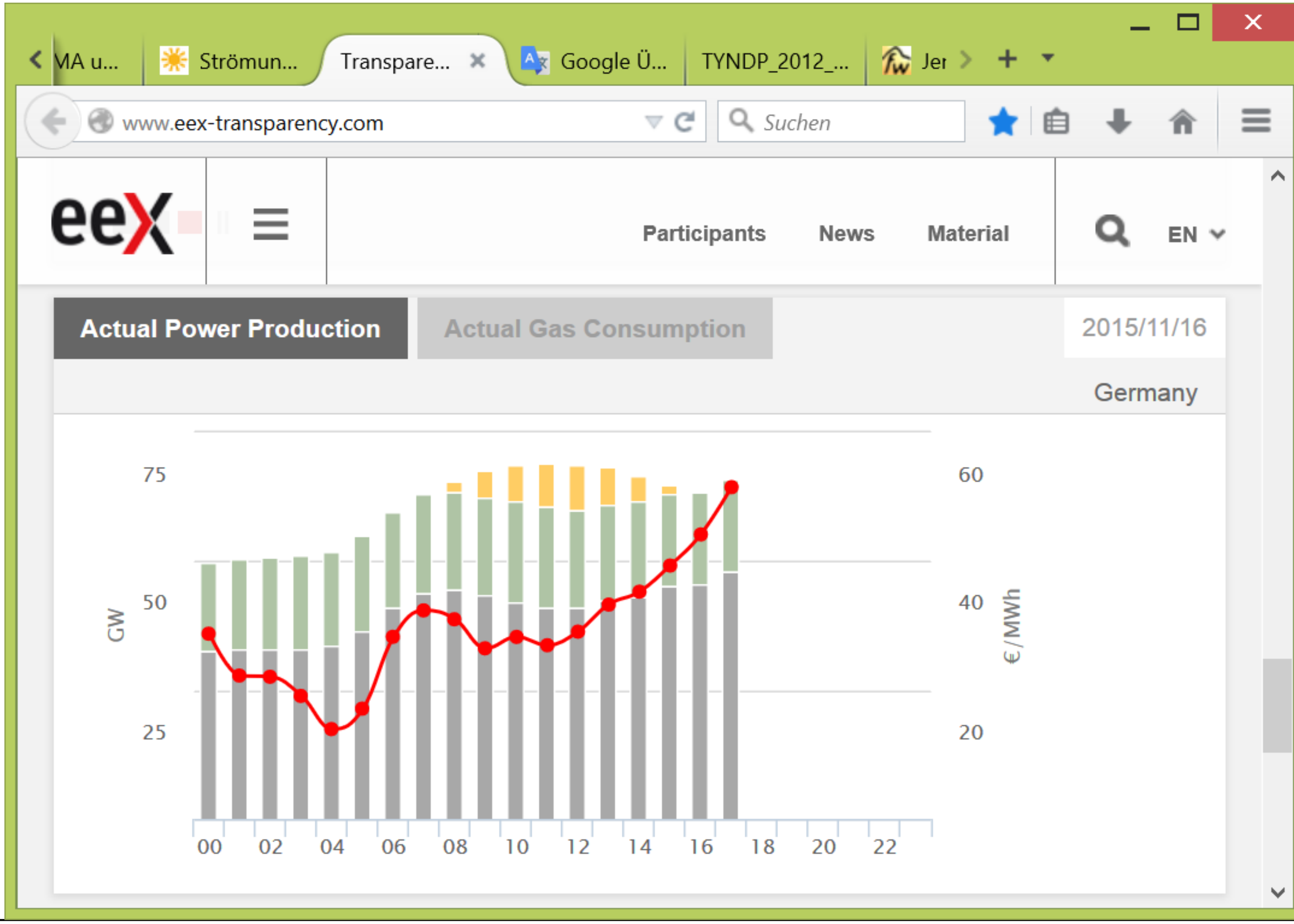
Wind Power on Spot Market



Wind Power has strong influence on spot market

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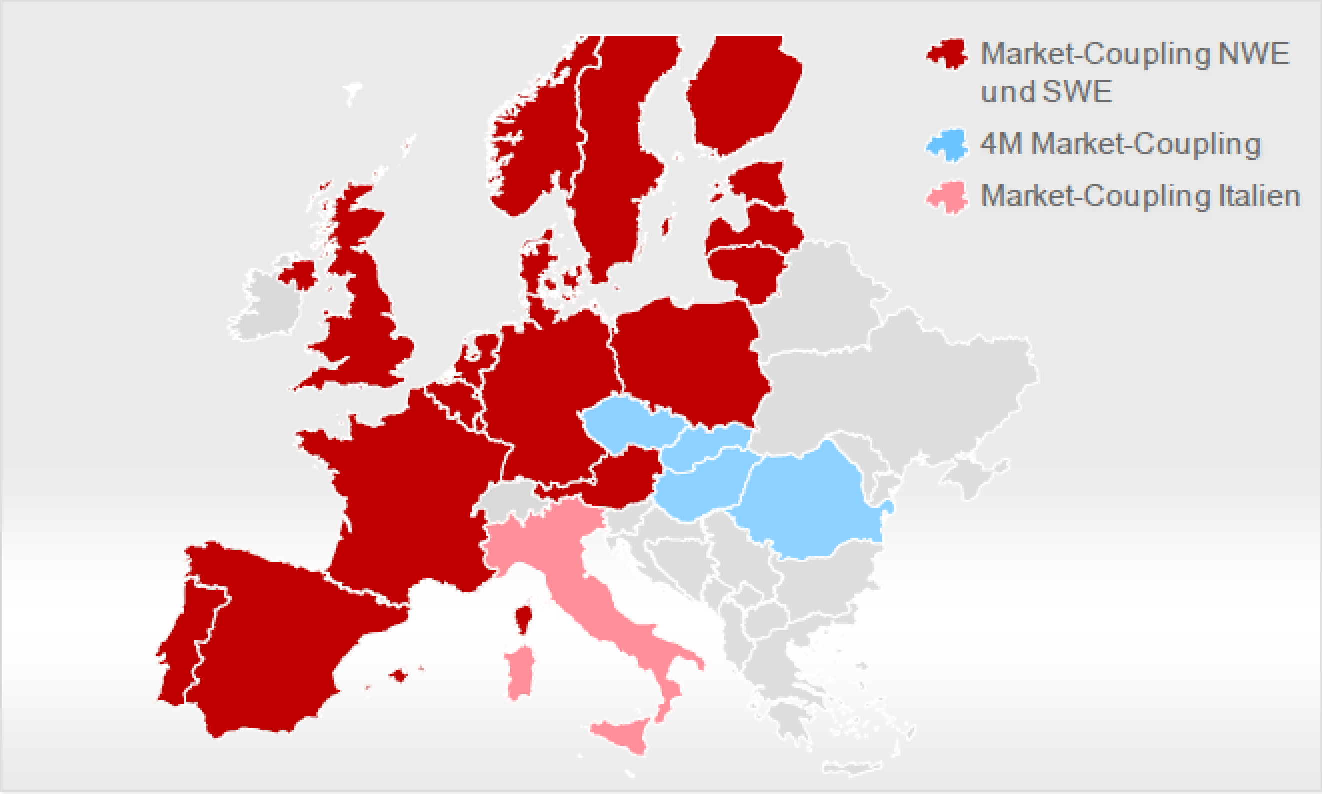
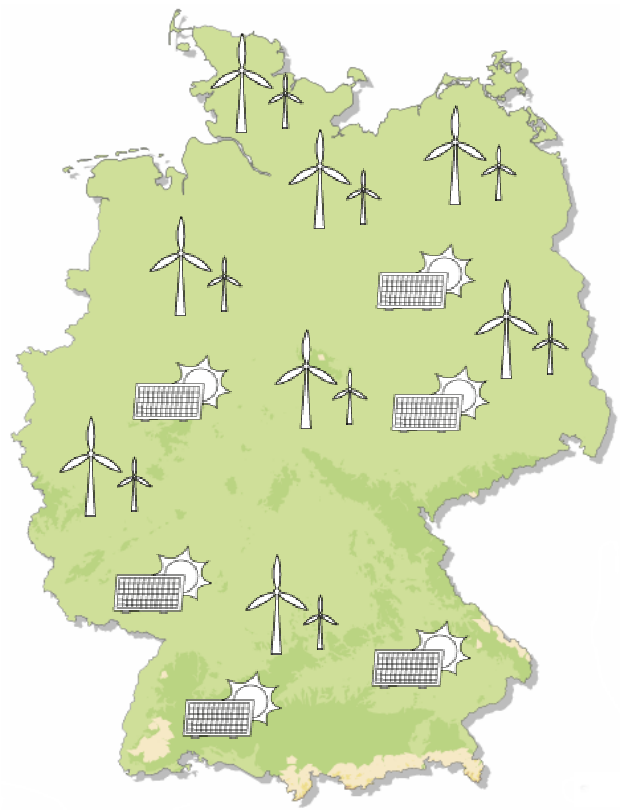
European Energy Scenarios – Market Coupling



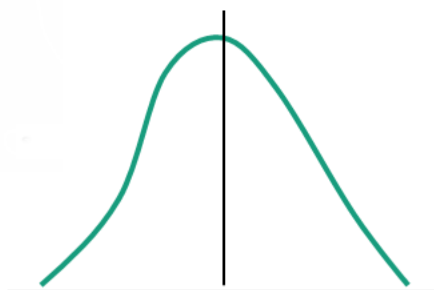
NWE: North Western Europe, SWE: South Western Europe
Quelle: swissgrid 2015

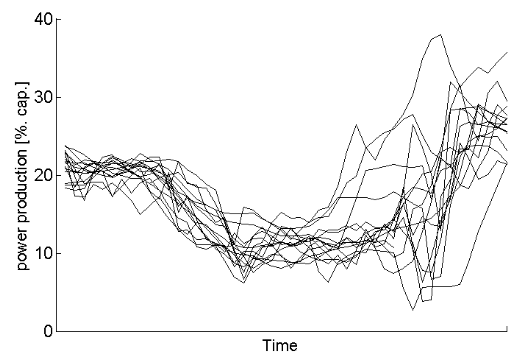
Market coupling supports price stability and security of supply

Optimized trading of renewable energies using probabilistic forecasts



- Optimized trading activities are based on stochastic optimization approaches using
    - Scenario price forecasts
    - Scenario wind and PV power forecasts
- Scenario forecasts can be generated out of probabilistic forecasts given by probability density functions.

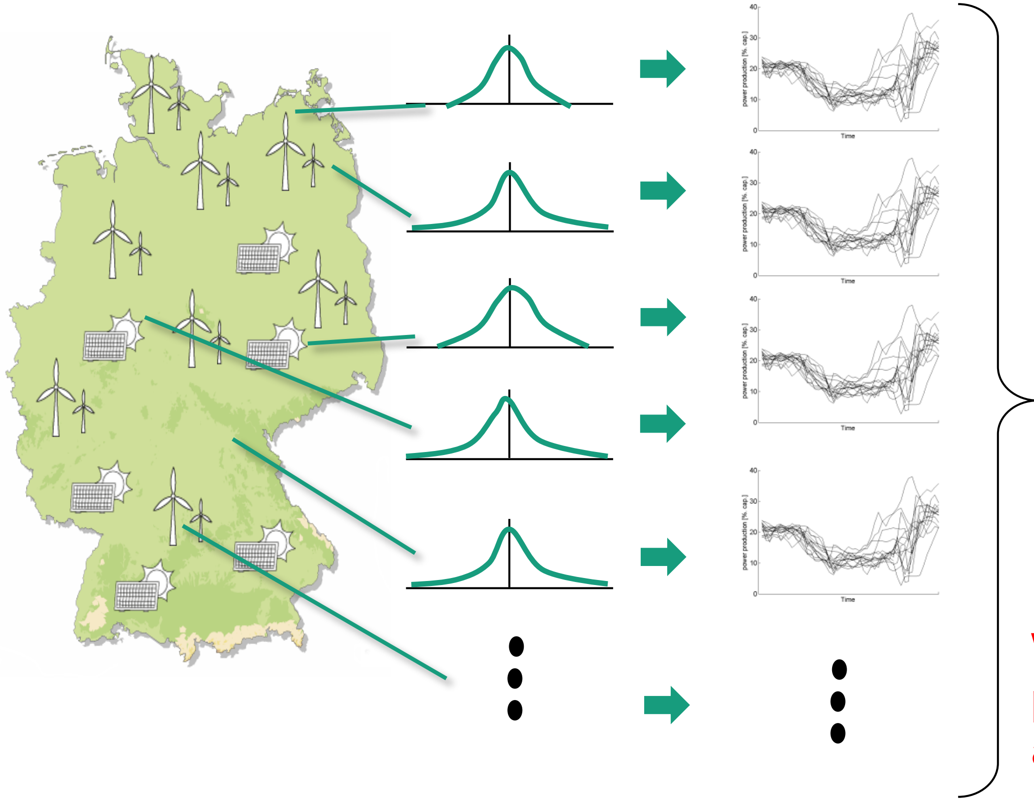




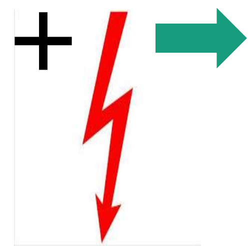
Traders are using probabilistic forecasts to optimize their portfolio

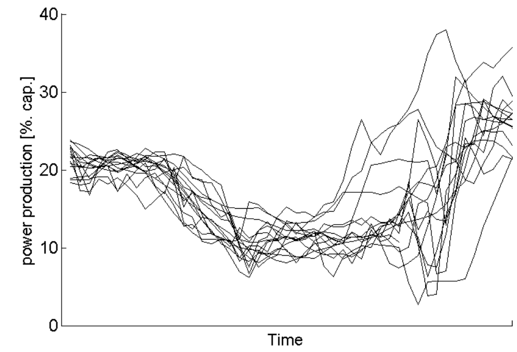
Probabilistic forecasts of portfolios with changing number of generators

Aggregation approach 1



Aggregation by
a simple sum
of scenarios



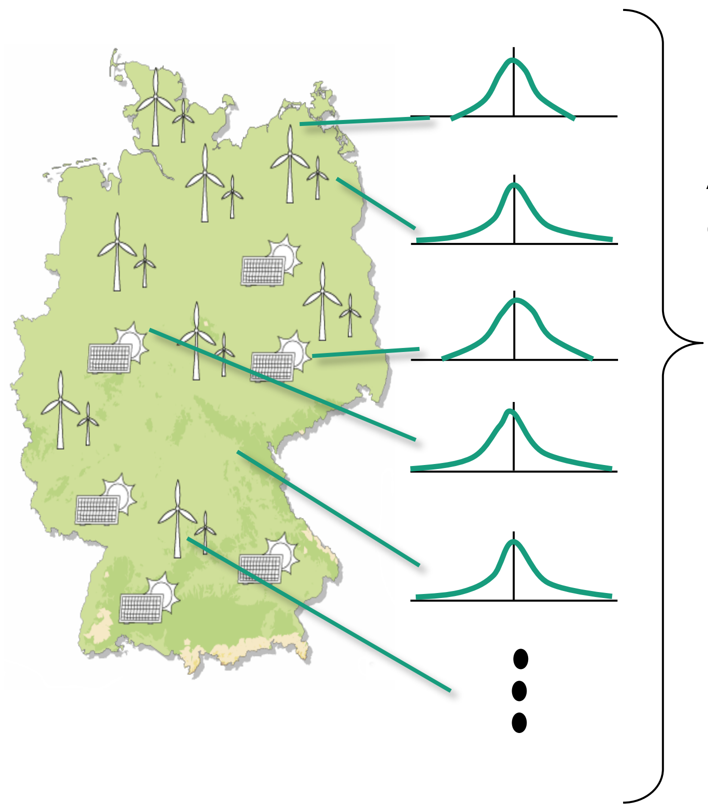


Weather driven correlations of the power production between spatial distributed wind and/or photovolatik farms are not considered.

→ Simple sum of scenarios not possible!

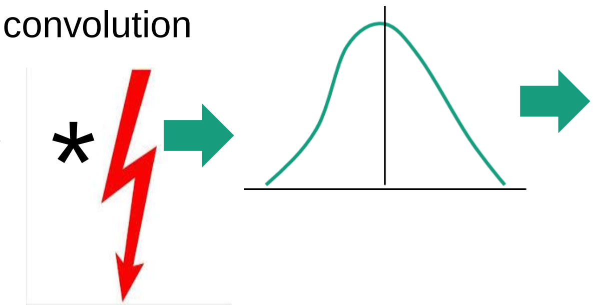
Probabilistic forecasts of portfolios with changing number of generators

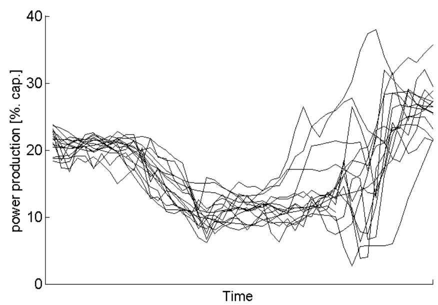
Aggregation approach 2



Assumption for convolution:
Statistical Independence

Aggregation by convolution





Aggregation of probabilistic forecasts of single wind and/or photovoltaic farms is also not trivial due to weather driven correlations in the power production.

→ Statistical dependency !
→ Simple convolution also not possible !

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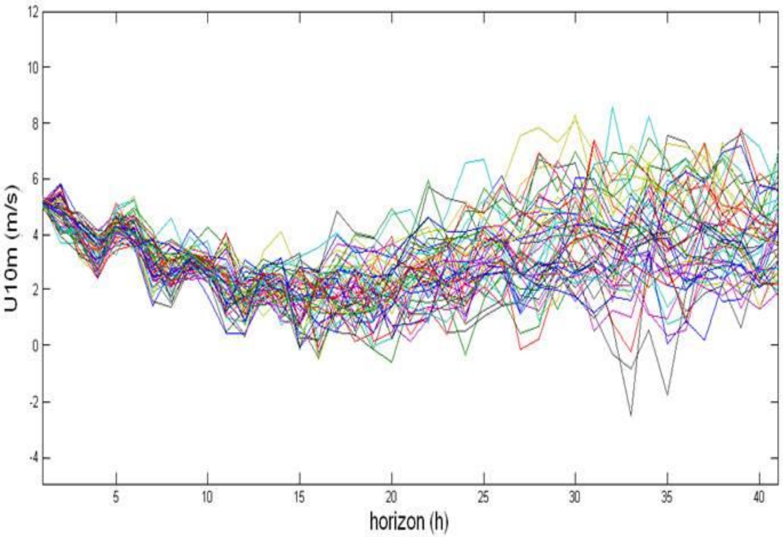
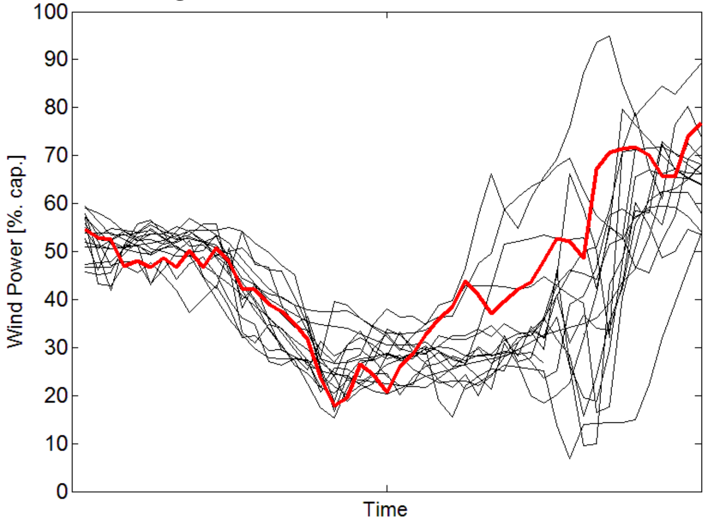
Producing raw ensemble forecasts based on ensemble weather predictions

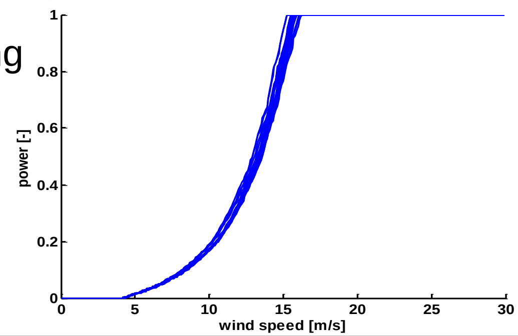
Example: ECMWF ensembles of wind speed at 10m



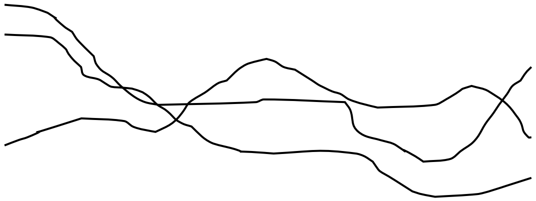
Time series of ensemble and measurment at a single wind farm



Wind to power transformation using a common power curve approach

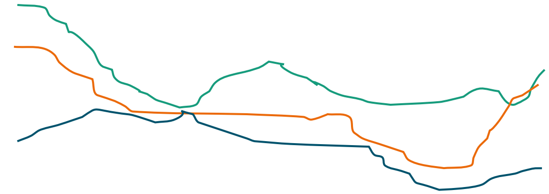


Producing reliable scenario forecasts based on Ensemble-Copular-Coupling



1. Raw Ensemble

sorting

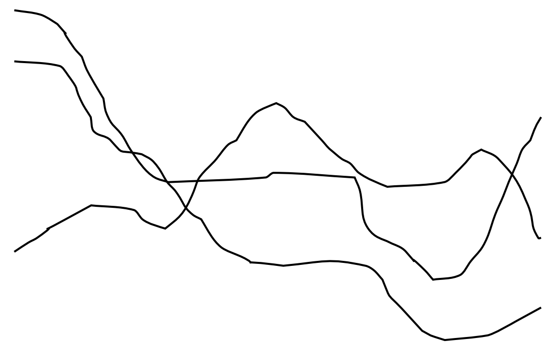


2. ‚Ranked‘ Ensemble

Quantile calibration to increase the spread of the ensemble based on power measurements

3. Calibrated ‚Ranked‘ Ensemble

Inverse sorting



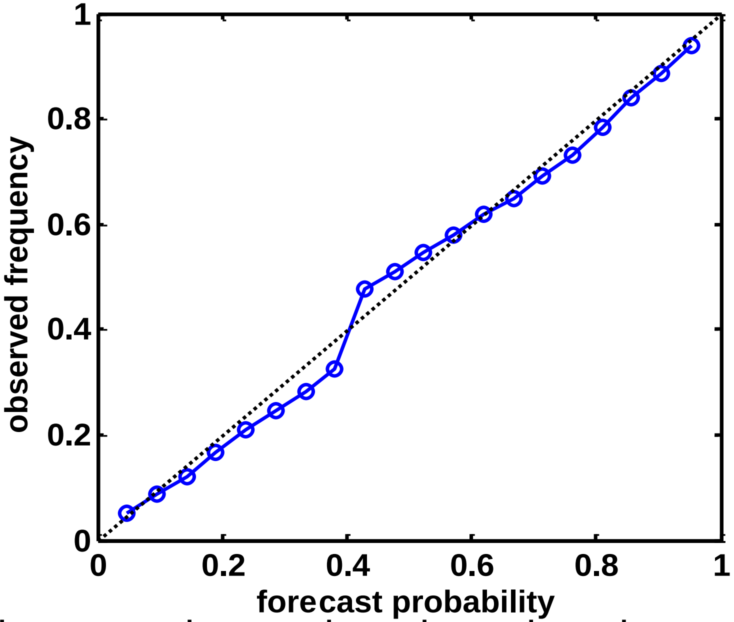
4. Calibrated ensemble

= Reliable Scenarios

Characteristics of the scenario forecast approach based on weather ensembles

The final scenario of each wind and/or photovolatik farm ….

- ✓ … is reliable due to the calibration:



- ✓ … can be aggregated by a simple sum of the scenario members based on the same weather ensemble member.
- ✓ … considers realistic spatial and temporal correlation between different locations.

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Control Power Market

Control reserve use:

TSO uses control reserve in case of power imbalances in his control area
Power imbalance: sum of all ± power imbalances in a control area

Reasons for power imbalances:

- Breakdowns
  - Generation or load inside of a control area
  - Outage of commercial transactions between control areas
  - Common European grid operation (UCTE)
- Forecast error (load or production)

Source: Patrick Hochloff, Fraunhofer IWES

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Control Power Market Requirements

Requirements for different types of control reserve

	Primary control reserve	**Secondary control reserve**	**Minute reserve**
Maximum energy	15 min	4 h	4 h
activation	automated: +/-200 mHz	Set-point by TSO	Call by telephone
Power gradient	ΔP/30 sec	ΔP/5 min	ΔP/15 min

Source: Patrick Hochloff, Fraunhofer IWES

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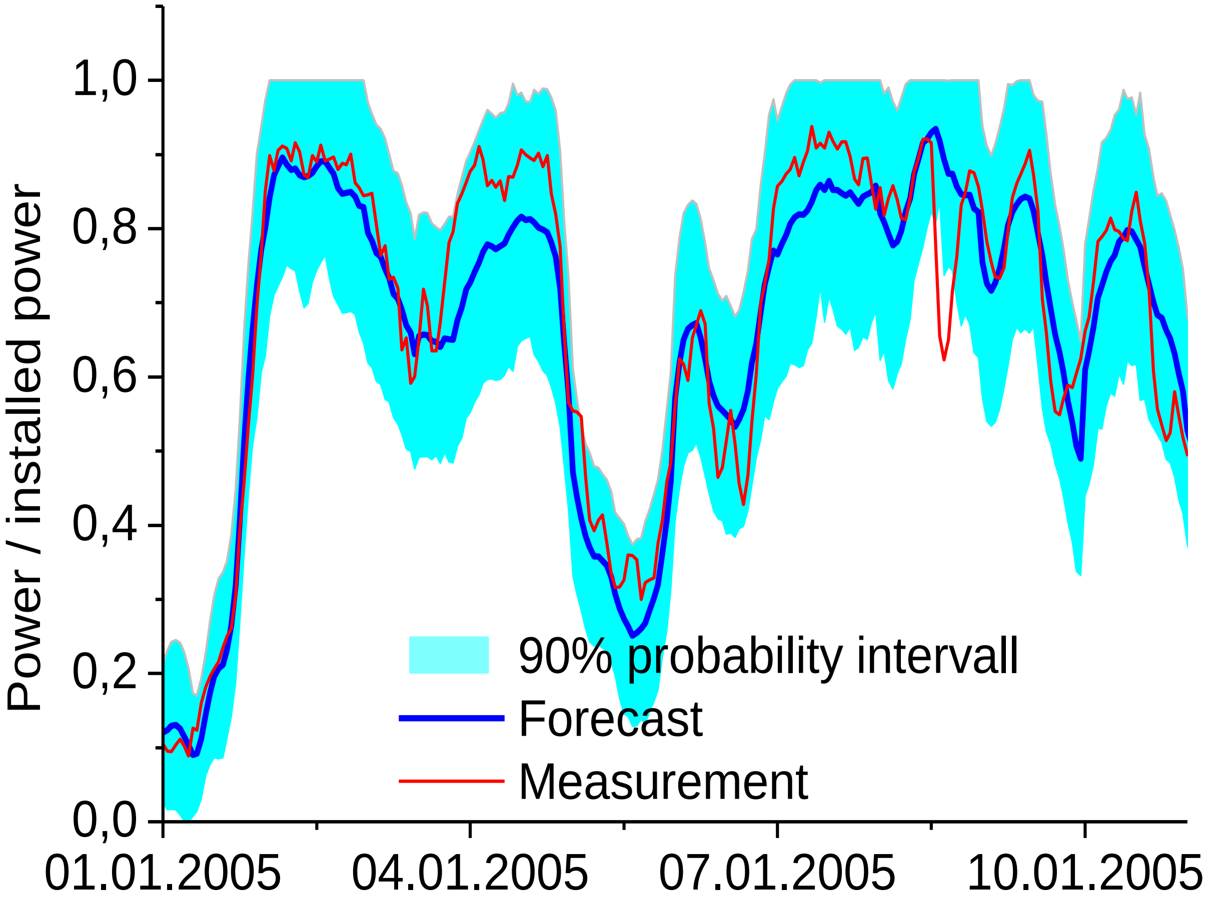
Source: Patrick Hochloff, Fraunhofer IWES

Probability Intervall for Control Power Provision



Probability Intervals support control strategies

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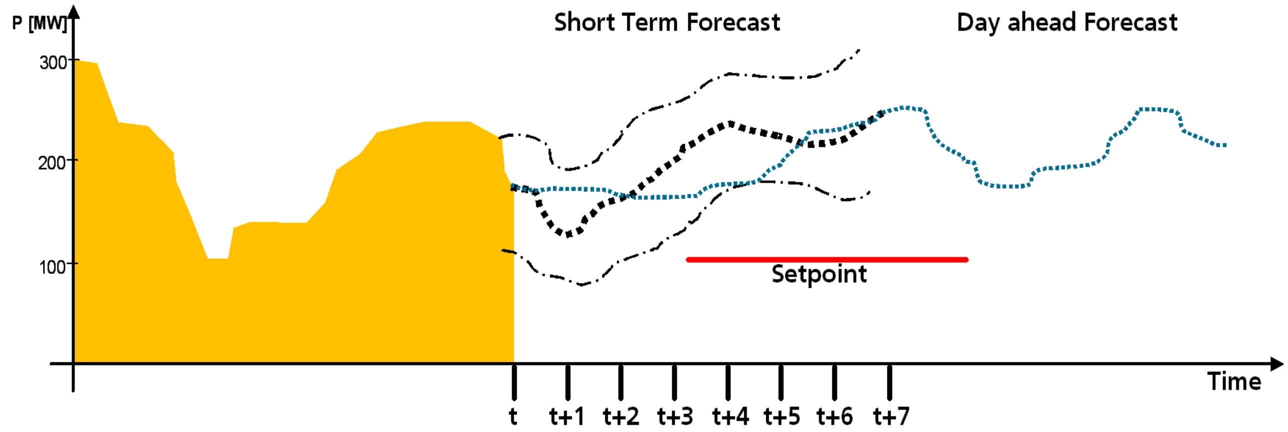
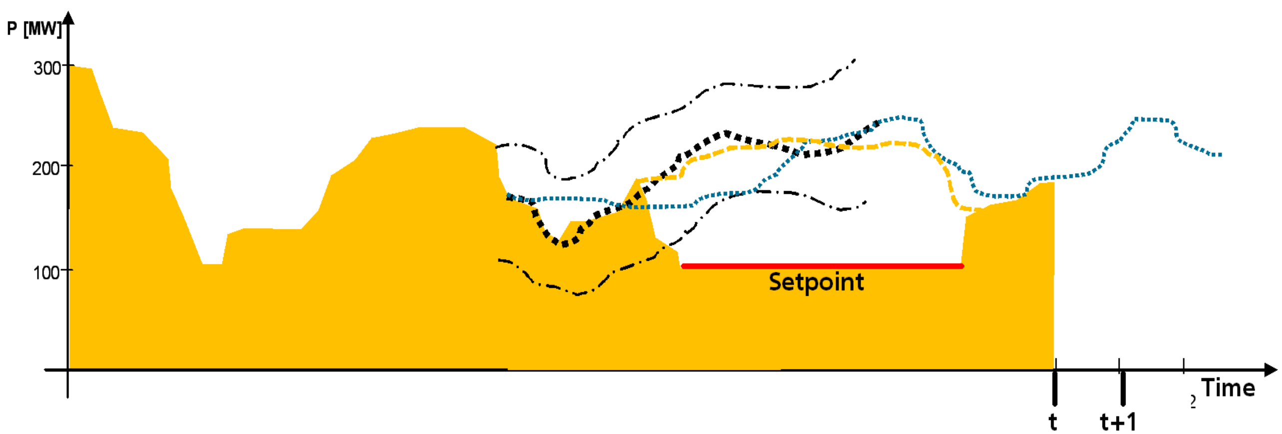
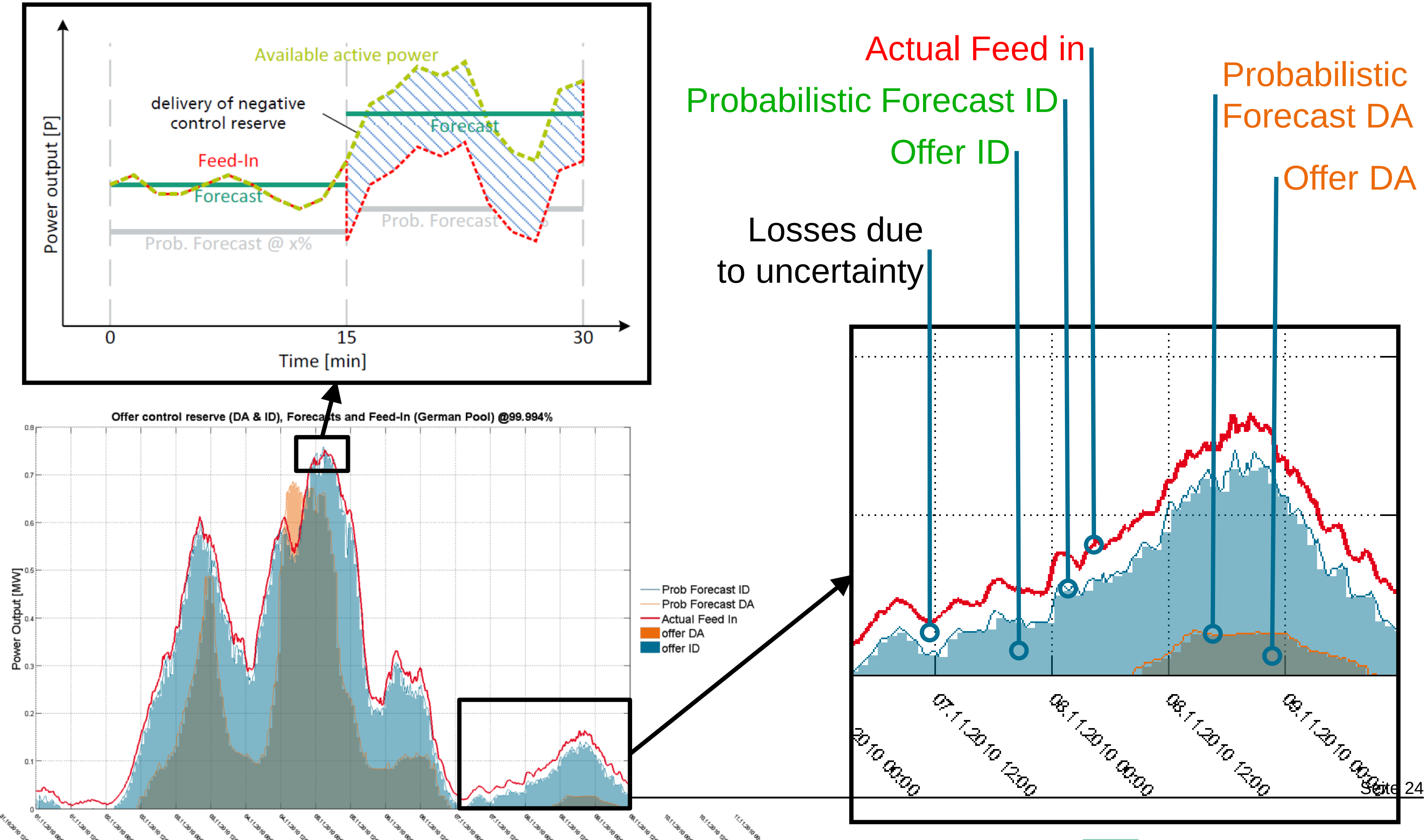
Power Control with Wind Farm Clusters





Probability Intervals are used to offer reliable power bands

Services based on forecasts and confidence intervals



Source: Malte Jansen – Fraunhofer IWES

DA = day ahead, ID = intra day

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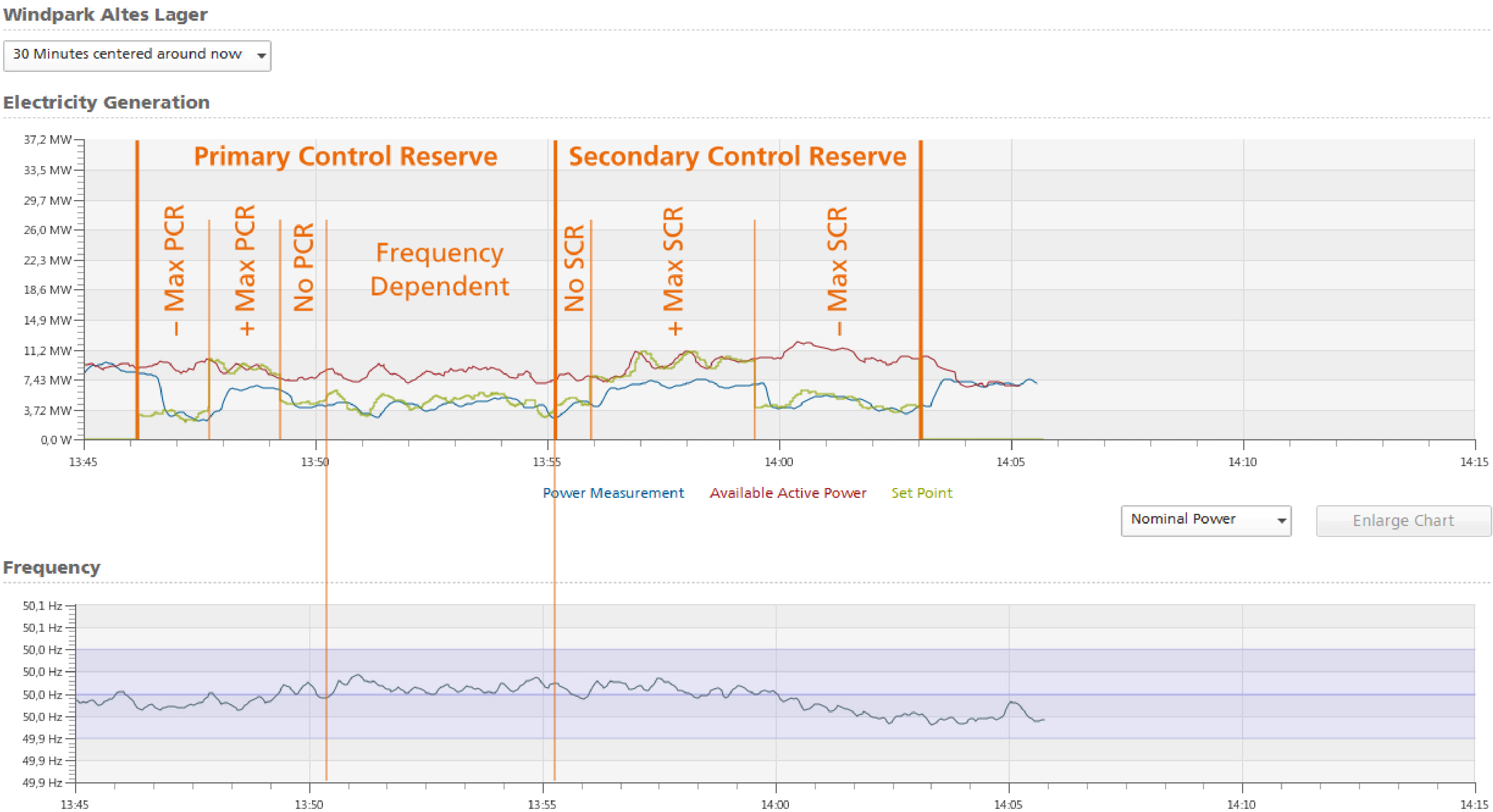
Services based on forecasts and confidence intervals



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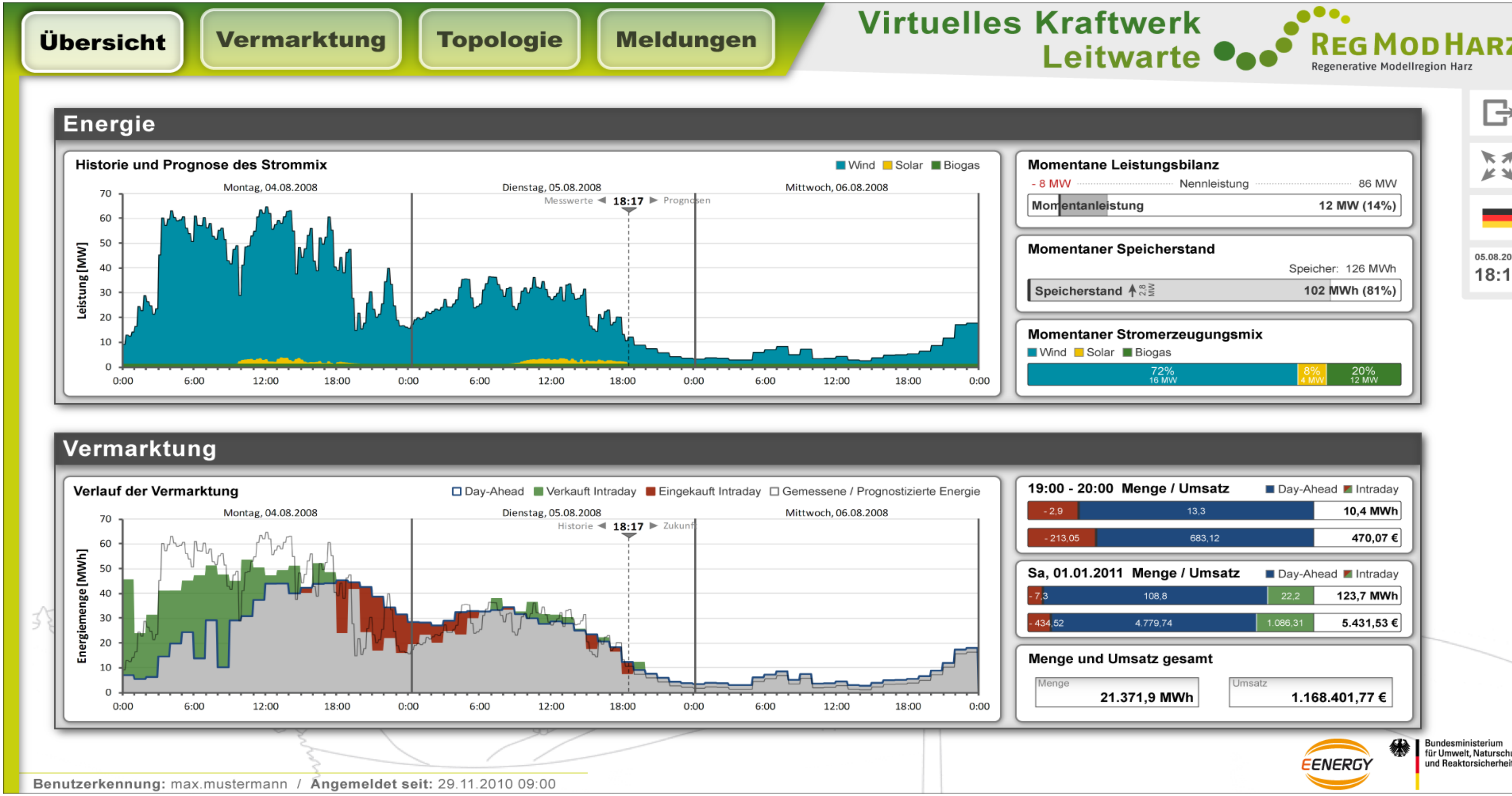
Virtual Power Plants Support Wind Power Marketing



Short-Term forecasts are essential for wind power marketing

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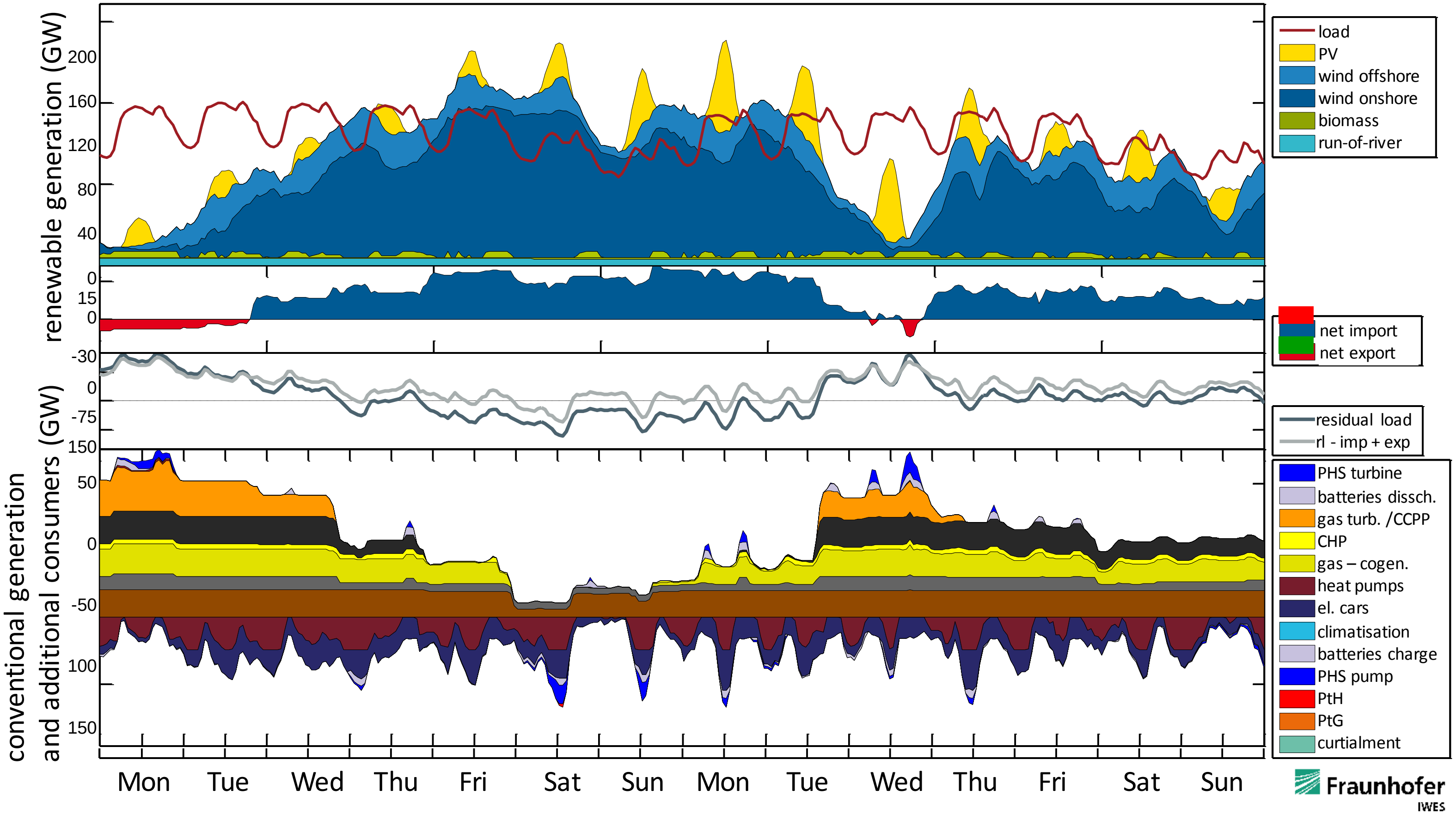
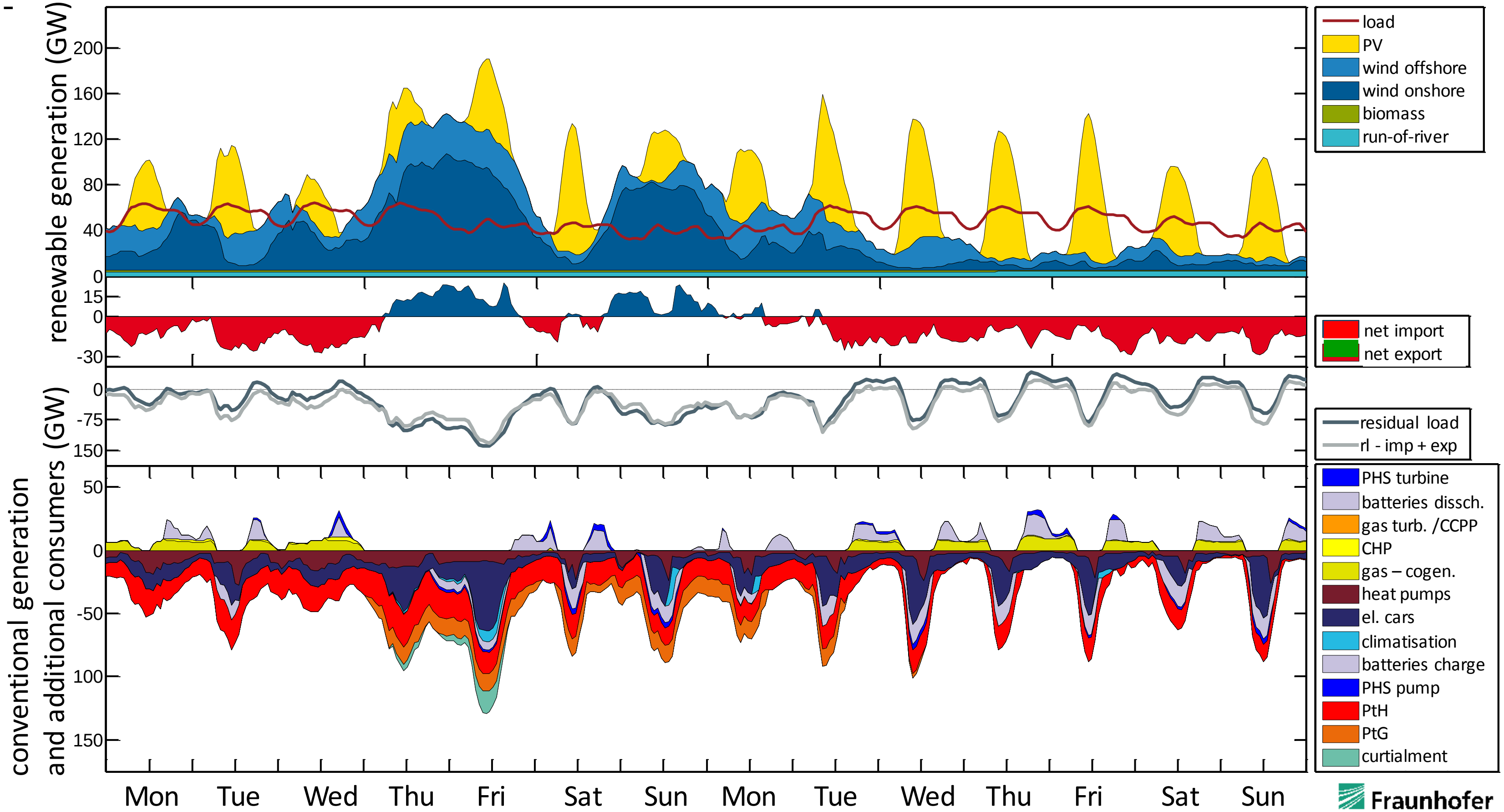
Demand and Generation in Germany 2035



Simulation: Demand and generation in Germany – scenario 2035
import and export, sector coupling

Demand and Generation in Germany 2050



Simulation: Demand and generation in Germany – scenario 2050
import and export, sector coupling

Any Questions?

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Conclusion

- Energy and control power markets are strongly influenced by wind power
- Wide area balancing needs wide area forecasts
- Probabilistic forecasts support market participation
- Wind turbine control straegies are supported by forecasts
- Active freuency control and grid management by wind farms will be supported by wind farms tomorrow
- All integration efforts can be reduced by increased forecast precision

Source: Patrick Hochloff, Fraunhofer IWES