
Software tools for wind power prediction

Wolfgang Slaby, Reinhard Mackensen, Arne Wessel, Manuel Wickert

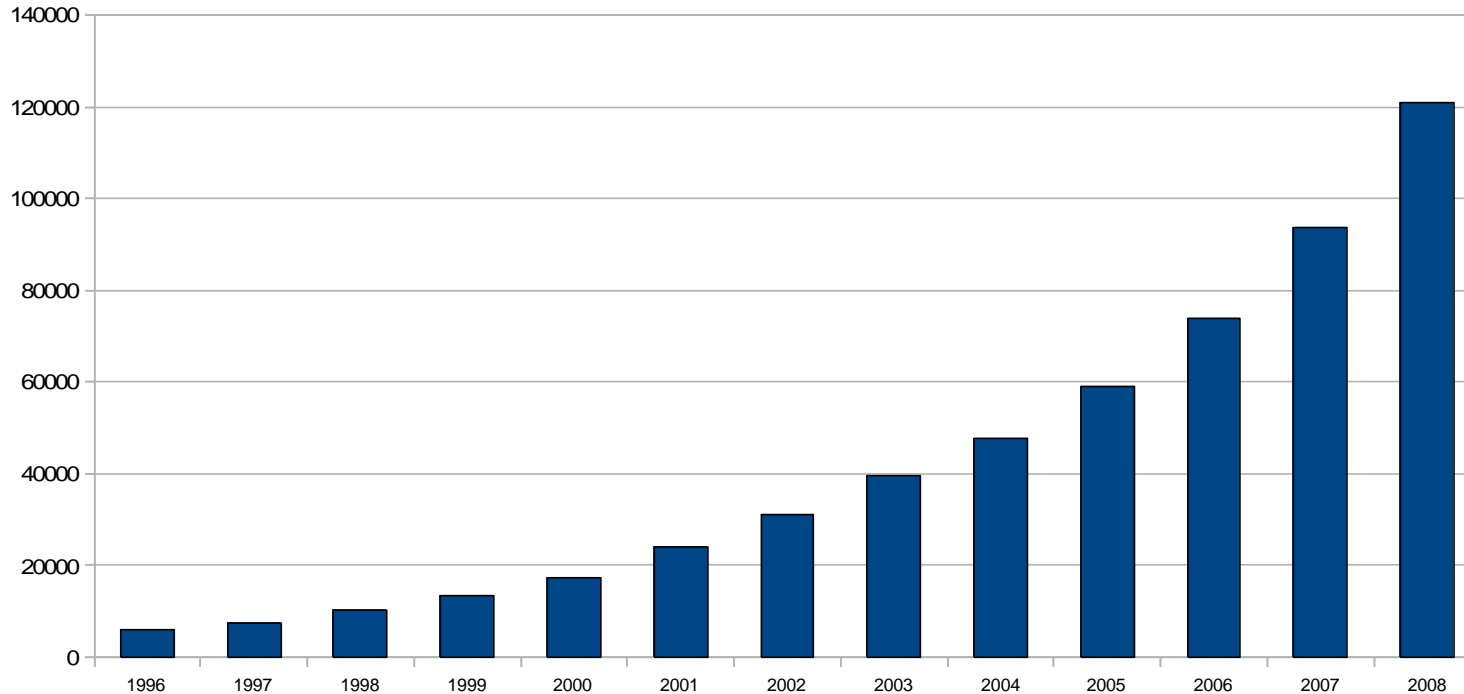
**GTZ-TERNA Expert Workshop 2009:
Grid and System Integration of Wind Energy**

Outline

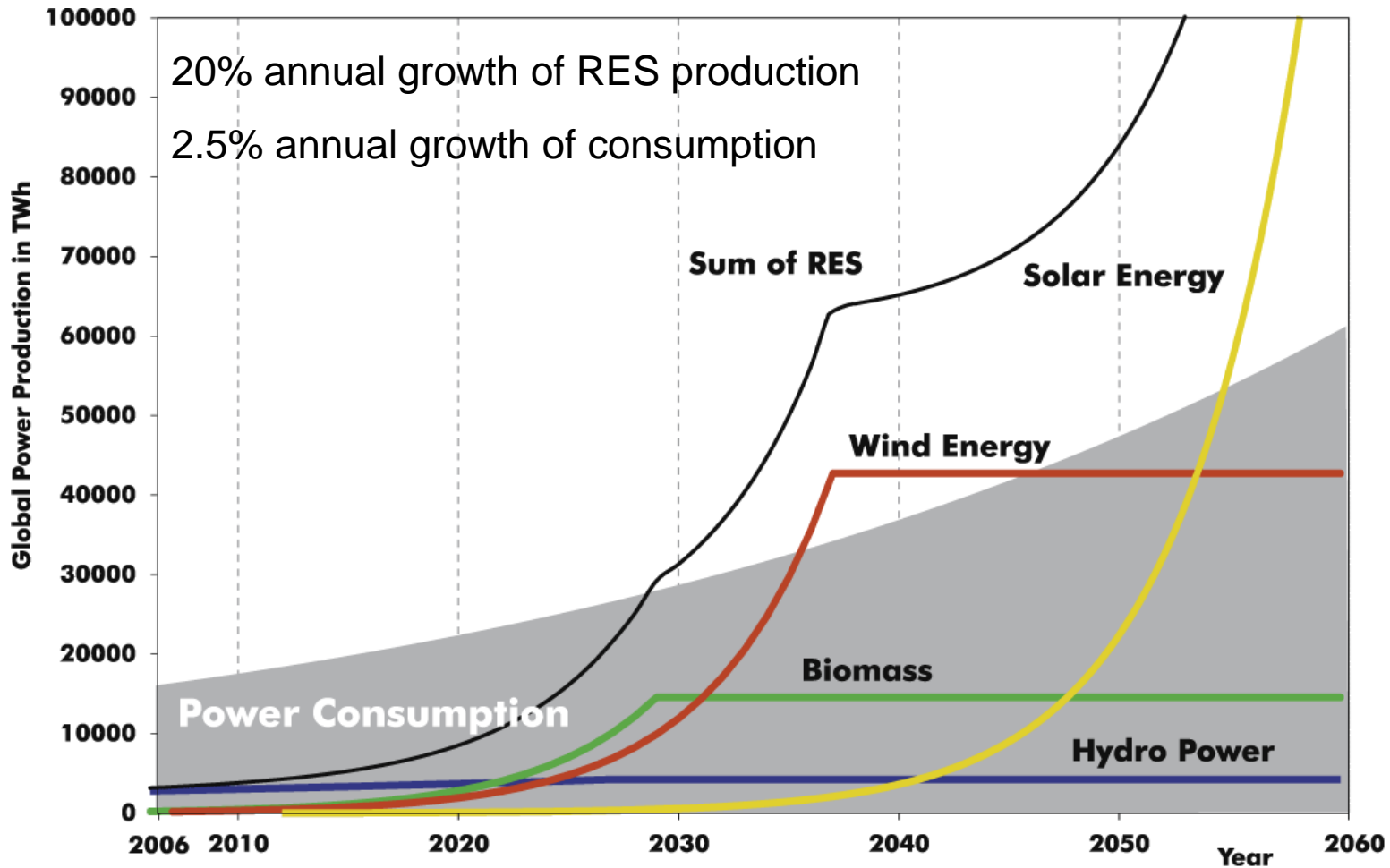
- Importance of forecasts
- Forecast approaches
- Common features and operational use
- WPMS (IWES forecasting tool)
- Architecture of forecasting tools
- Research and forecasting tools
- Strategies to improve forecasts
- Future architectures
- Outlook

Importance of wind power forecast

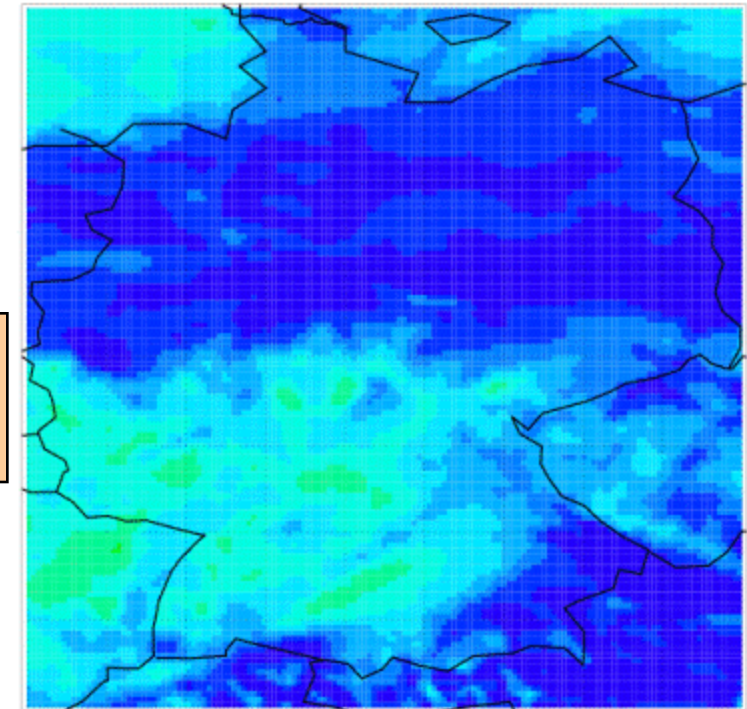
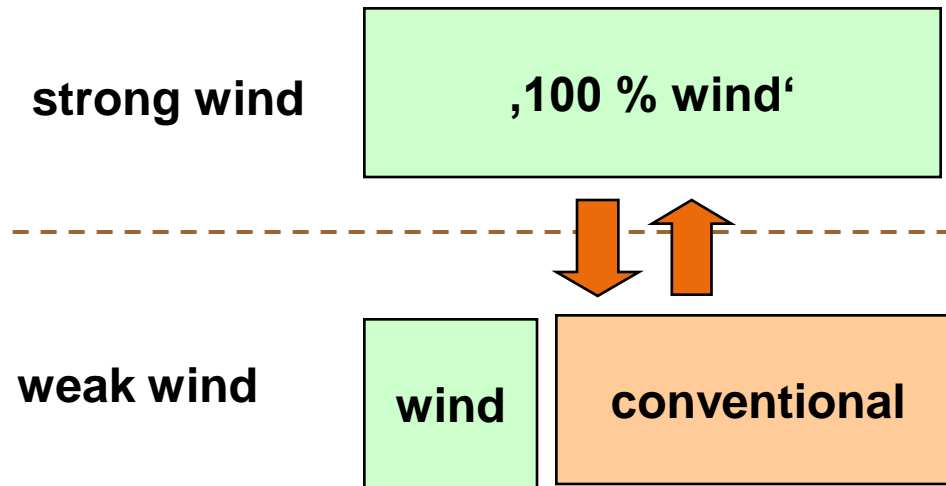
Global Wind Energy Council: „Global cumulative installed capacity“:



Importance of wind power forecast



Problems of the integration of wind power



20070118 6 UTC

For wind power a discrepancy between production in space and time exists

The power plant ,wind turbine' changes this capabilities depending on the weather situation

Approaches for wind power forecast

Modeling the interrelation between weather forecast and power production

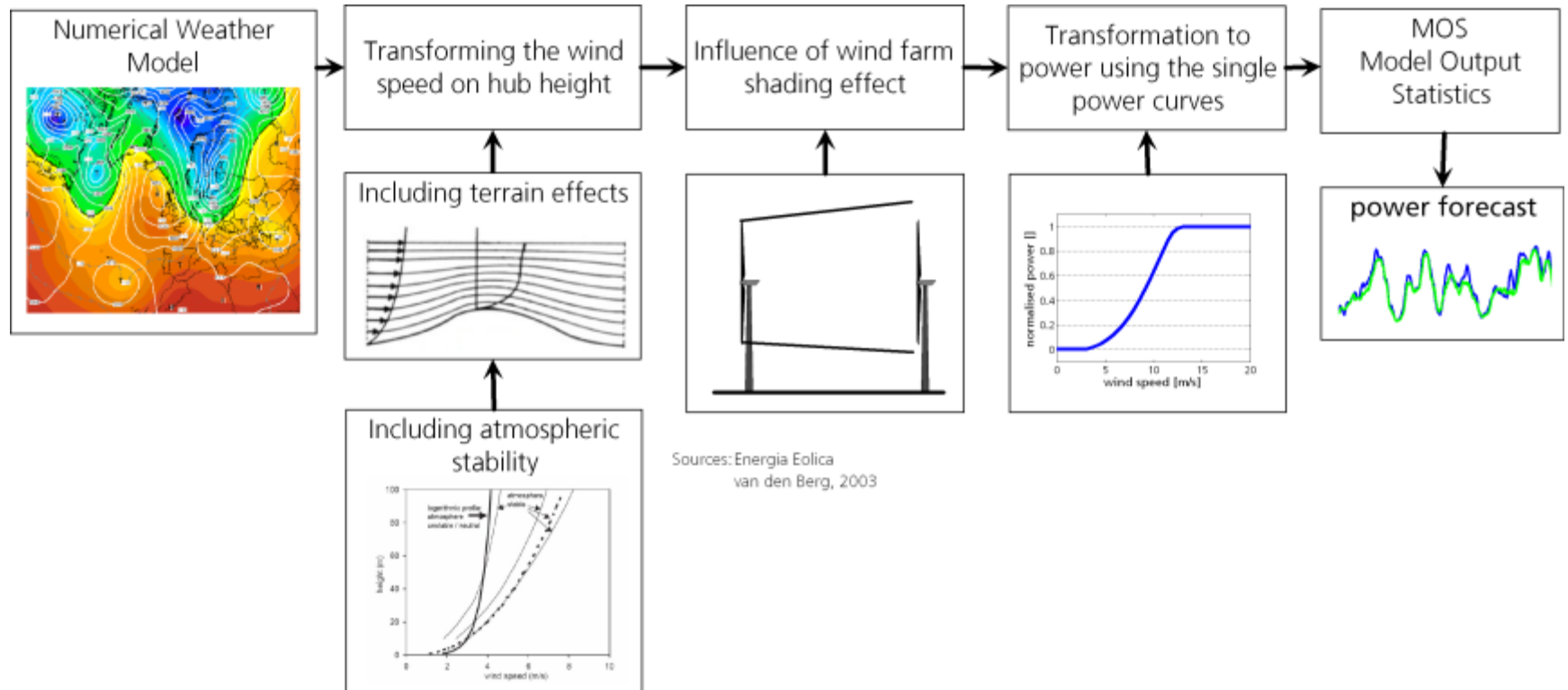
Physical models use physical parameterizations

- modeling of the wind farm
- transformation of forecasted wind speed to hub height

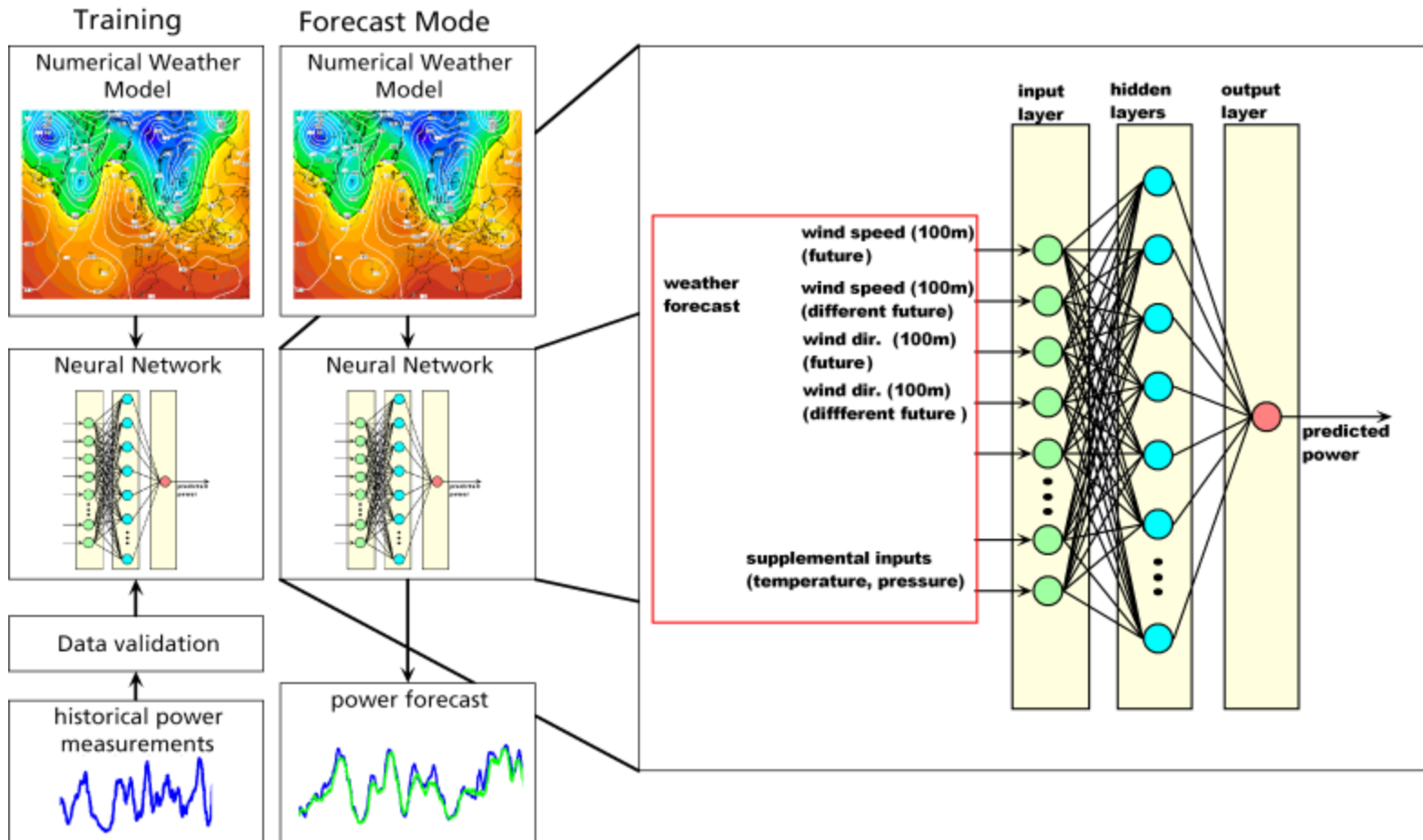
Statistical models use historical measured data in combination with statistical approaches

- methods of artificial intelligence (AI) 'learn' the relationship based on historical measured data

The physical approach



The statistical approach – The Neural Network



Ad- and disadvantages of the different forecast approaches

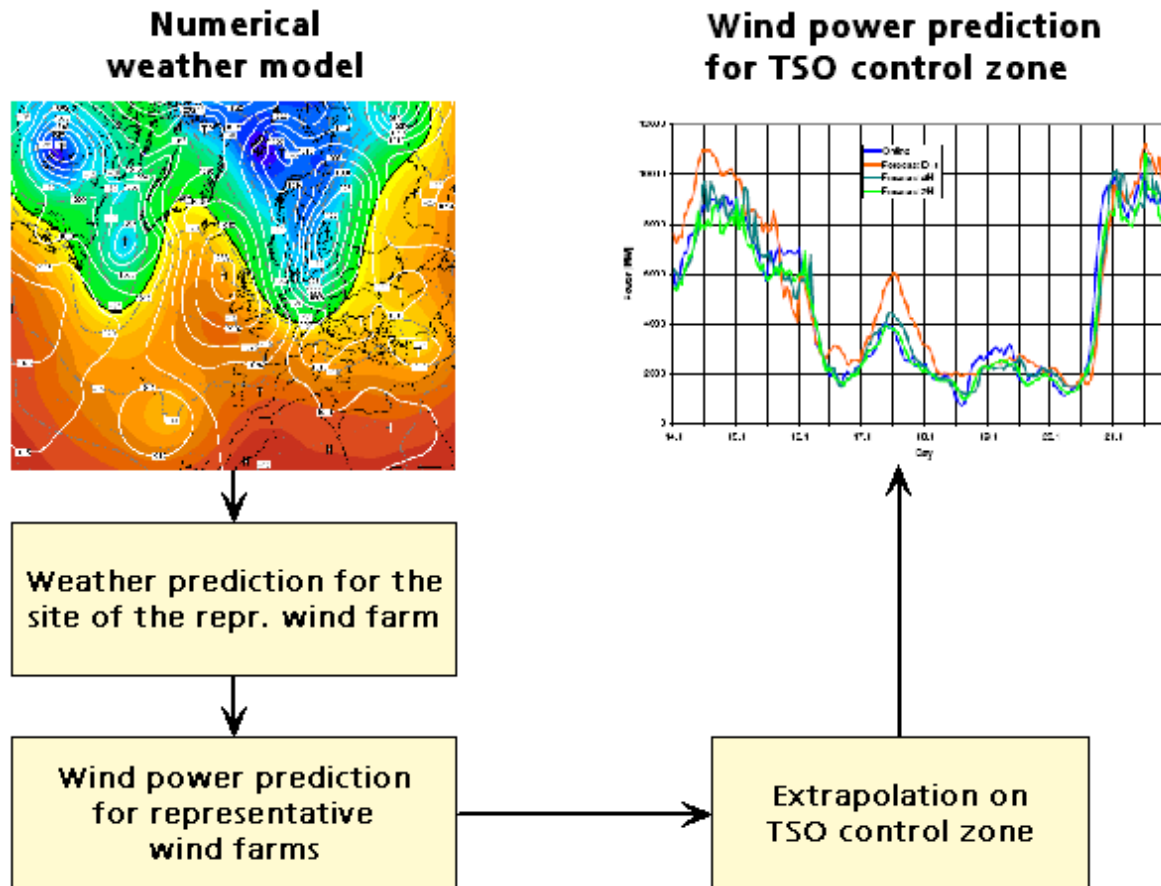
Statistical and AI-methods

- + no detailed physical information needed
- + fast calculation
- depends on premium historical power data
- uncertainty at new or seldom situations

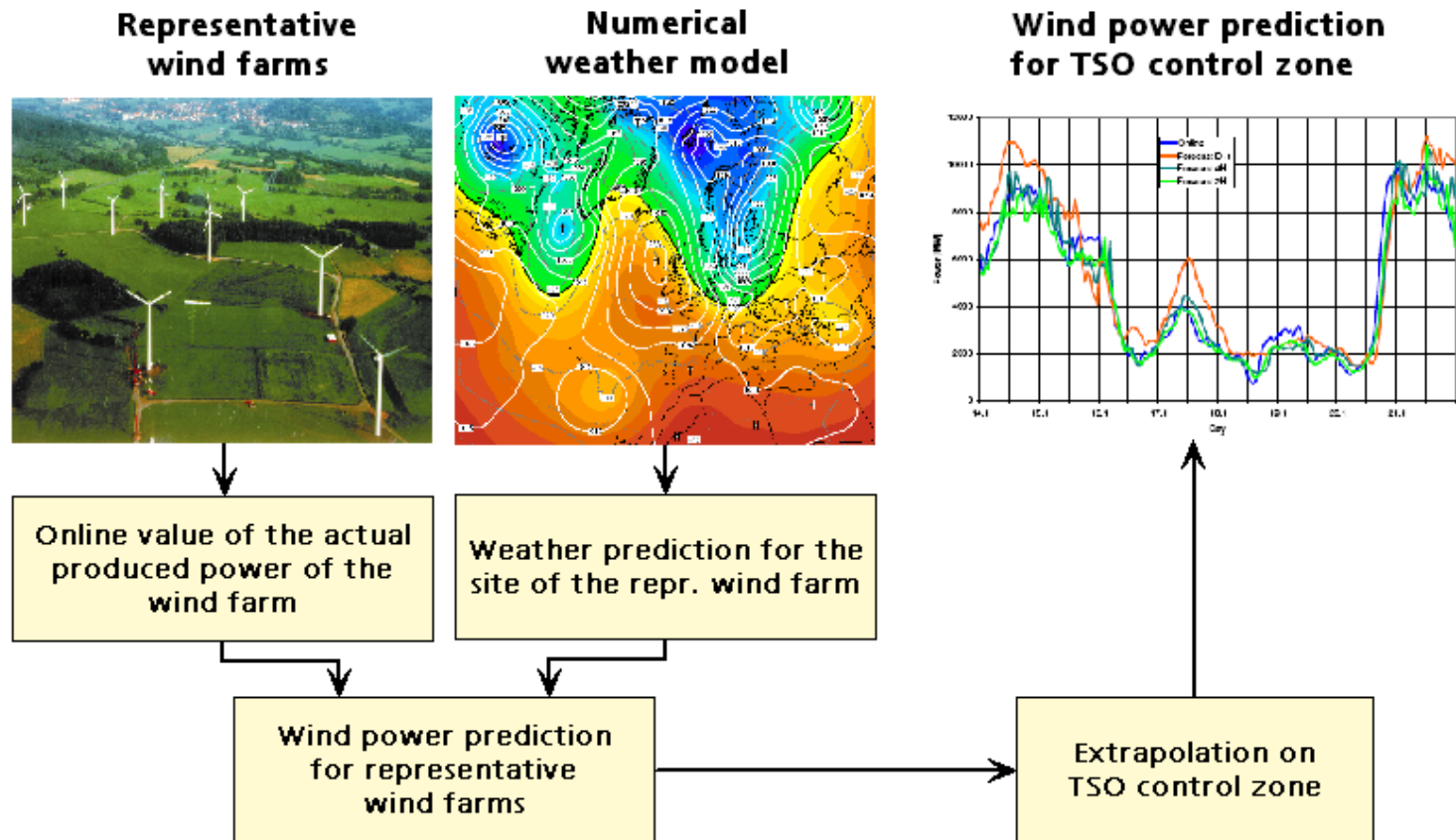
Physical methods

- + Quality and amount of measured data a second order
- Detailed information about wind farm and surrounding necessary
- large efforts for building the model

Common features: day ahead forecast



Common features: short term forecast



Common features: extrapolation to control zone

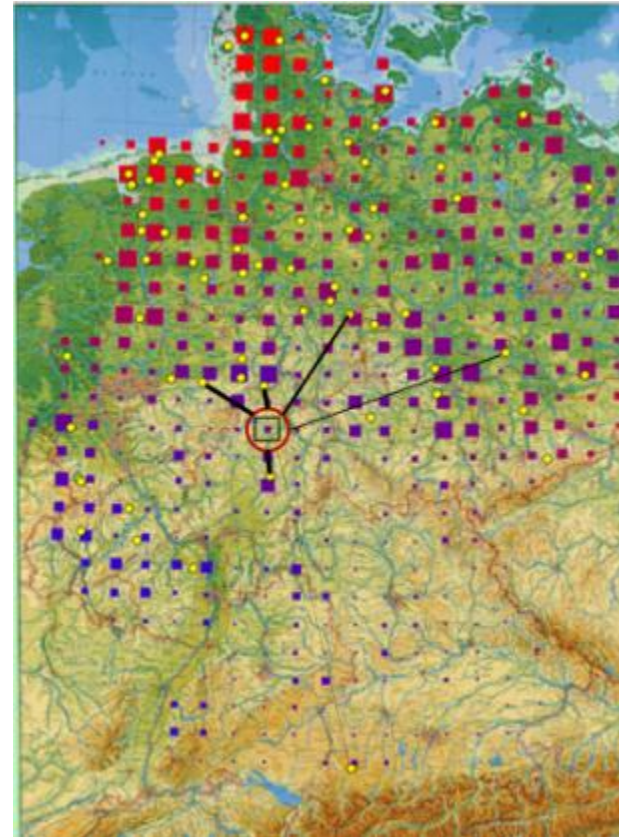
Control zone is divided into grid squares

The installed power in each grid square is known

Forecast of each reference wind farm is extrapolated to grid square

Extrapolation using inverse distance weighting

All grid squares in control zone are summed up



Users

Users of forecasting tools:

- Transmission System Operators
- Distribution System operator
- Utility
- Wind Farm Operator
- Virtual Power Plant Operator
- Traders
- Dispatch Centres
- Windfarm Projectors
- Research Organisations

Operational purpose

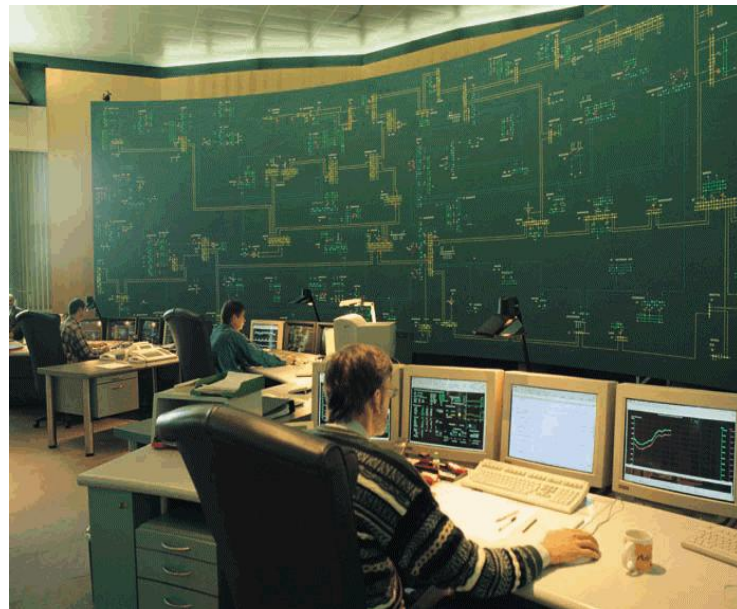
Operational purpose:

- Grid stability
- System management
- Power plant scheduling
- Extrapolation to larger areas
- Dispatching
- Trading (day ahead, intraday)
- Planning/projecting wind farms
- Maintenance and operation of windfarms
- Research
- ...

Operational use

Operational use of forecasting tools:

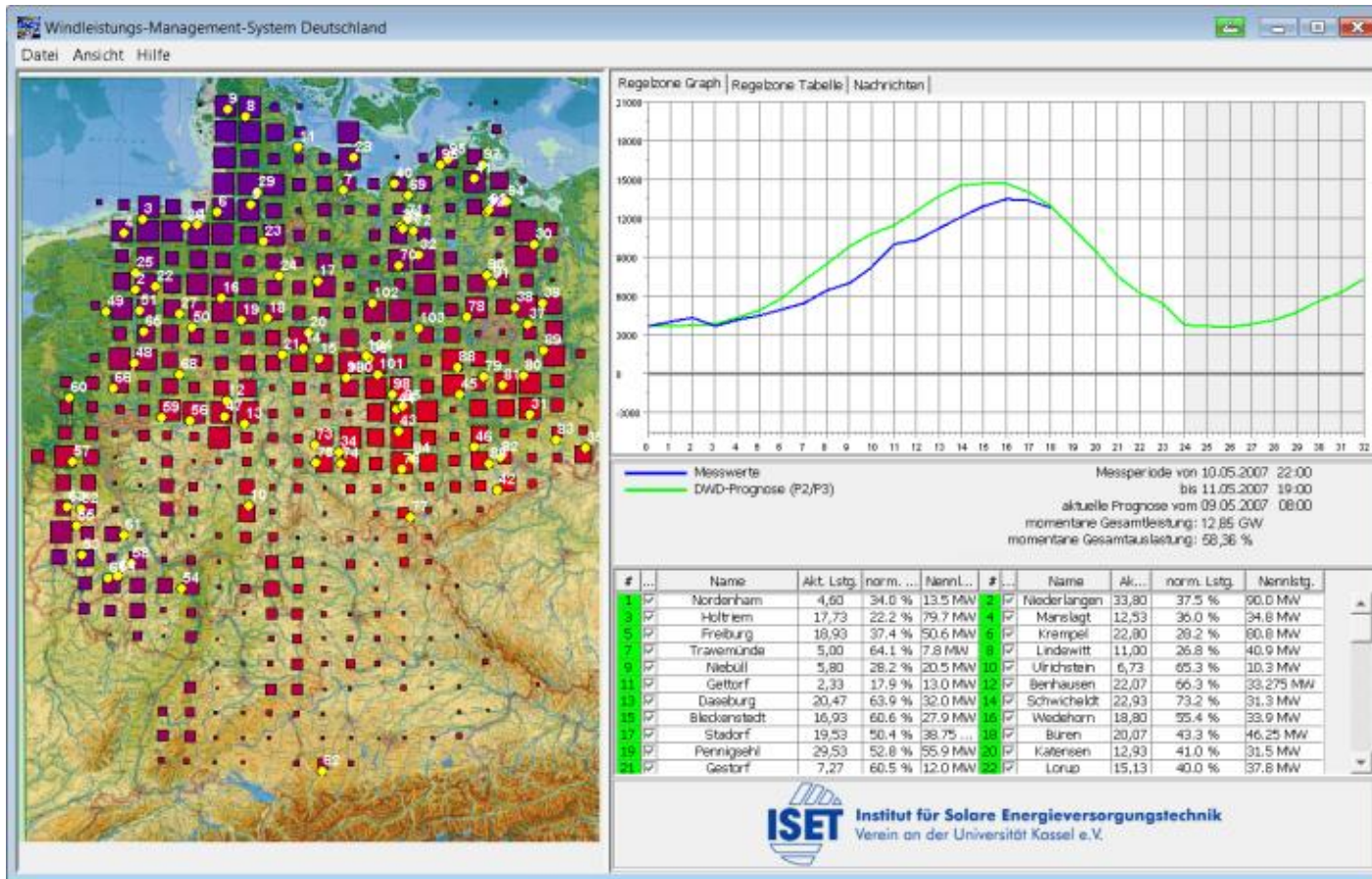
- Control Centres
- Data Centres
- Desktop applications
- ...



Transpower TSO control centre

Forecasting tool: WPMS

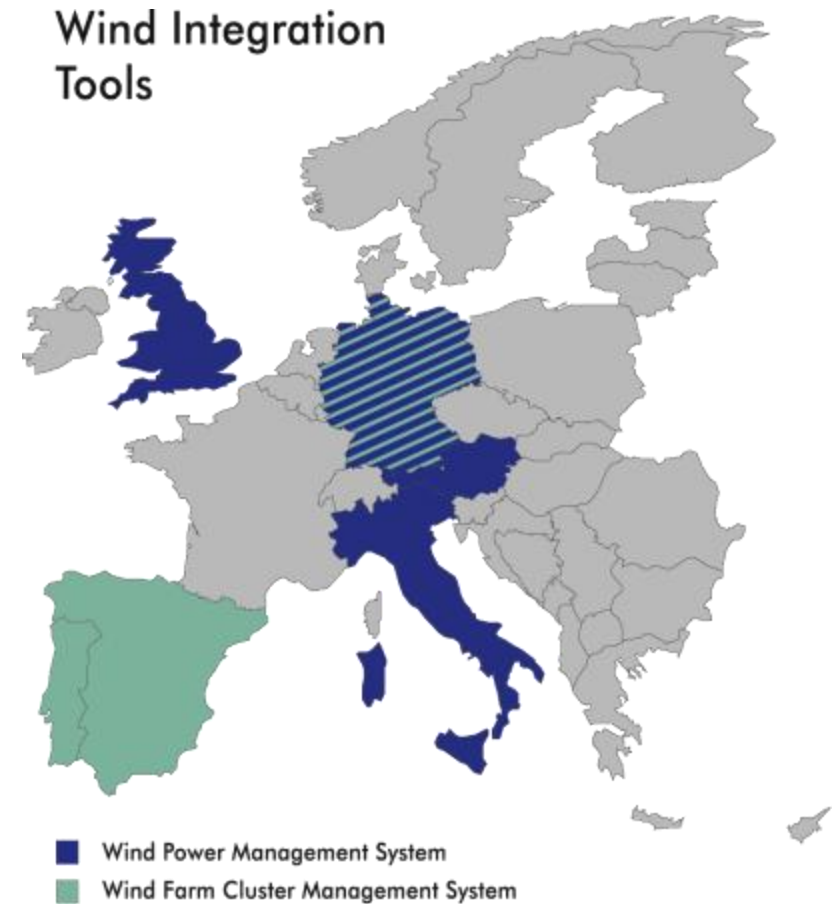
Wind Power Management System



Operation of WPMS

Wind power forecast system WPMS

- 3 german TSO's
- Wind farm owner (2010)
- Austria, Italy, UK, Romania, Egypt, China



Operation of WPMS

WPMS is used operationally for

- Grid control
- Day ahead market
- Intraday trading (in 2010)

Used default components

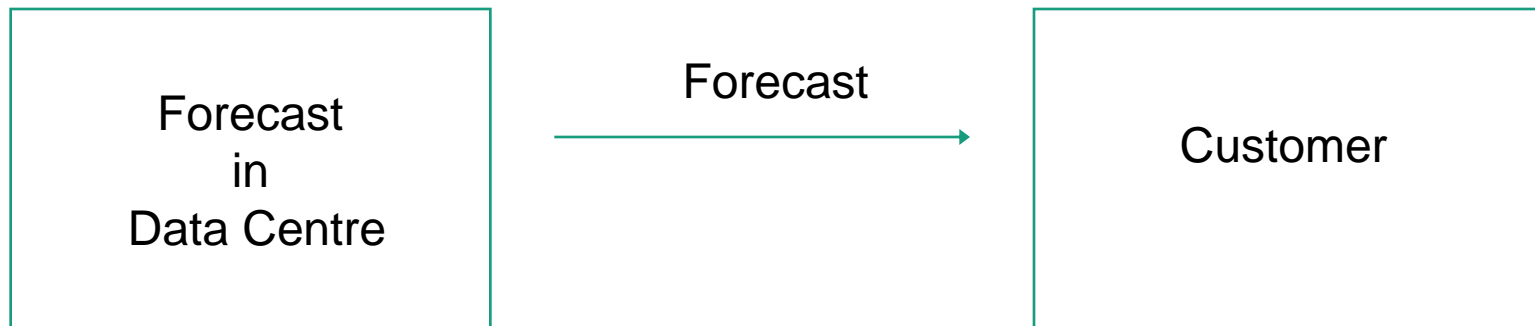
- Day ahead forecast
- Short term forecast
- Upscaling



Architectures of forecast tools

Service architecture:

- Forecasts are delivered as a Service (24/7)



Architectures of forecast tools

ServiceArchitecture:

Pros:

- Easy delivery of forecast results
 - External Operation
 - SLA's are possible
- No integration needed
 - NWP, Software, ...
- No customer installation needed
- Service provider handles data
 - Data input
 - Data purchase

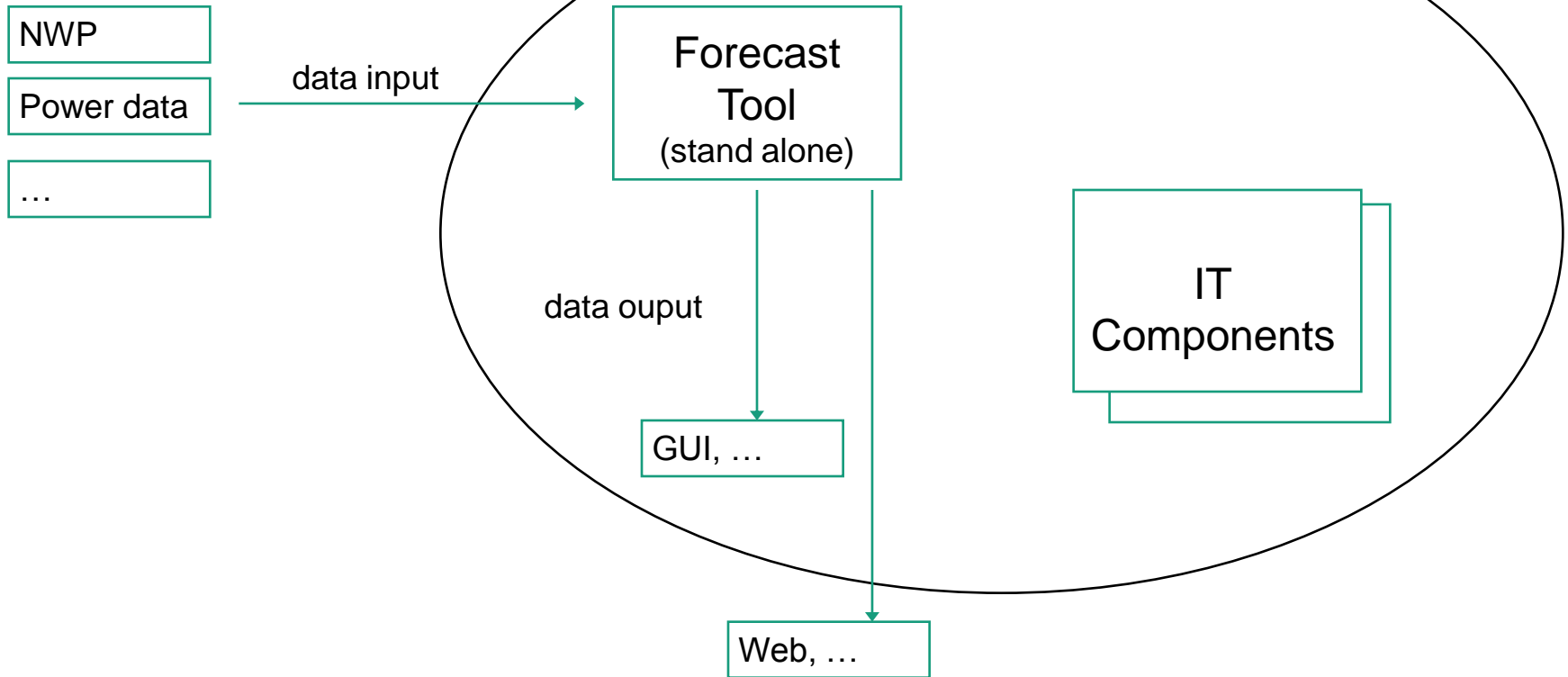
Cons:

- Dependency to external service
 - External connections necessary
 - External know how
- Loose integration
- Reliability
- Security

Architectures of forecast tools

Customer side architecture (I):

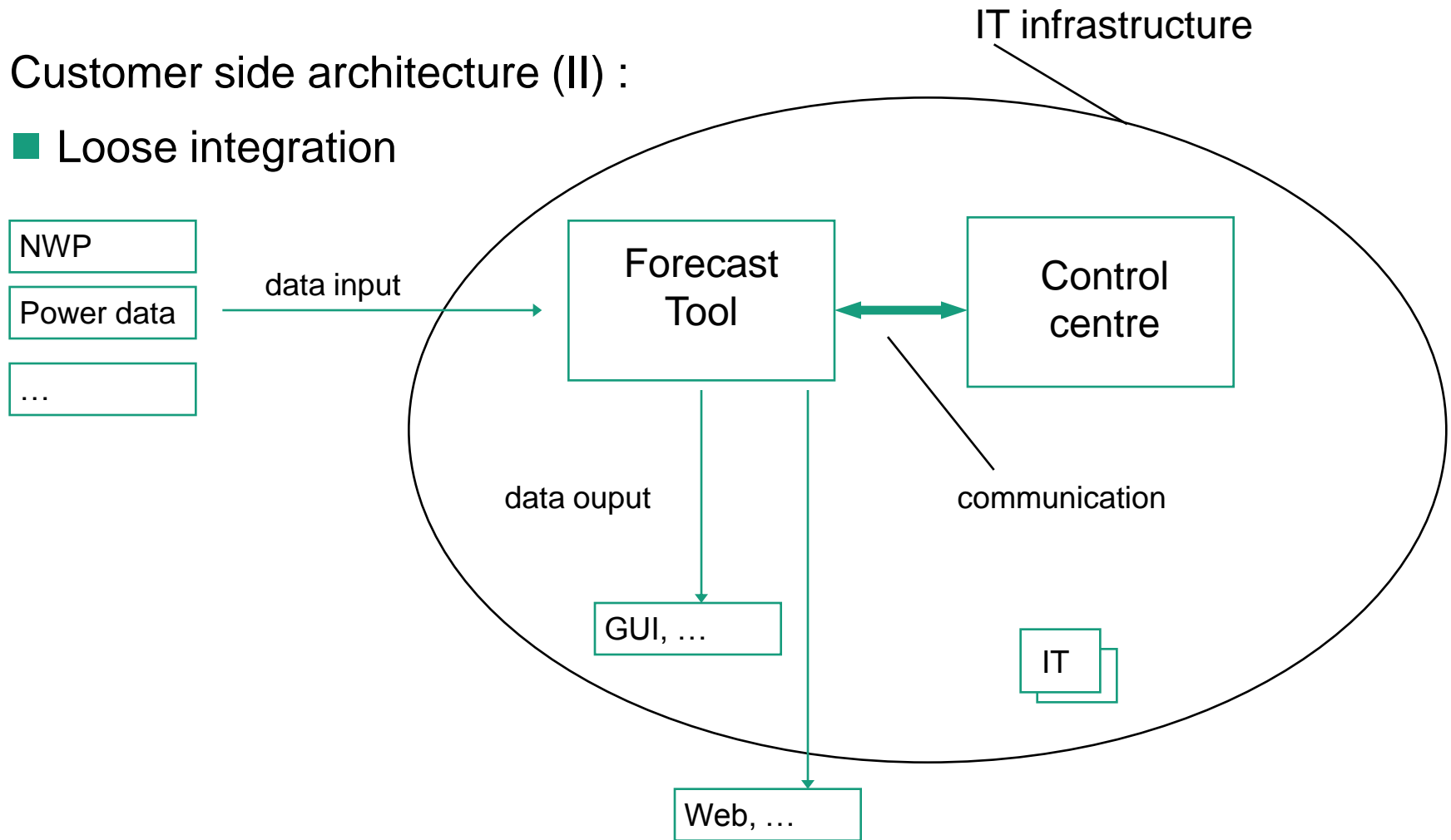
■ Stand alone



Architectures of forecast tools

Customer side architecture (II) :

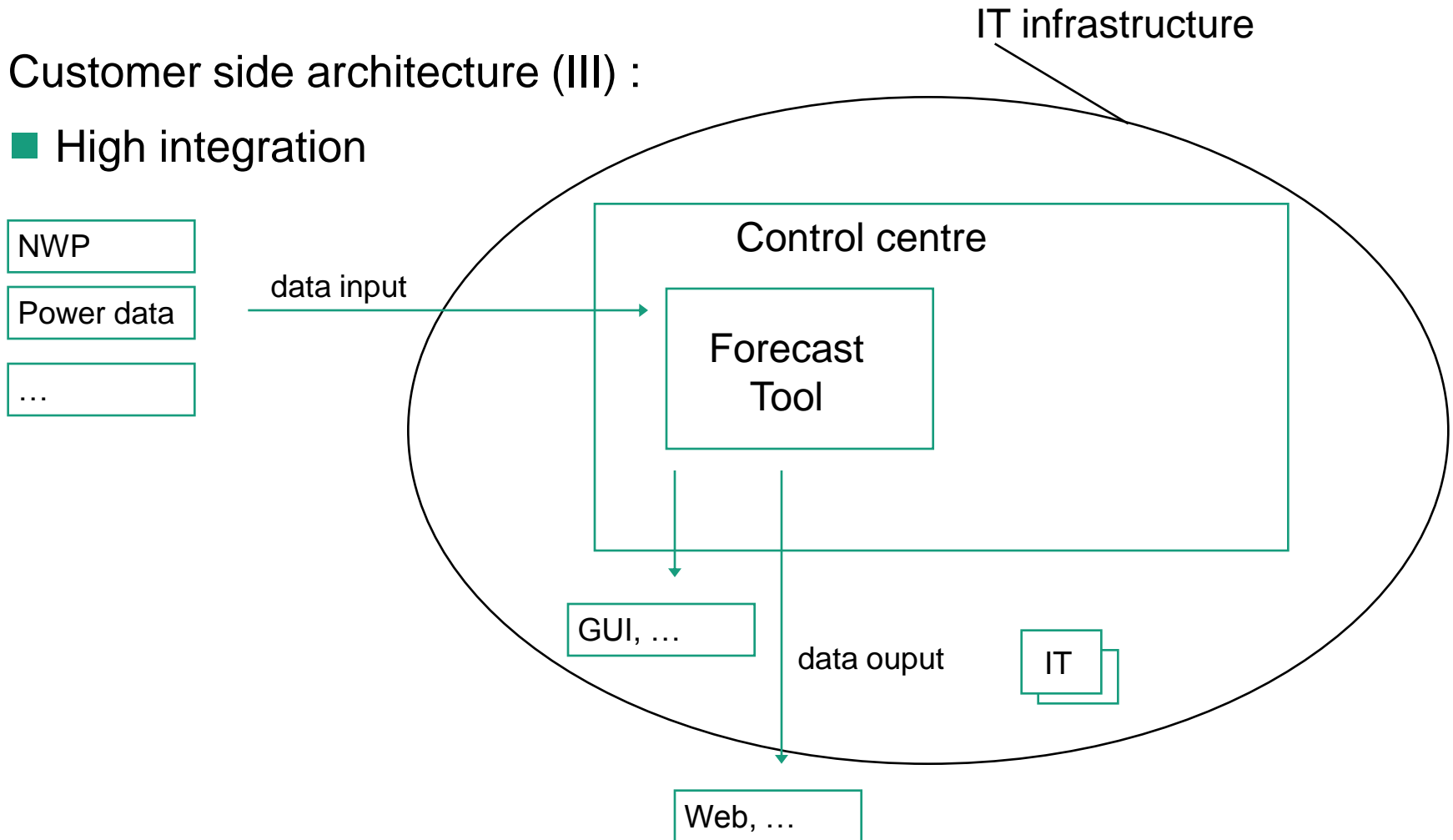
■ Loose integration



Architectures of forecast tools

Customer side architecture (III) :

■ High integration



WPMS-Architectures

Customer side architecture:

Pros:

- More control
- Customized integration
- Lesser external dependency
 - Fewer external connections
 - Fewer external tools
 - Know how in house
- Higher capability of acting

Cons:

- Higher internal complexity
- Necessary integration
 - NWP, infrastructure
 - Software (control centre,...)
- Installation/deployment
- Responsible for operation
- Responsible for data handling

Research and software development

Research:

- Ongoing research
 - Example: short term forecast

Research and software development:

- Research results are unknown
 - Since research results lead to requirements → requirements are vague
 - New research results lead to changes

Software development

- Research results have to be integrated
- Software processes and software development have to support research results

Research and software development: Processes

Heavy weight software development processes:

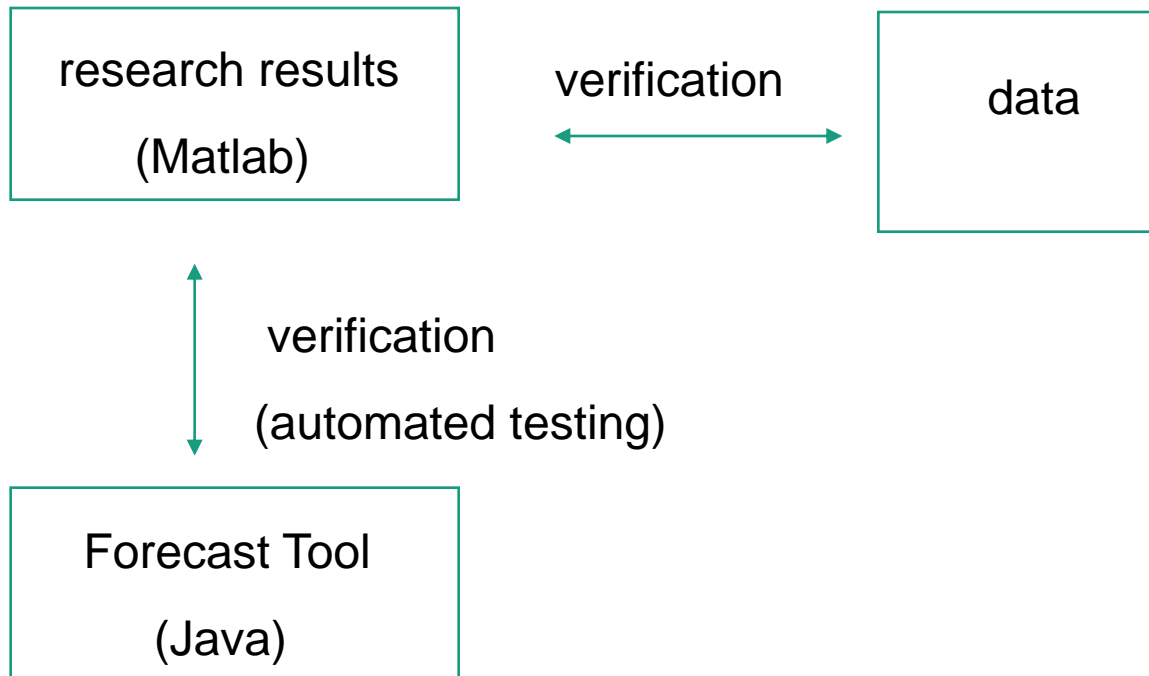
- predictive
- heavyweight
- difficult to respond to changes

Agile software development processes:

- adaptive
- lightweight
- iterativ and incremental
 - requirements and solutions evolve iterative
- embracing changes

Research and software development: Tool chains

- Collaboration of research and software development tool chain is important
- Example: transitive verification tool chain



Strategies to improve forecasts

Strategies to improve forecasts

- NWP:
 - Better NWP
 - Combination of NWP
 - Short term forecast (for example 1h-8h)
- Others
 - Combination of power forecast methods
 - Prediction intervals
 - Wind power prediction for grid nodes

Comparison between NWP-models

Forecasting whole Germany

Test range: 01.01.08-30.04.08

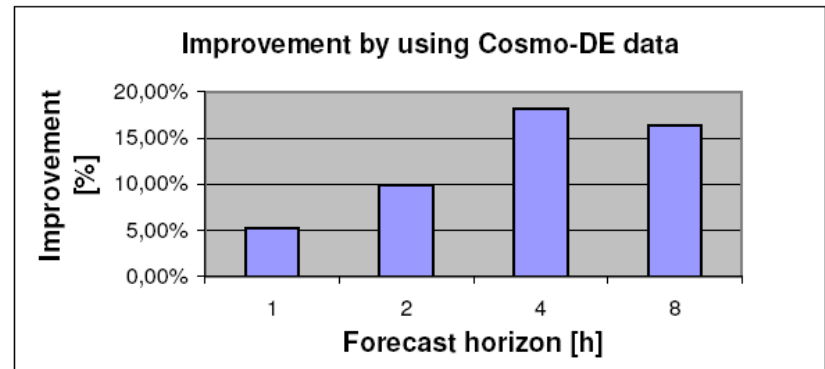
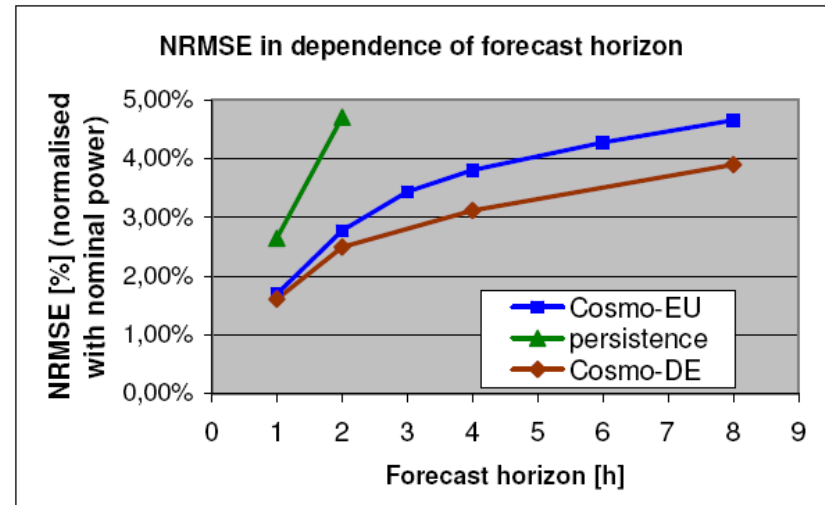
NWP Models:

- Cosmo-EU
- Cosmo-DE

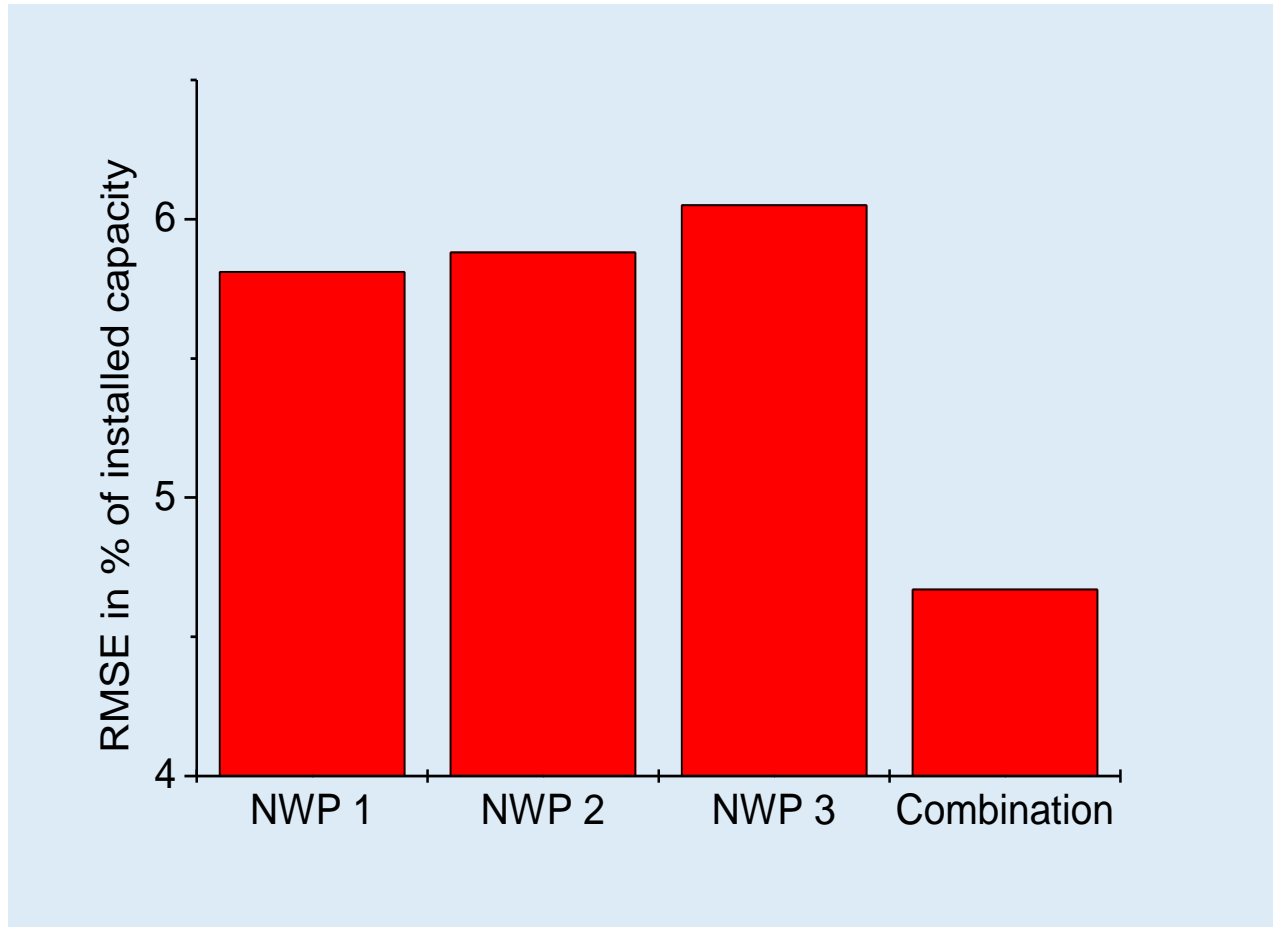
Results:

- Improvement at each forecast horizon
- Highest improvement at forecast horizon of 4h

$$\text{Imp} = \frac{NRMSE_{old} - NRMSE_{new}}{NRMSE_{old}}$$

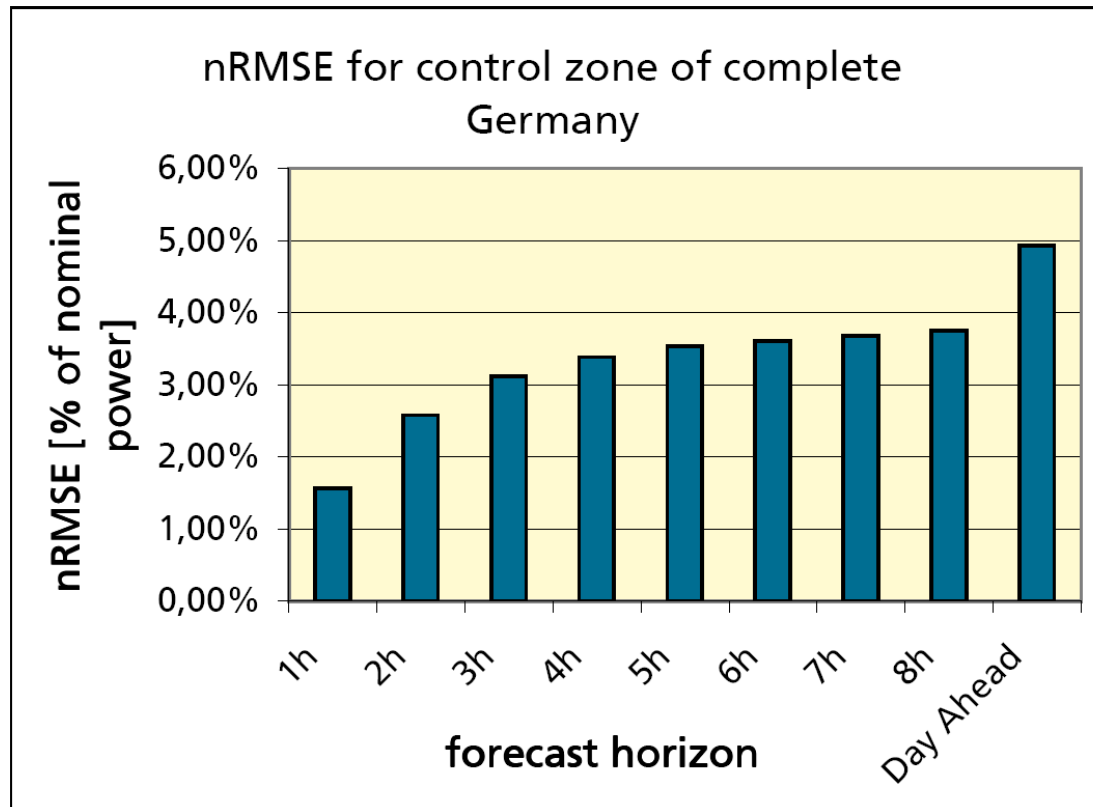


Combination of weather predictions



Forecast Error for complete Germany

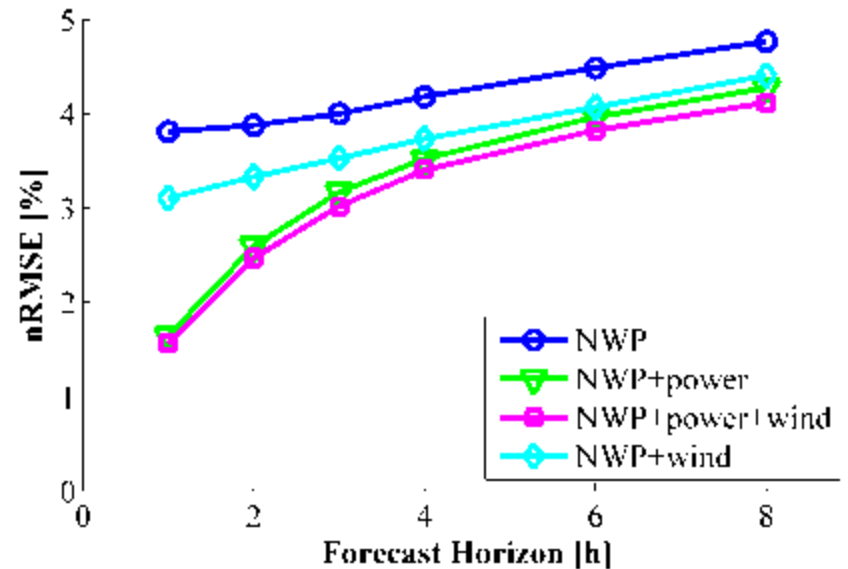
Short term forecast



Results of short term prediction for complete Germany

Four different scenarios are evaluated:

- Only NWP data
- NWP and actual measured power data (PW)
- NWP and actual measured wind data (Wind)
- NWP and actual measured power and wind data



Requirement for NWP's

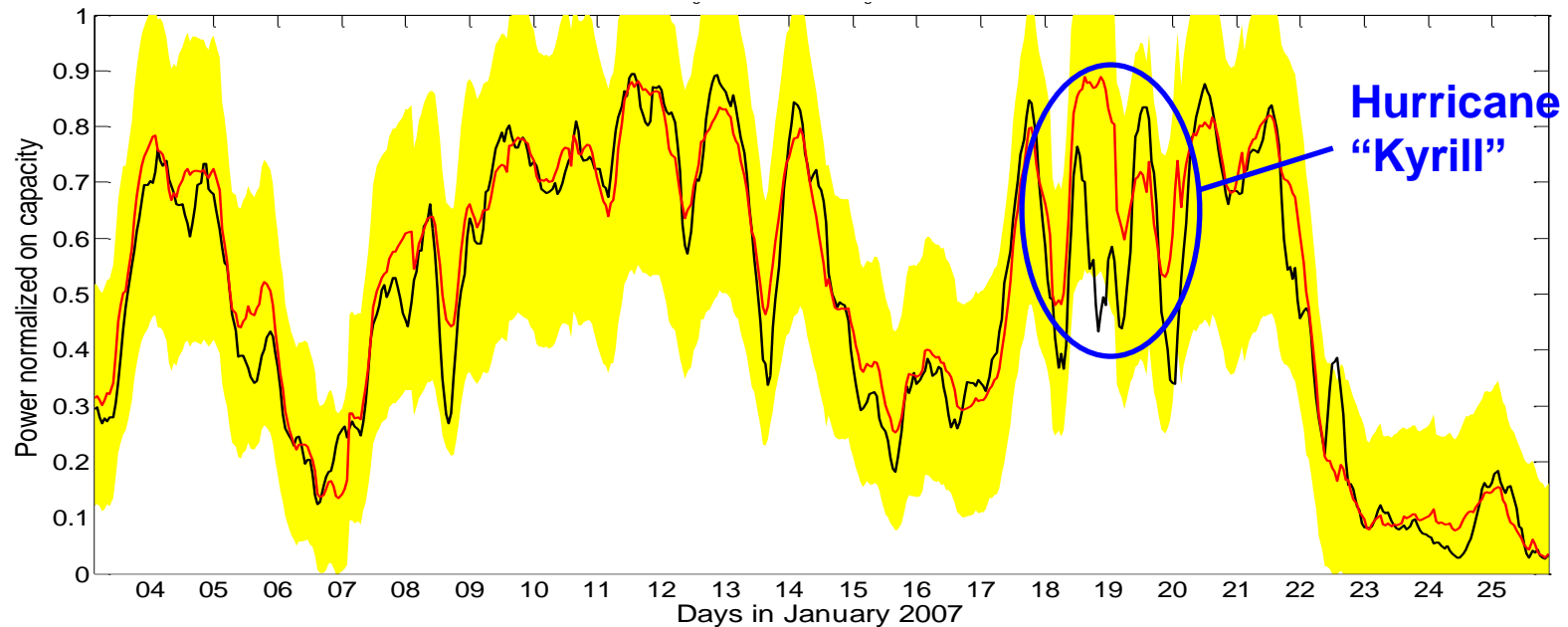
Requirements:

- Exchangeable NWP provider
- Multiple NWP provider
- Forecasts for different forecast horizons
- Integration of additional input data

Affected components:

- data transfer
- data validation
- data preparation
- forecast computation
 - Multiple NWP's
- Use of power data
- Use of offsite wind measurements

Prediction intervals



8 h forecast → mean interval size ~ 37 %

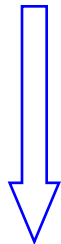
All observed
reliabilities
> 99.7 %



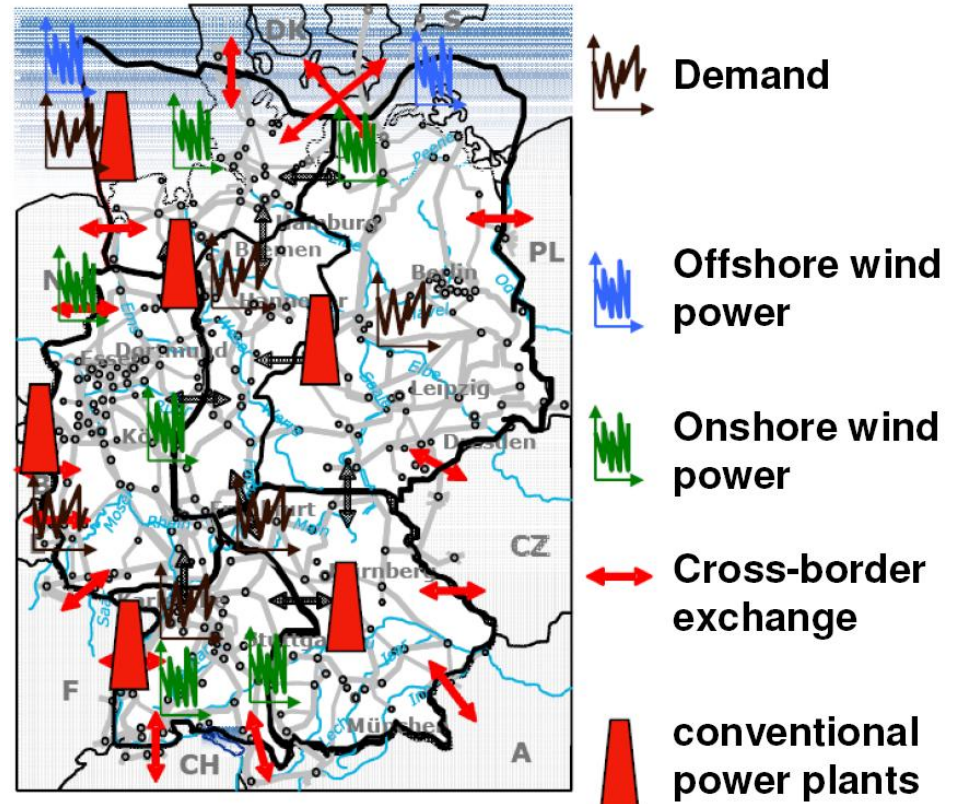
“The model cannot estimate the uncertainty for maximal 24 hours of one year. During the rest of the year, the fluctuating wind power can be controlled accurate.”

Wind Power prediction for grid nodes

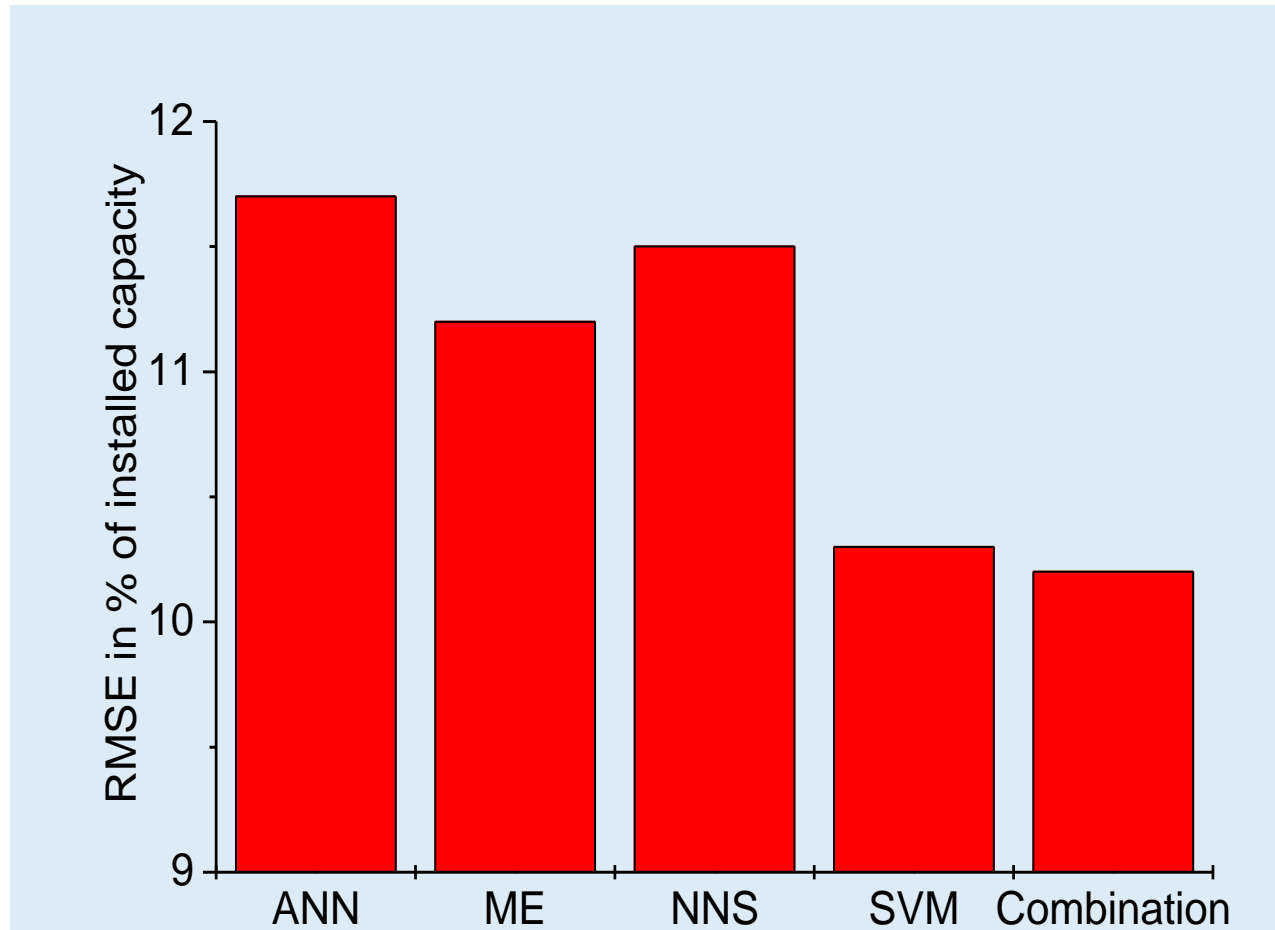
integration of renewable energies, and particularly wind energy, into the German power grid



need for time series of wind power in a high spatial and temporal resolution



Combination of power forecast methods



Requirements

Prediction intervals requirements:

- confidence interval module

Affected components :

- Computational core

Grid node forecast requirements:

- Upscaling module

Affected components :

- Upscaling

Requirements

Requirements for combination of forecast methods:

- Exchangeable forecast method
- Multiple forecast methods

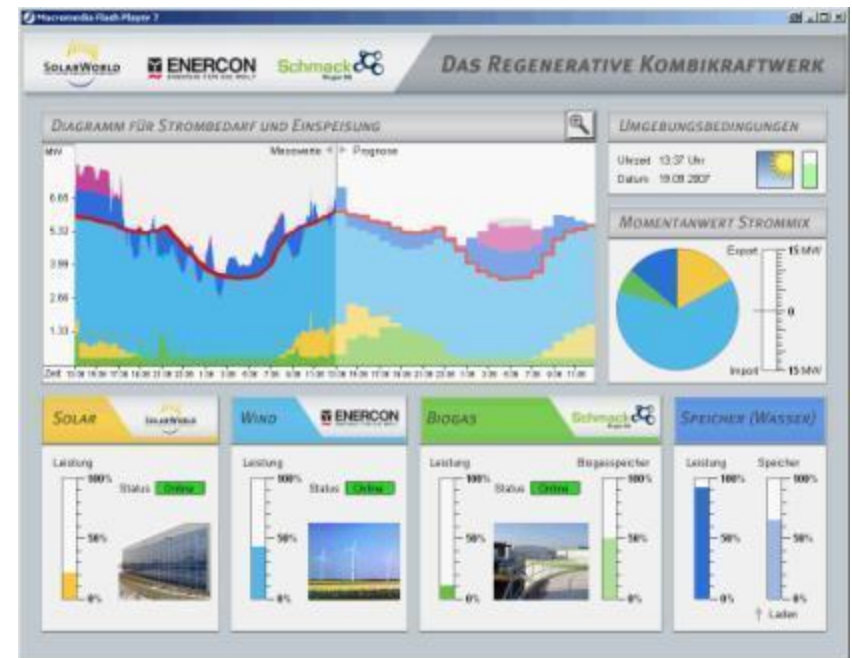
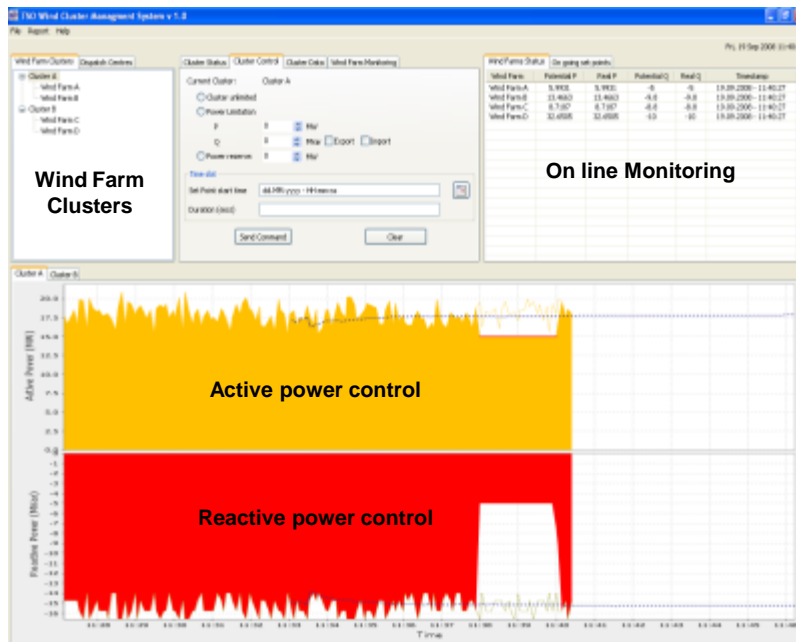
Affected components:

- forecast computation

Future architectures with forecast tools

New architectures and concepts:

- Cluster Management
- Virtual power plant

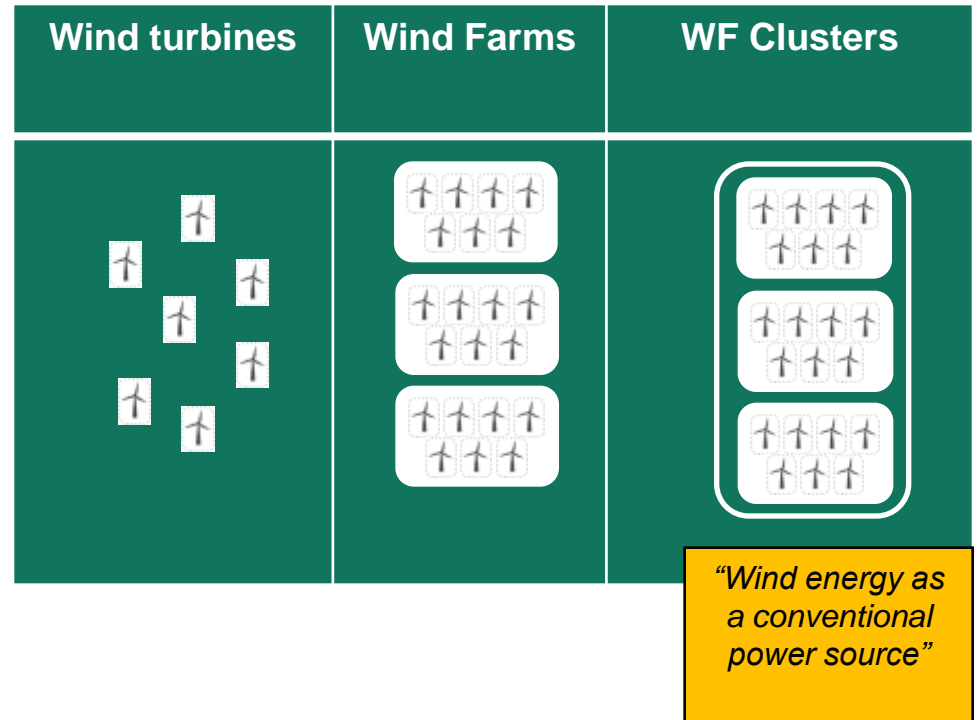


Wind Farm Cluster Management

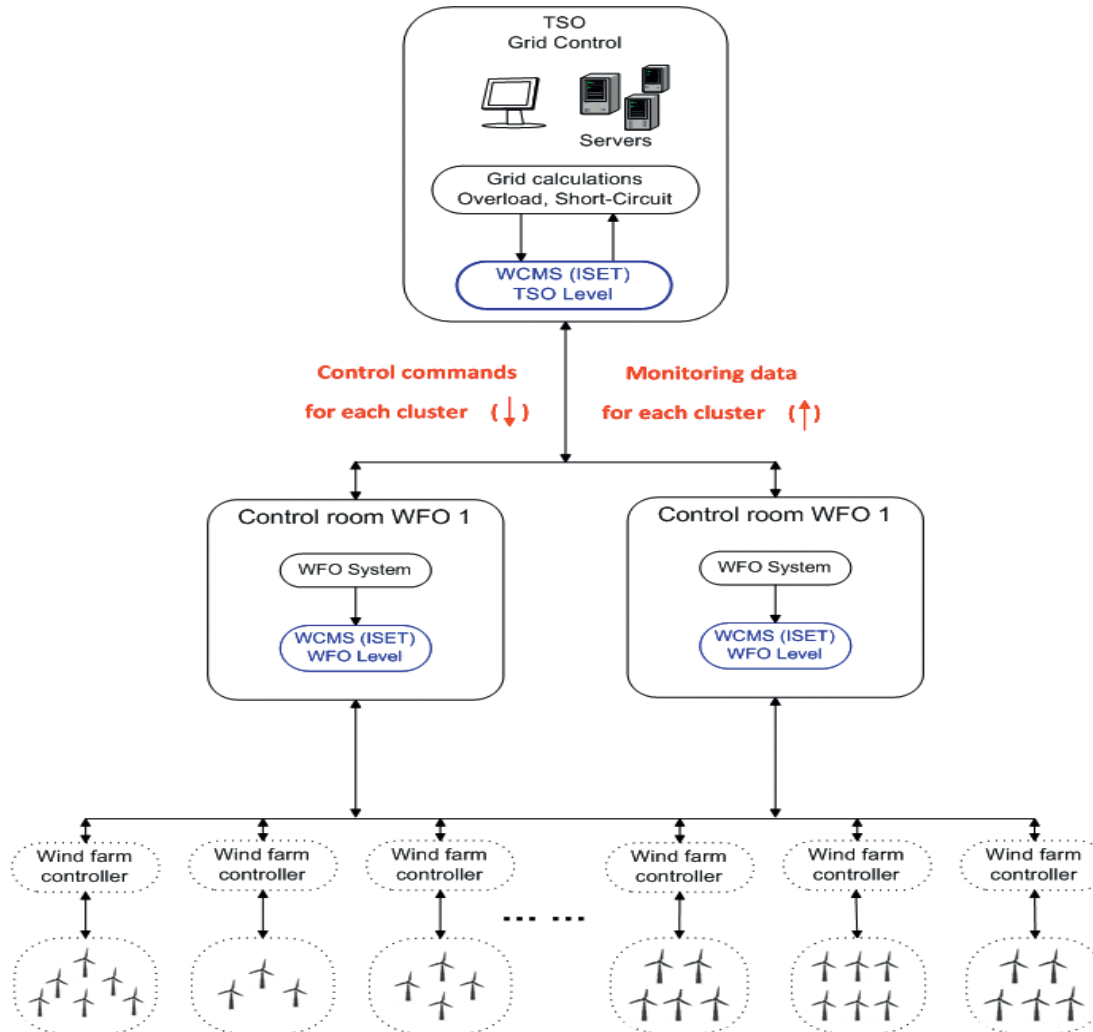
“Logical aggregation of physical existing wind farms connected under the same grid node”

Grid requirements:

- active power control
- reactive power control
-

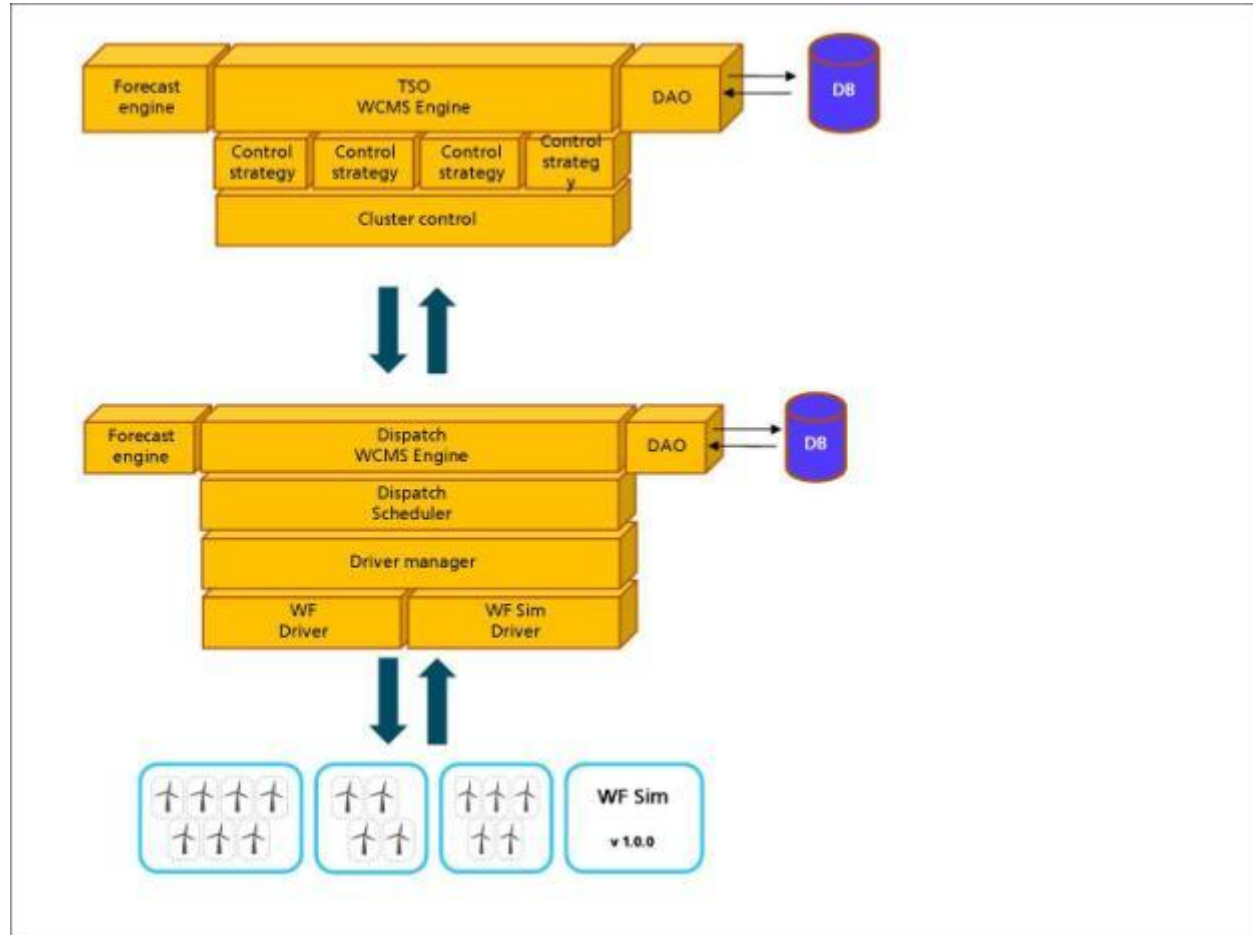


Wind Farm Cluster Management



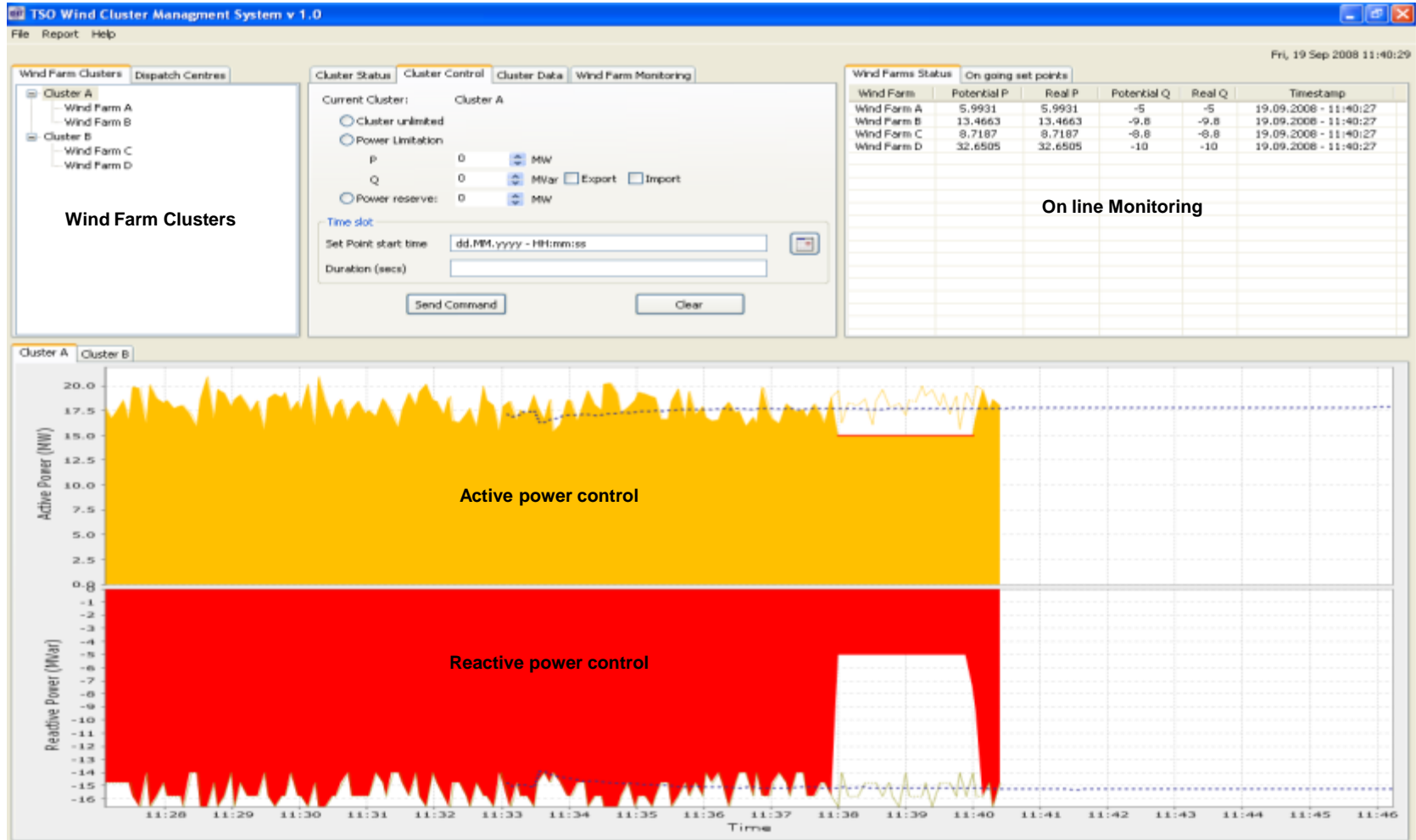
Wind Farm Cluster Management

Architecture:
(Example)



Future architectures with forecast tools

WCMS GUI:



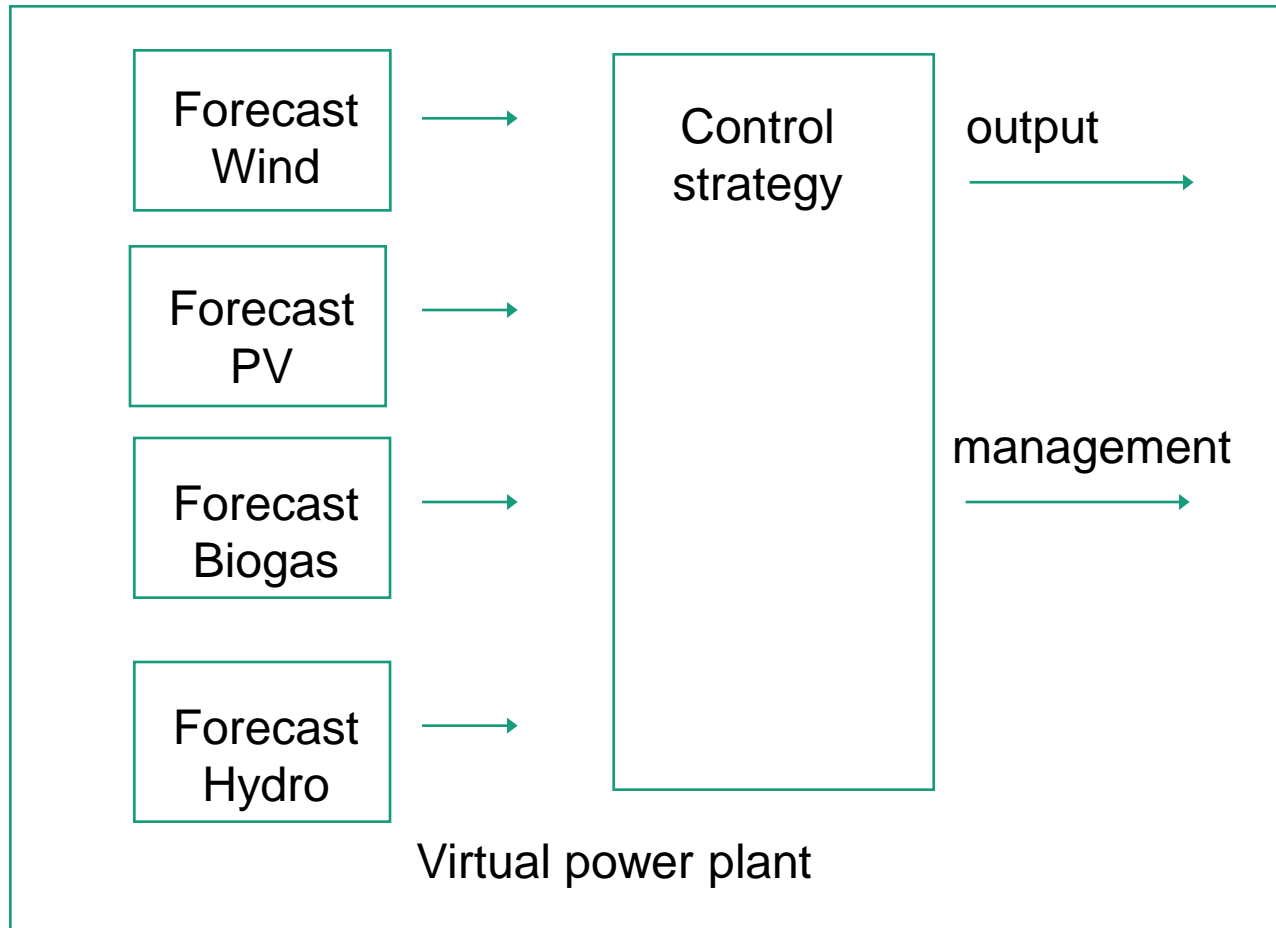
Virtual Power Plant

Virtual combination of real power plants:

- Wind farm
- Photovoltaic system
- Biogas plant
-

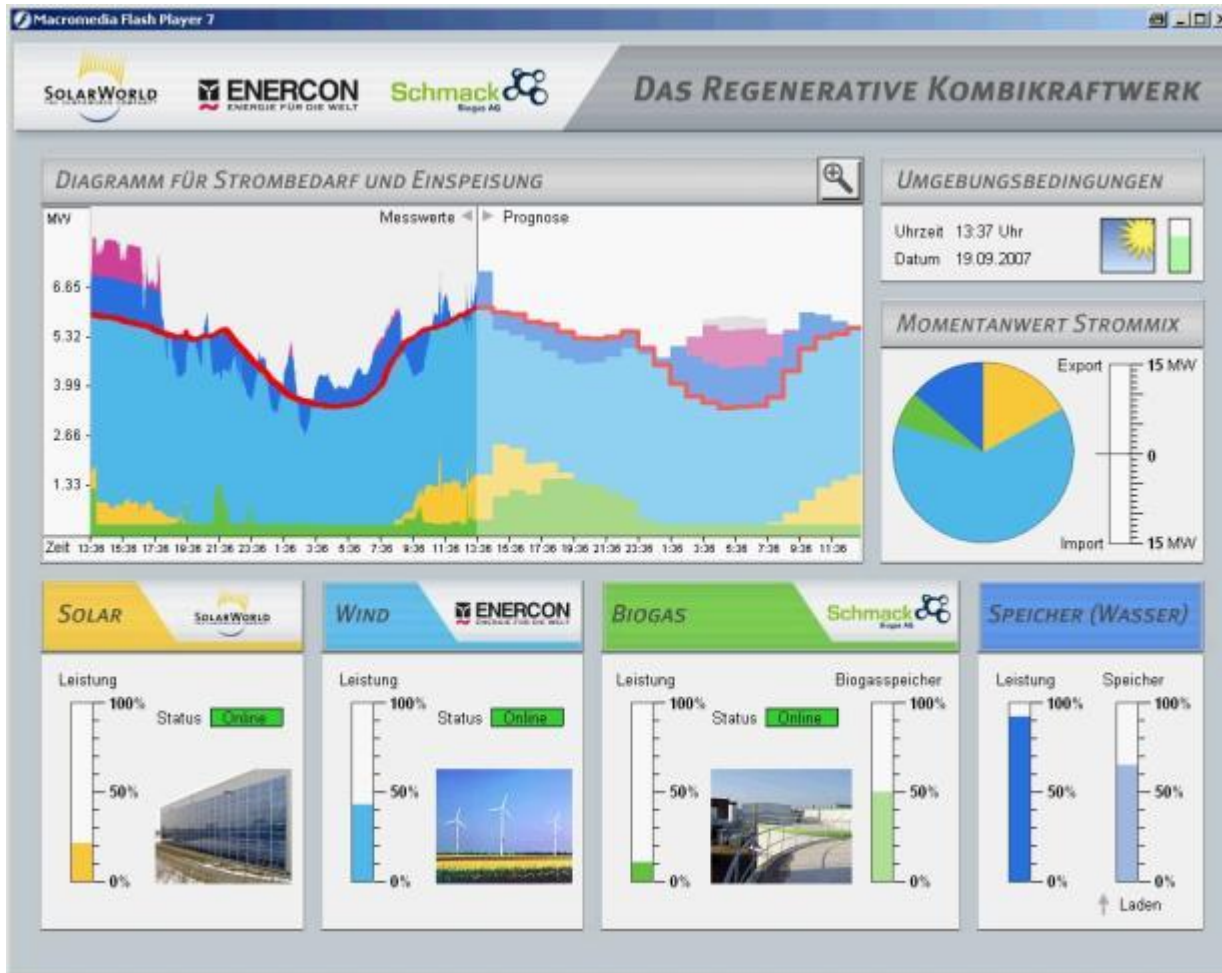


Virtual Power Plant



Virtual Power Plant

Virtual Power Plant GUI:



Challenges for these architectures

- Integration in complex software environments
 - integration in control structures
 - integration in trading structures
 - supply services for system management
- Complex interactions
- Operation of complex systems

Outlook

The future:

- New fields of application
- Interdisciplinary requirements
- More system management tasks
- New research results
- More and complex requirements
- Rapid delivery of high-quality software
- Faster changing business processes
- More competition and changes

Thank you for your attention!

Wolfgang Slaby

wslaby@iset.uni-kassel.de

**Fraunhofer Institute for Wind Energy and Energy System Technology
IWES**

**R&D Division Energy Economy and Grid Operation
Energy Meteorology & Wind Power Management
Königstor 59, 34119 Kassel**