



# Combination of numerical weather prediction models and online measurement data for wind power forecasting using artificial intelligence methods

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# Overview

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**Introduction**

**Wind power forecasting**

**Short-term forecasting**

**Multi-model approach for numerical weather predictions**

**Multi-model approaches – AI methods**

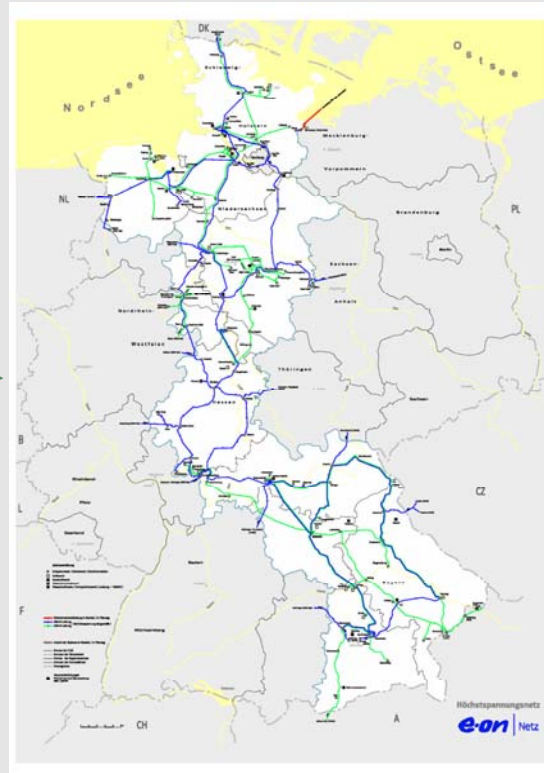
**Future plans**

**Conclusion**

# Introduction

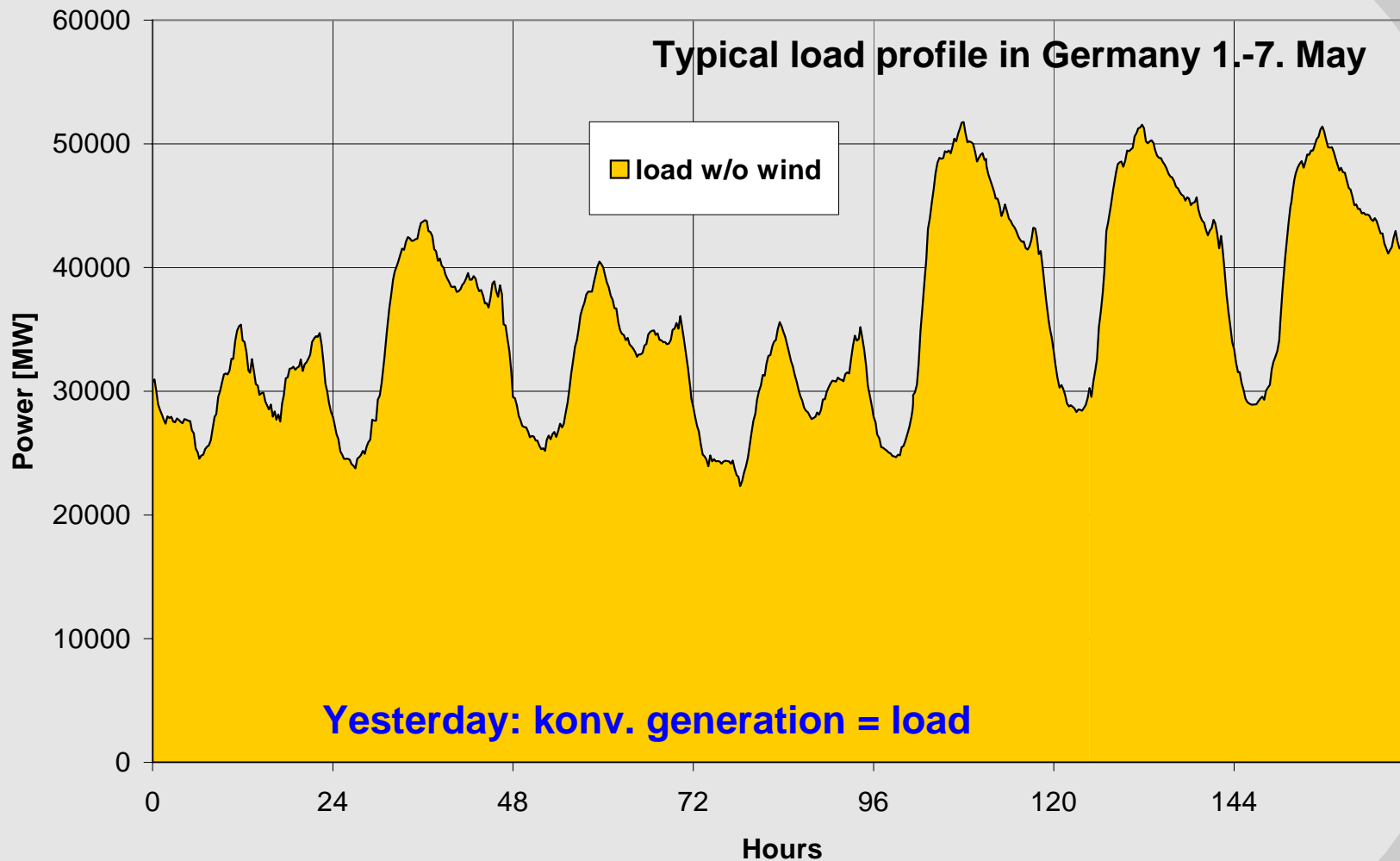


**Controllable**

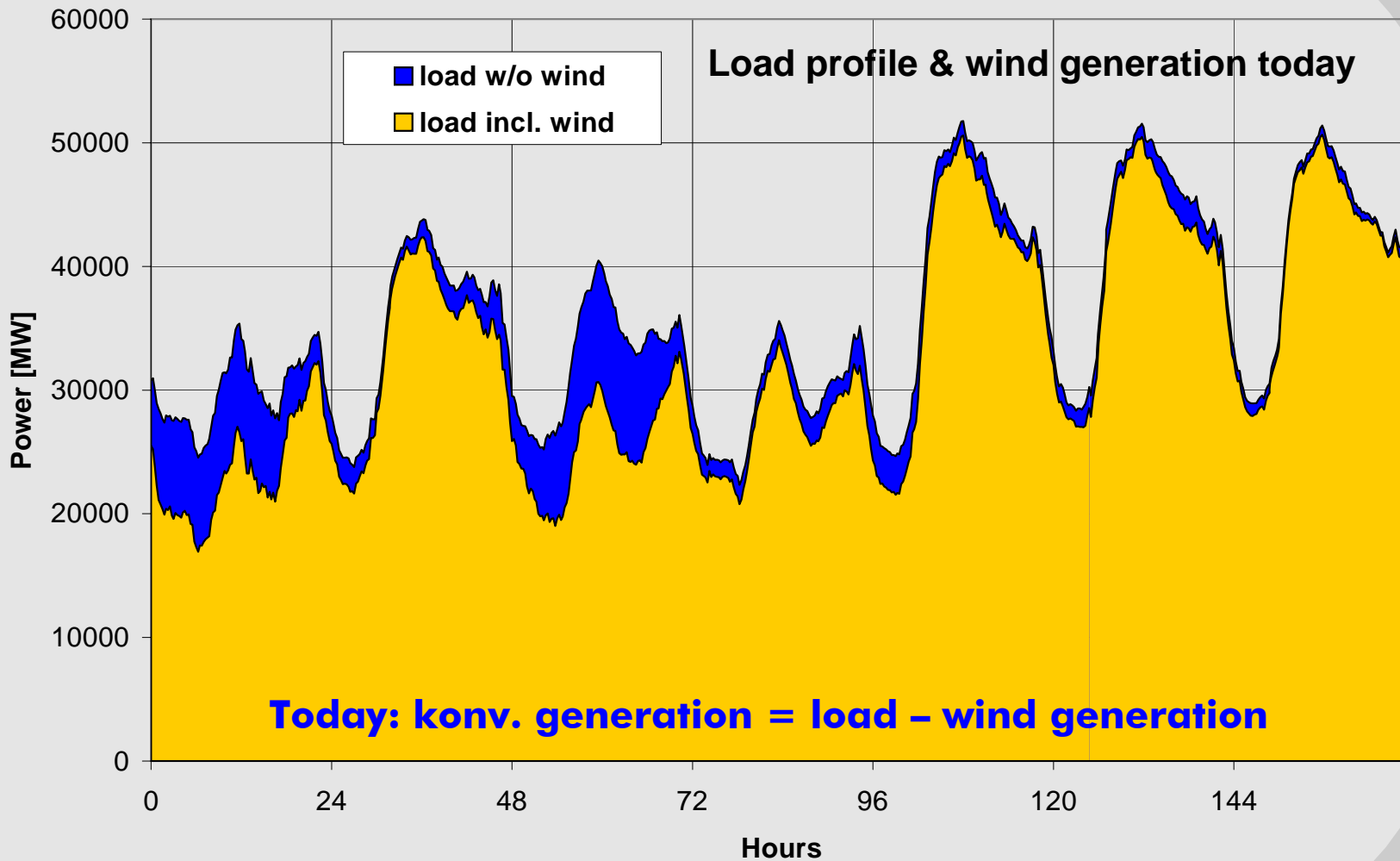


**Weather dependent**

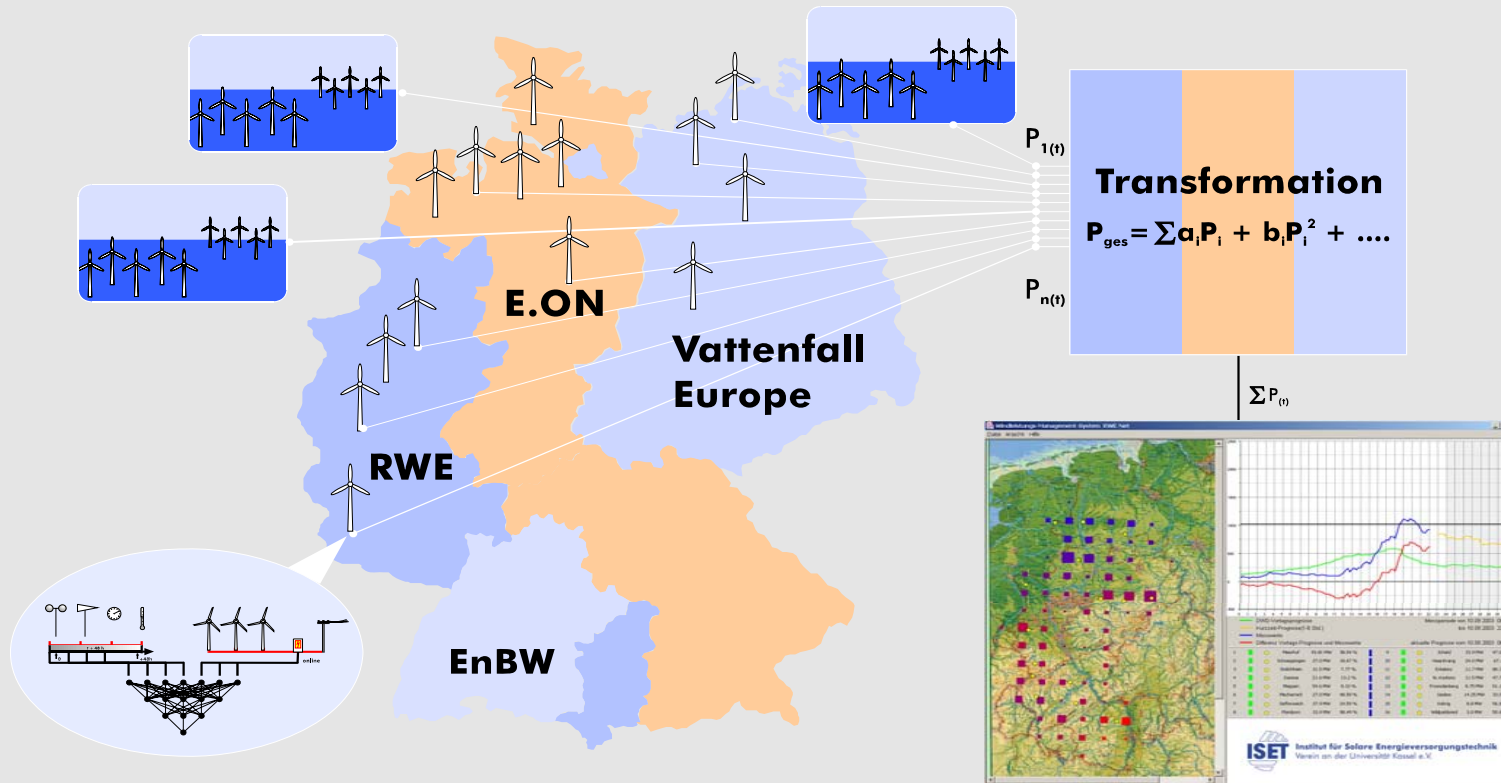
# Introduction



# Introduction



# Wind power forecasting

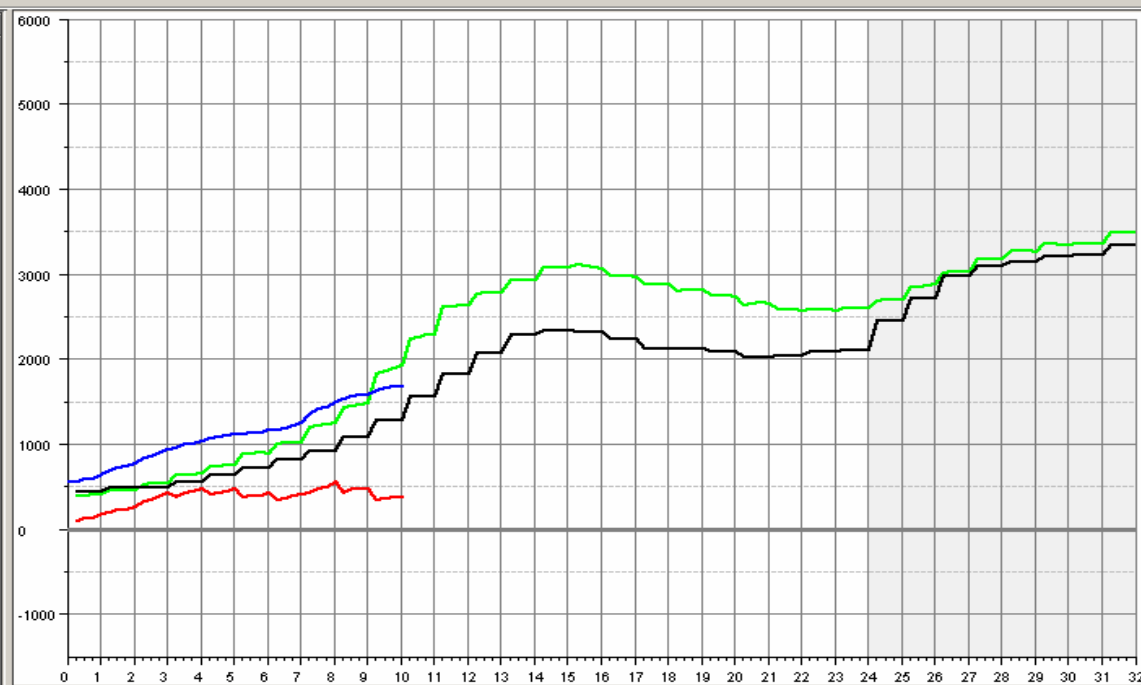
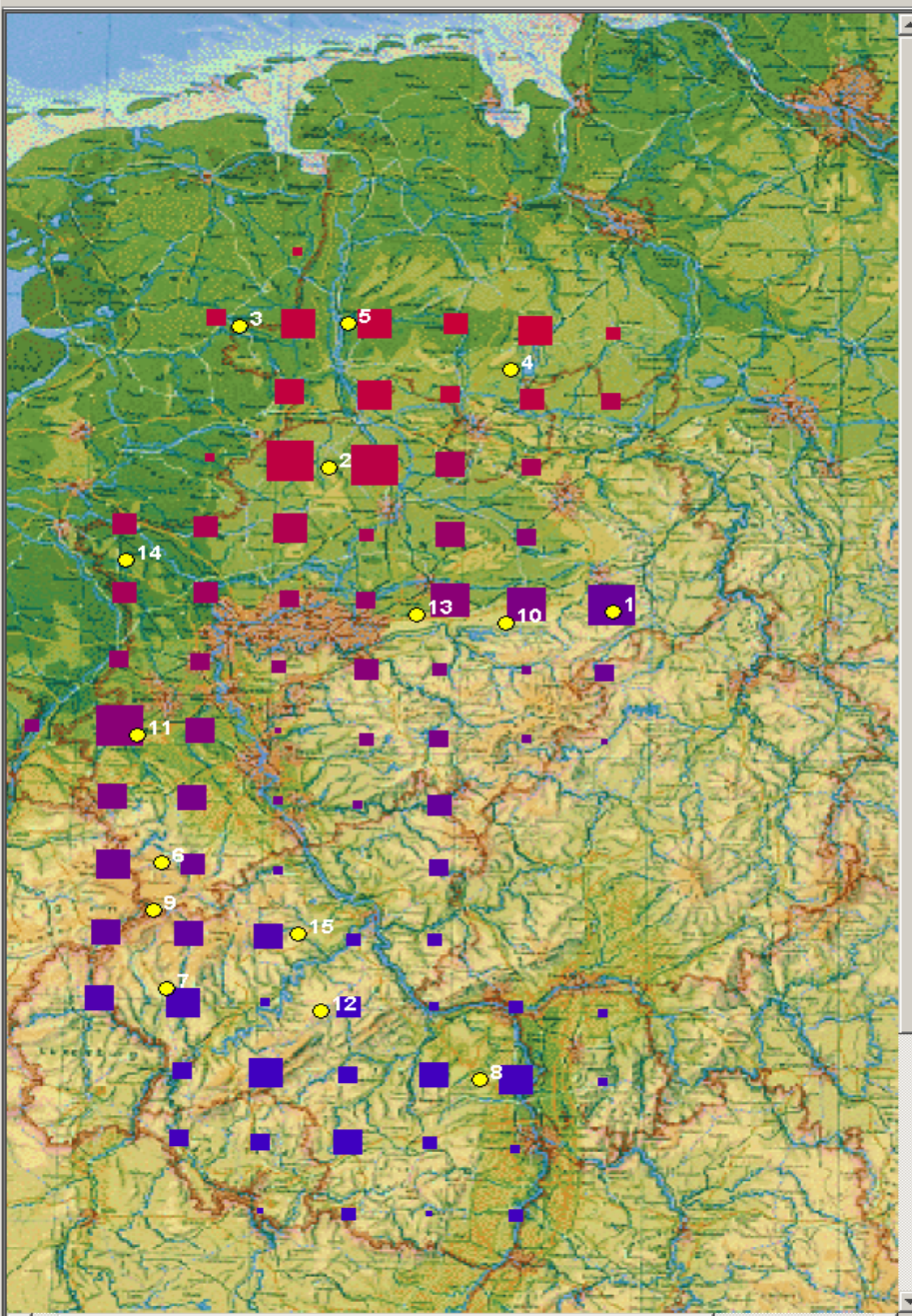


## Wind Power Management System (WPMS)

In operation at: E.ON Netz, Vattenfall Europe Transmission, RWE Transportnetz Strom,

Currently implemented at: EnBW Transportnetze

Basis for horizontal exchange of wind power (EEG §14)



— DWD-Prognose  
 — Kurzzeit-Prognose(1-8 Std.)  
 — Messwerte  
 — Differenz Arbeitspunkt-Messwerte  
 — Arbeitspunkt

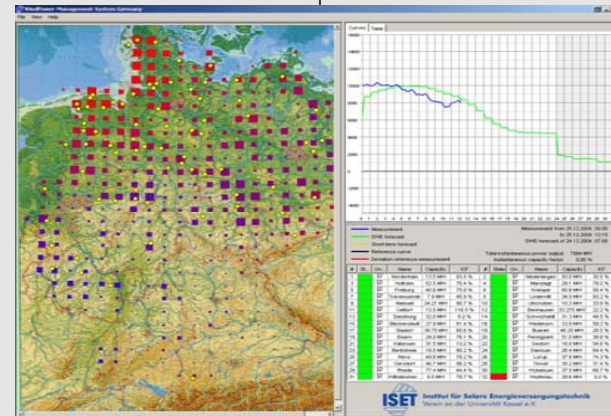
Messperiode von 20.09.2004 00:00  
 bis 20.09.2004 10:00  
 aktuelle DWD-Prognose vom 20.09.2004 08:00

momentane Gesamtleistung: 1695,36 MW  
 momentane Gesamtauslastung: 30,02 %

#	Stat.	an/aus	Name	Nennlsg.	norm. Lstg.	#	Stat.	an/aus	Name	Nennlsg.	norm. Lstg.
1	■	✓	Meerhof	93.81 MW	13.9 %	2	■	✓	Schöppingen	27.0 MW	69.0 %
3	■	✓	Emlichheim	31.5 MW	58.4 %	4	■	✓	Damme	30.0 MW	70.1 %
5	■	✓	Meppen	21.6 MW	0.0 %	6	■	✓	Mechernich	54.6 MW	36.0 %
7	■	✓	Sefferweich	27.0 MW	7.3 %	8	■	✓	Flomborn	37.9 MW	21.7 %
9	■	✓	Scheid	33.9 MW	44.6 %	10	■	✓	Haarstrang	24.0 MW	39.0 %
11	■	✓	Erkelenz	18.9 MW	46.1 %	12	■	✓	Nieder Kostenz	11.5 MW	7.8 %
13	■	✓	Fröndenberg	8.75 MW	44.3 %	14	■	✓	Üdem	14.25 MW	55.4 %
15	■	✓	Kehrig	8.8 MW	18.4 %	16	■	✓	Wildpoldsried	3.0 MW	1.9 %



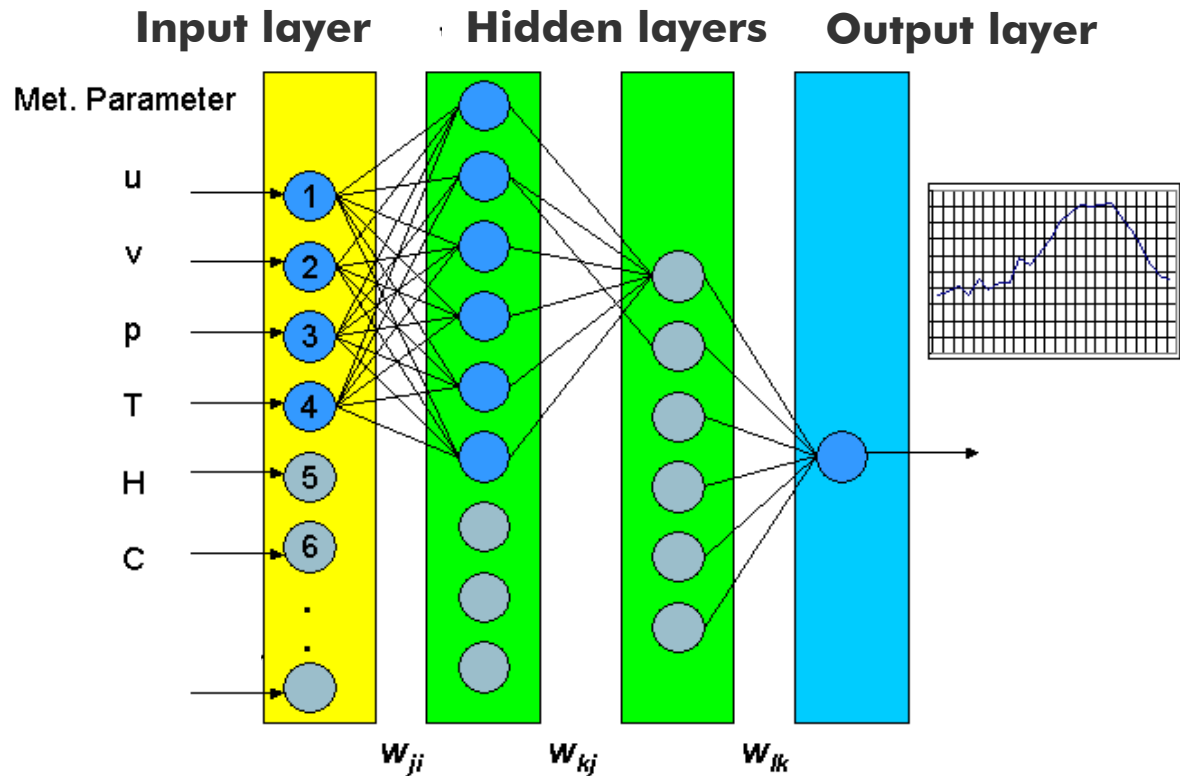
# Wind power forecasting





# Power output forecasting

## WPMS uses artificial neural networks for wind power forecasting



**Input data**

**u, v: Wind speed**

**p: Air pressure**

**T: Temperature**

**H: Humidity**

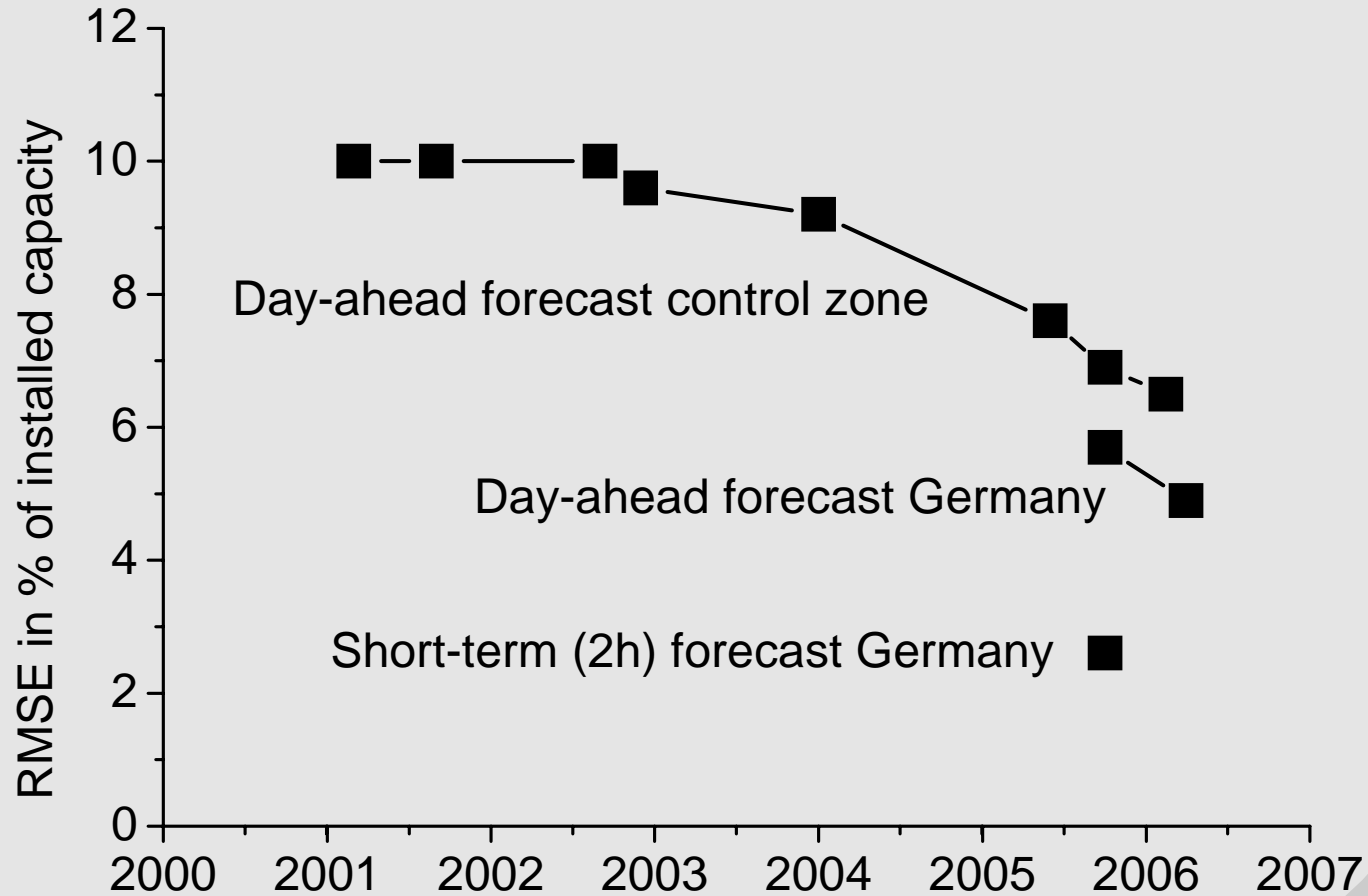
**C: Cloud cover**

**Output data**

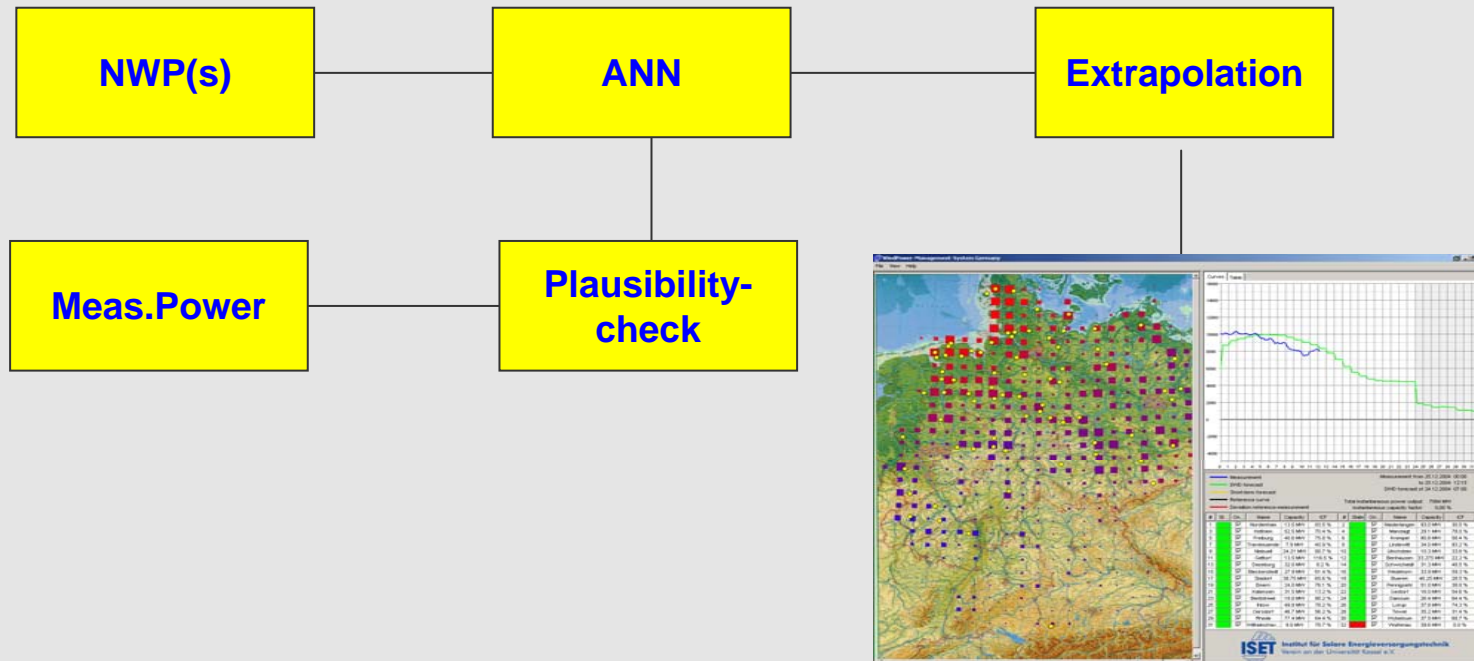
**Normalised Power**

# Wind power forecasting

## Development of forecasting error

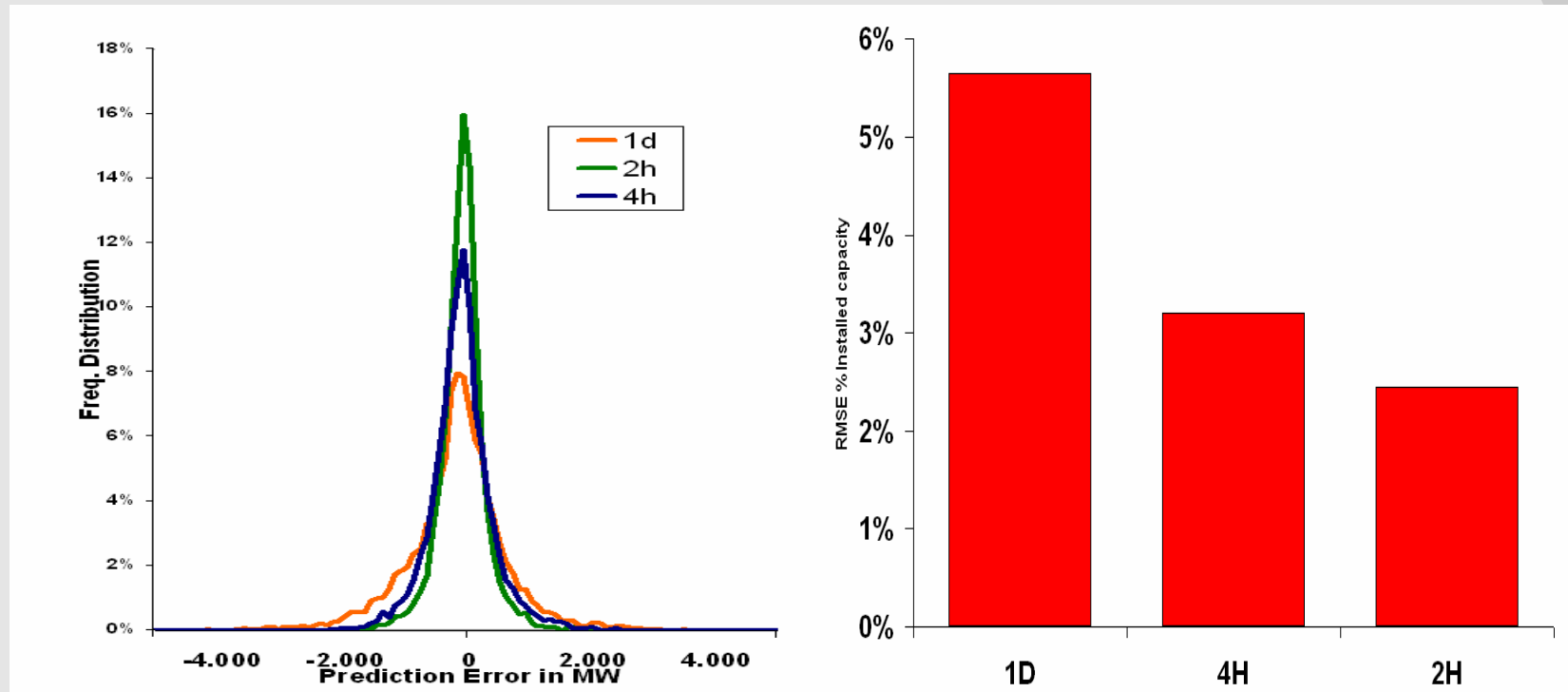


# Short-term forecasting



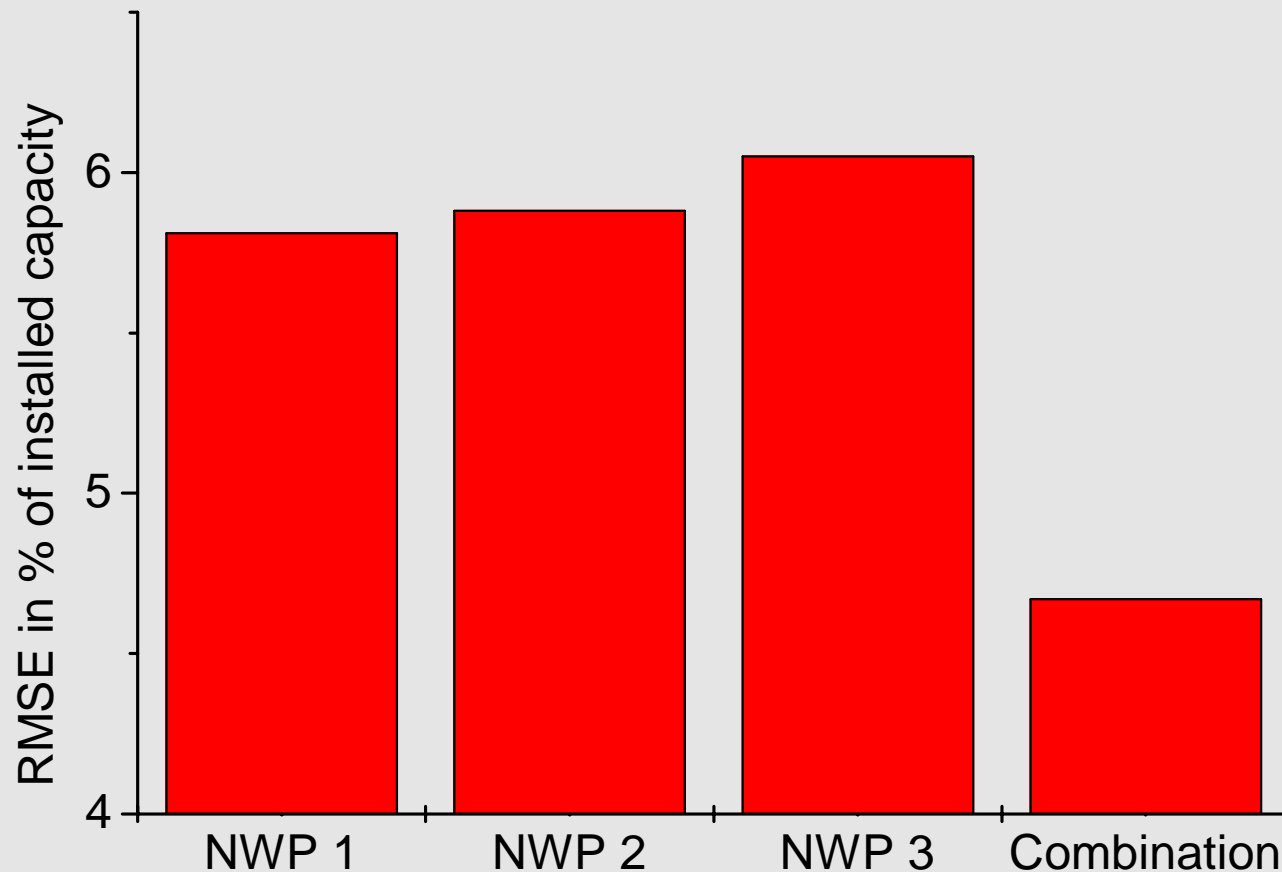
# Short-term forecasting

## Short-term forecast



# Multi-model approach for numerical weather predictions

## Example: Combination of different NWP models



## Multi-model approaches – AI methods

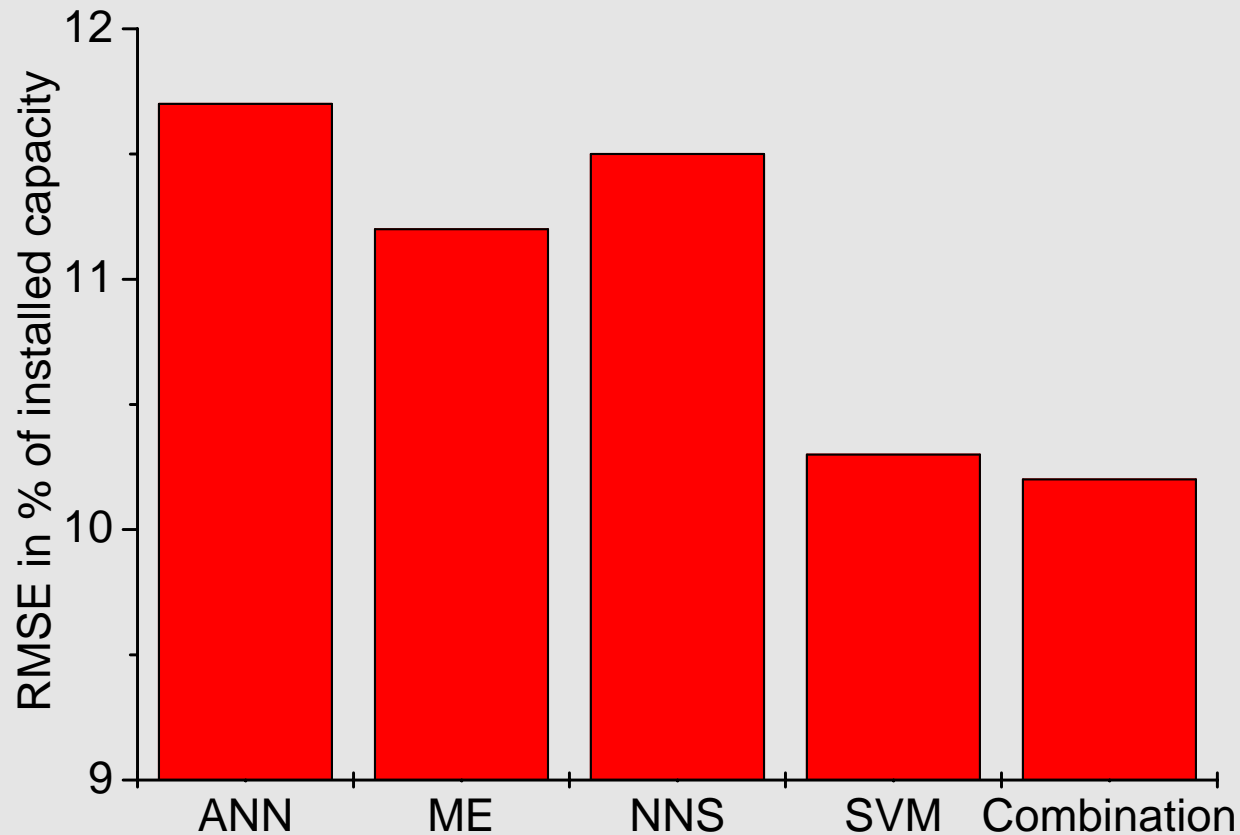
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### Use of other types of AI-models for wind power forecasting:

- **Mixture of Experts (ME)**
- **Nearest Neighbour Search (NNS) with particle swarm optimization for selection of input data**
- **Support Vector Machine (SVM)**

## Multi-model approaches – AI methods

### Example: Comparison of different artificial intelligence methods



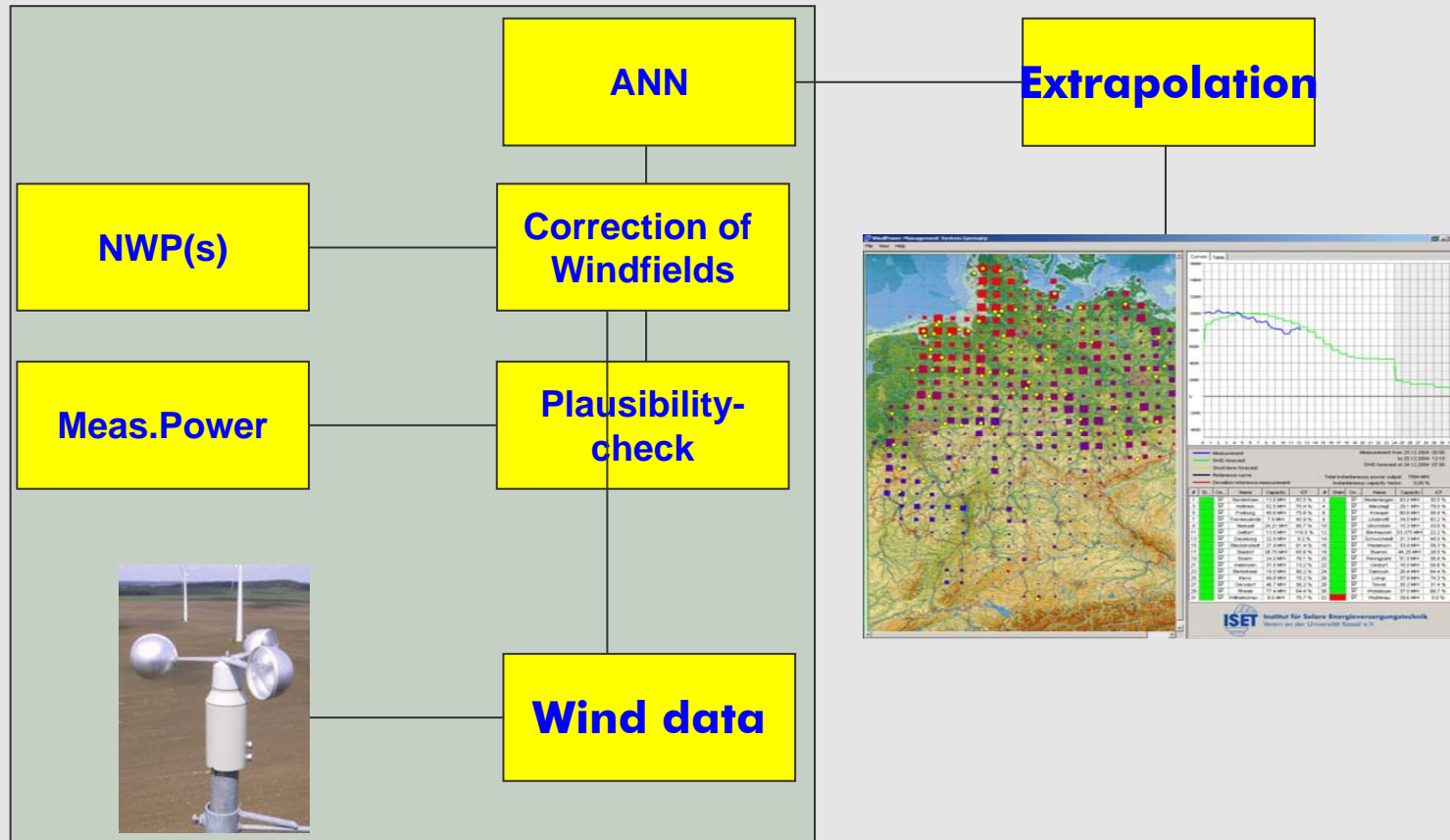
## Future plans

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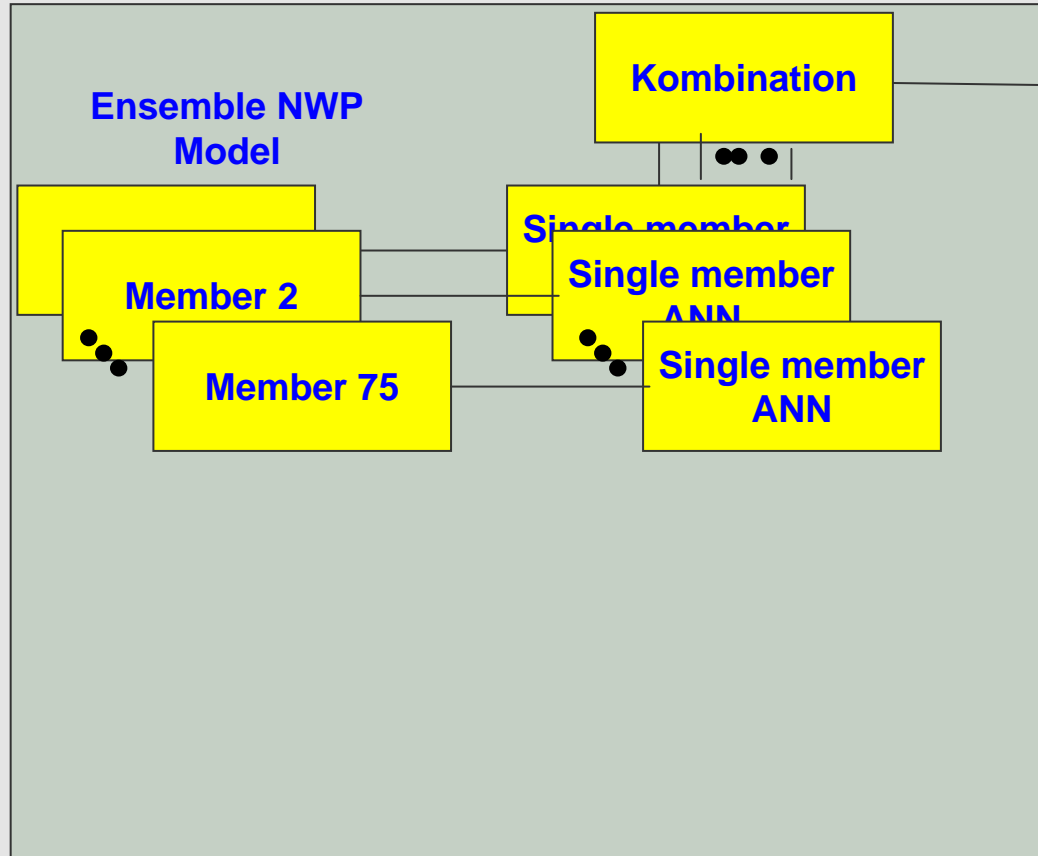
- **Additional use of online wind measurement data for wind power forecasts**
- **Investigations on optimized combination models for multiple NWP and Ensemble Prediction Models**
- **Wind power forecast in the offshore environment**
- **Adaptation of new short term NWP model LMK of the DWD**
- **Combination of different AI forecasting methods**



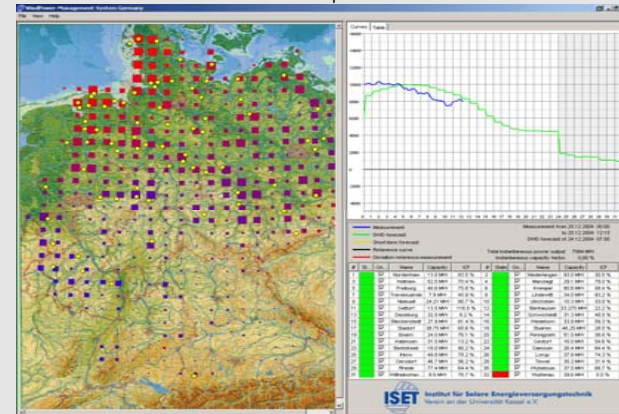
# Short-term forecasting concept with WPMS



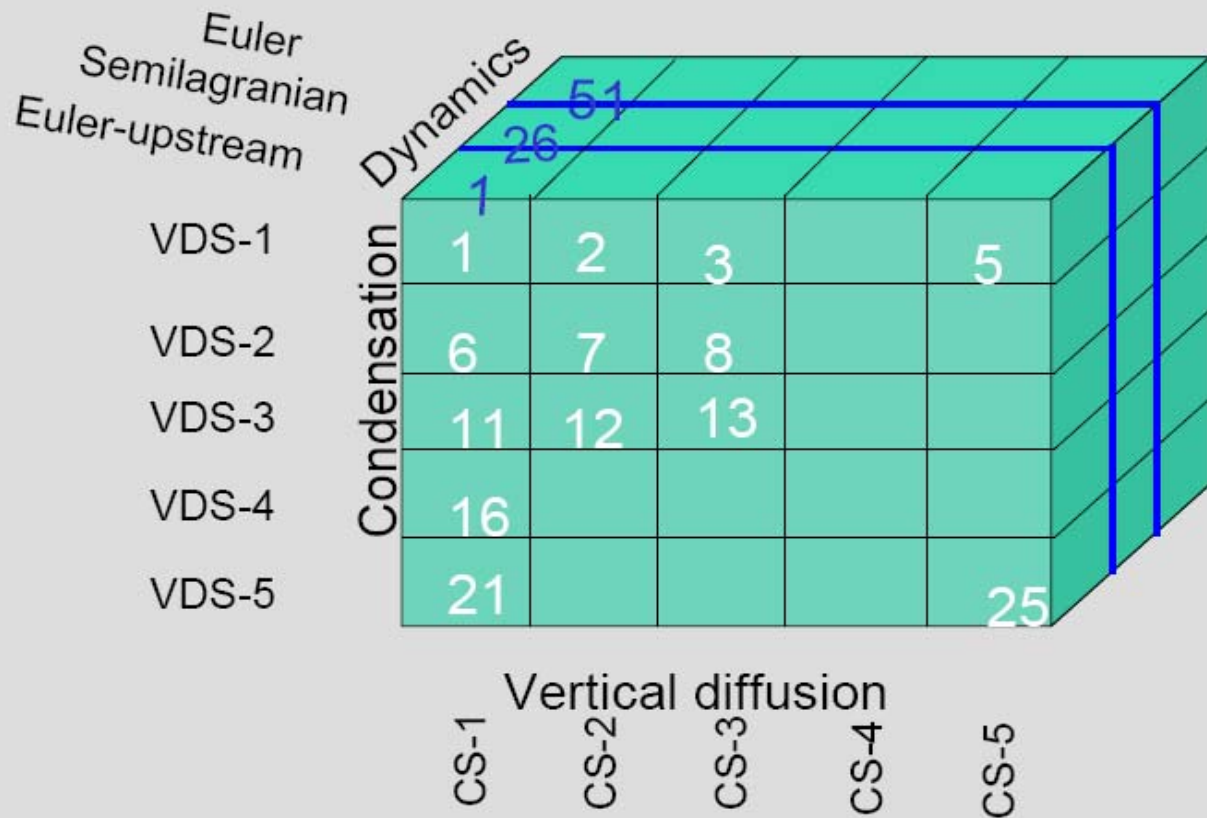
# Ensemble model forecasting concept with WPMS



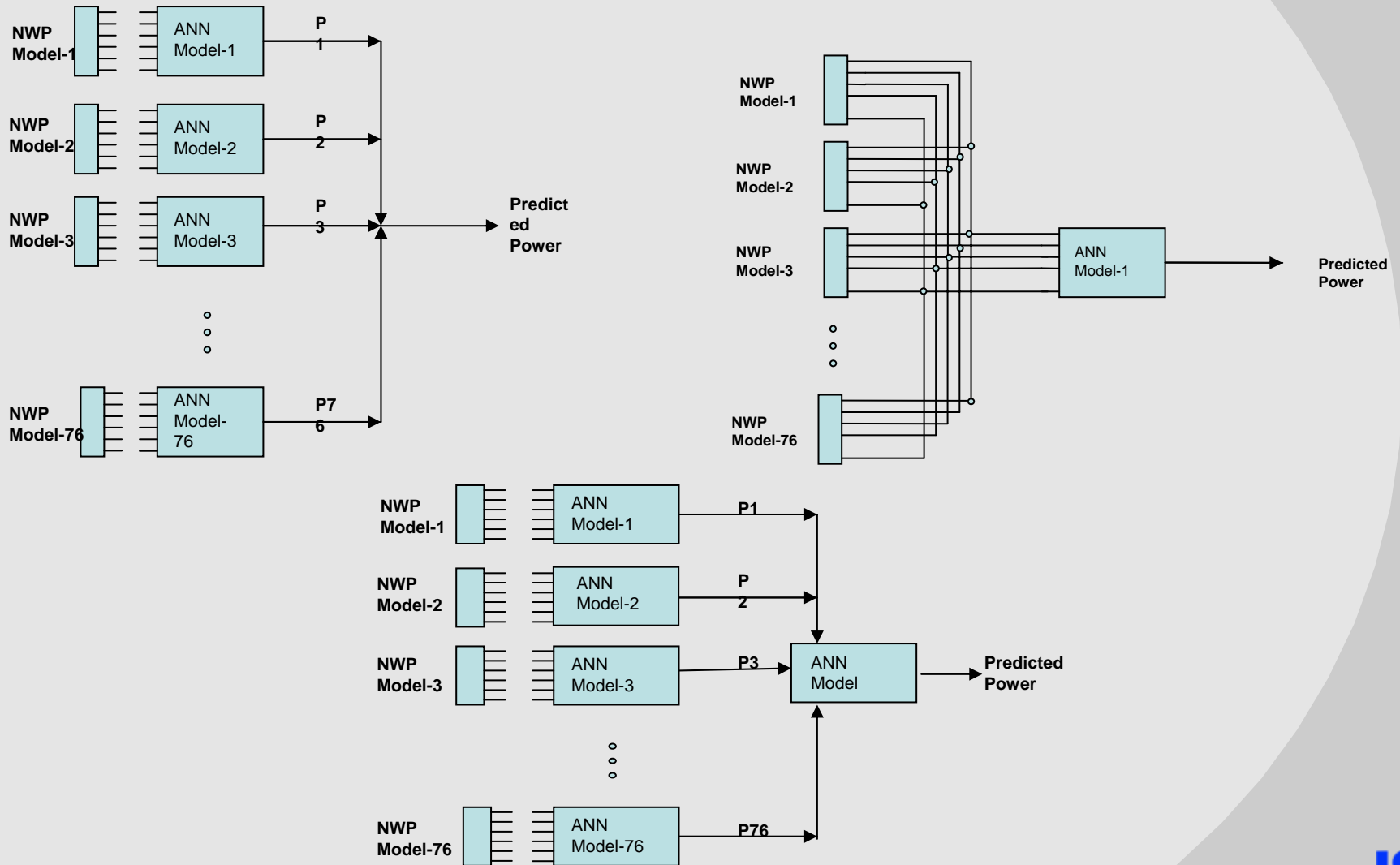
**Extrapolation**



# Ensemble model forecasting concept with WPMS



# Ensemble model forecasting concept with WPMS



## Conclusion

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**Wind power forecasting is today an essential tool for integrating a substantial share of wind power in the electricity system**

**The forecast accuracy has been improved continuously in the last years**

**Short-term forecast has much lower forecast errors**

**Combination of different NWP models reduces the error significantly**

**Use of different AI methods also has potential for improvement**

**Future research will focus on integrating online wind measurements and ensemble NWP models**



**Thank you for listening!**

**[www.iset.uni-kassel.de](http://www.iset.uni-kassel.de)**

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