

Overspeed Wind and Solar Power Forecasting Distributed PV as a Challenge for DSOs

Distribution Utility Meet 2023

Dr. Hans-Peter (Igor) Waldl, Barun Kumar, Naveen Kumar
Overspeed GmbH & Co. KG, Germany



Overspeed: 30+ Years of Experience in Renewables

- Original core activities: Consulting for investors, banks, project developers
- Biggest business field today:
Wind and solar power forecasting



Dr. Hans-Peter (Igor) Waldl

- R&D as background
- Energy Economy and Storage systems
(H₂, Power2Gas, Power2Liquid/e-fuels)



Thomas Pahlke



Dr. Hans-Peter (Igor) Waldl

- Managing director of and partner in Overspeed
- Wind and solar energy since 1985
- Consultant for wind energy, solar energy, and energy economy
- Working in Indian projects since 2014
- MSc in Physics
- PhD about Wind Farm Modelling
- IEEE reviewer
- Leading Oldenburg University wind energy research group until 2001
- Lecturer at Oldenburg University for wind energy applications, wind resources, wind and solar power prediction, wind farm operations, Hydrogen Technology and Storages



Wind and Solar Power Predictions

Windenergy Consulting Onshore/Offshore

Capacity Building

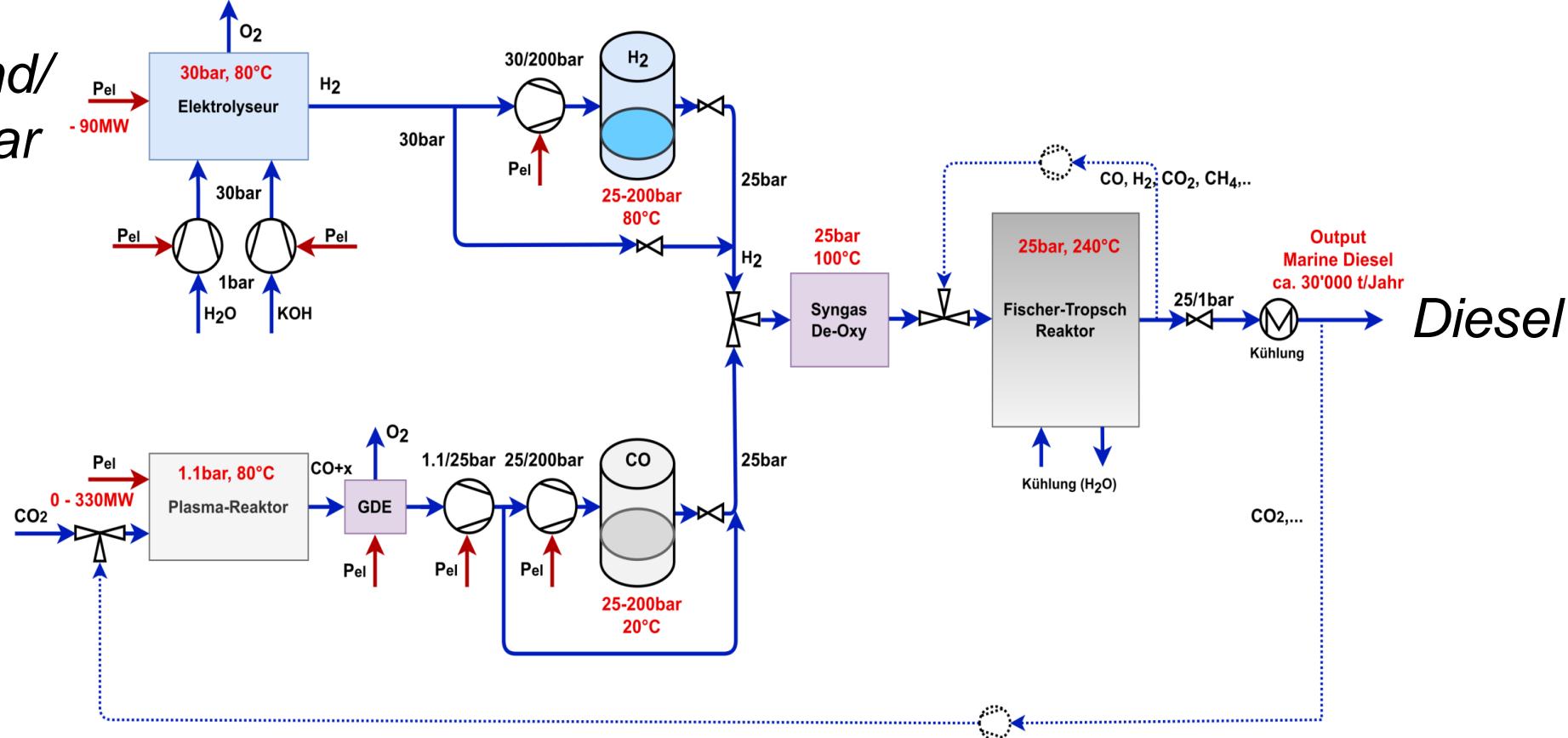
Storages and Systems: Hydrogen

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igor@overspeed.de*

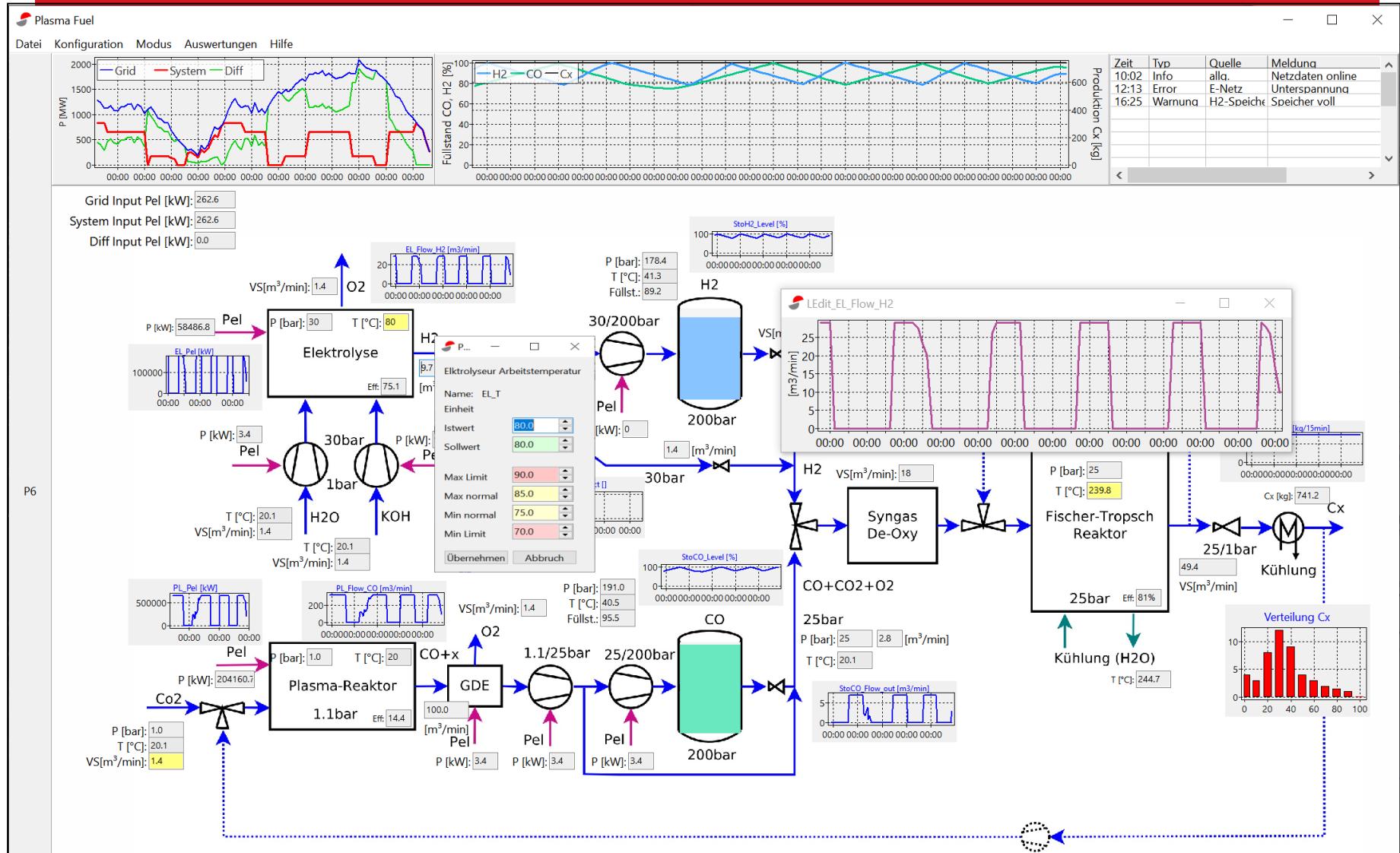


Hydrogen: Power2Fuel System

Wind/
Solar



Design, Control and Optimization Power2Fuel



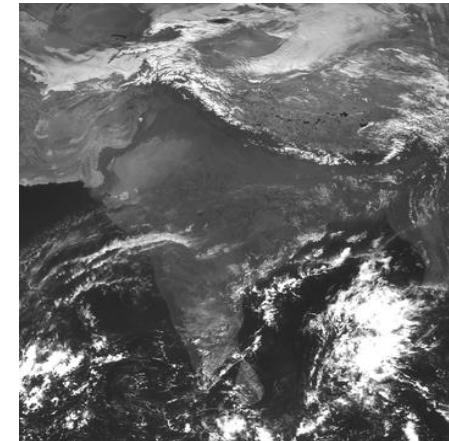
Anemos wind and solar power predictions worldwide

*World-wide around more than 160 GW
wind and solar power predictions*



India-specific Highlights

- R&D cooperation with NCMRWF and ISRO
- PV-Panel-Soiling (with NIWE and Oldenburg University)
- Capacity Building:
 - Training for NIWE team (GIZ): Indigenous Solar Power Prediction System for India
 - Training for REMC operators (GIZ)
- Endorsed by IEX
- **Supplier of Wind and Solar Power Forecasting System to Adani, 15 GW**



Team India

- Barun Kumar
 - Business Development
 - Solar Power Modelling
 - Quality Assurance

- Naveen Kumar
 - Solar Power Modelling
 - Prediction system surveillance
 - OandM

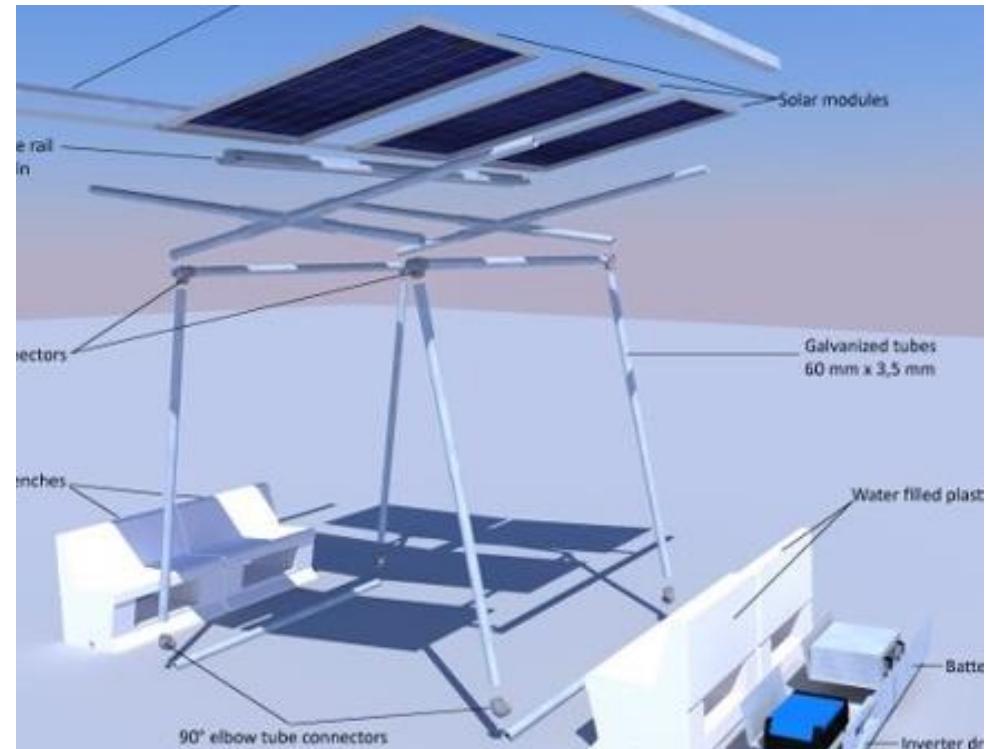


The Energy Transition: Small-scale PV



Small-scale PV: Advantages

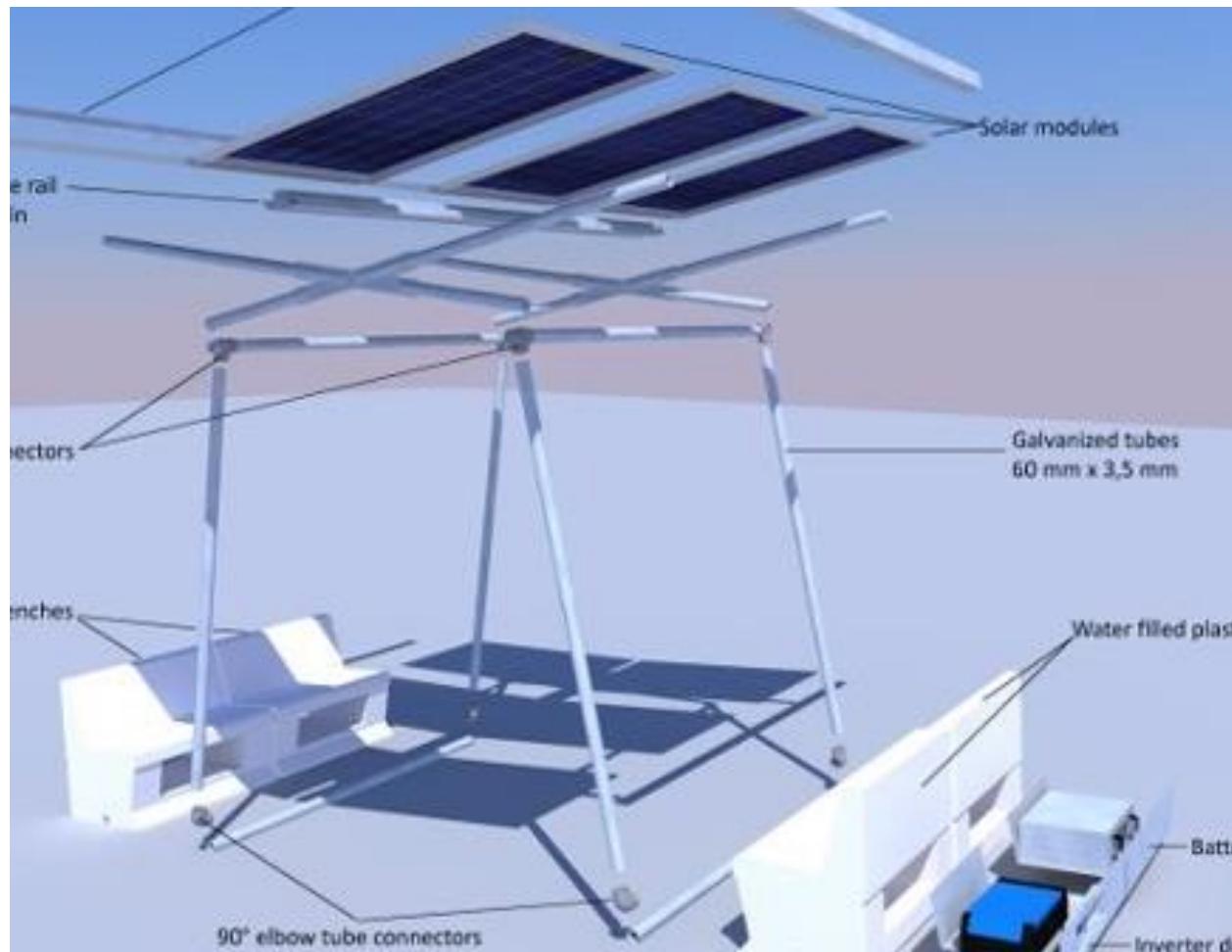
- Very fast installation
- Easy grid connection
- Economic feasibility



© giz

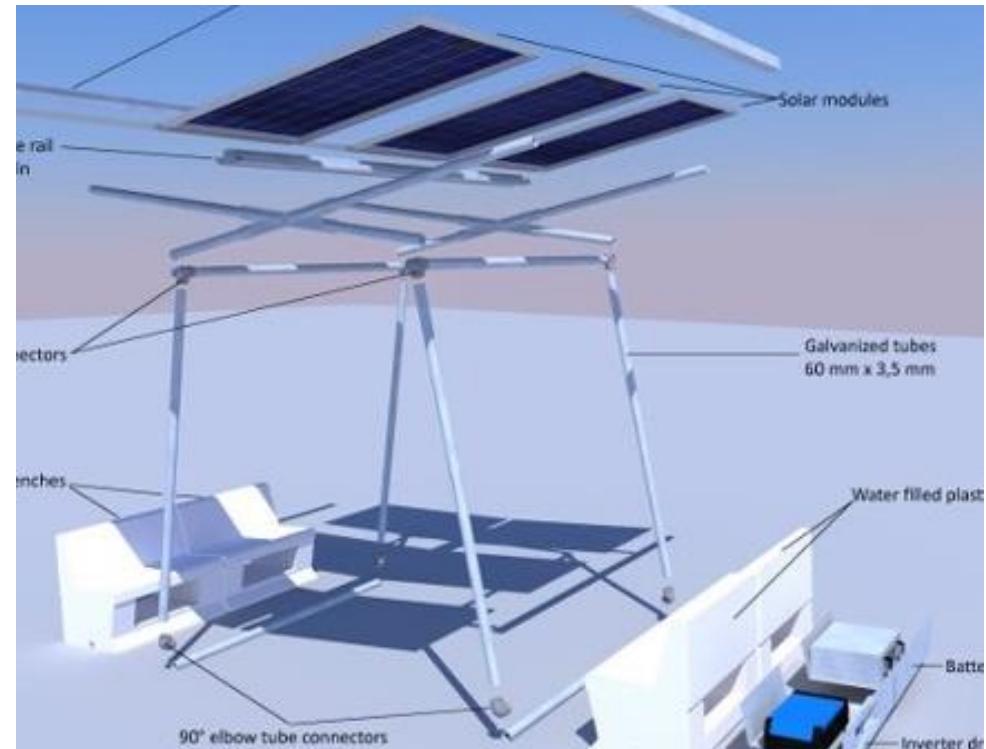


“Solar Pavillon” by giz



Small scale PV: Advantages

- Very fast installation
- Easy grid connection
- Economic feasibility for the roof-top owner



© giz

- **Good way to give RE-benefits to private people**
- **High political support and subsidies**



PV has high political support...



DSOs and small-scale PV: Challenges and Solutions

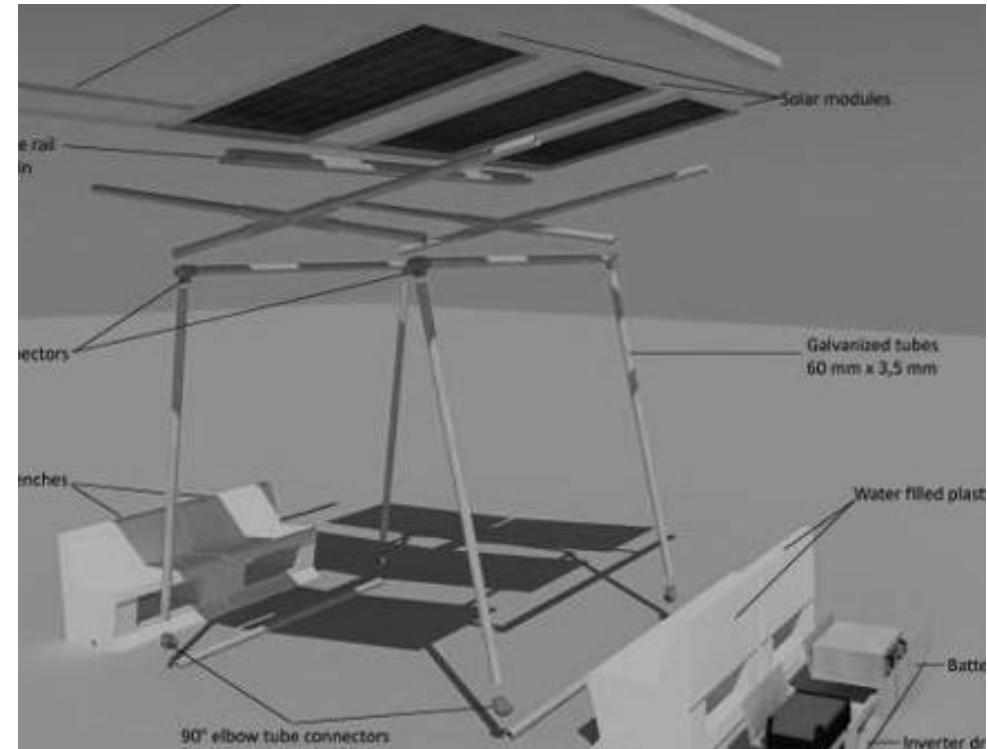


Small scale PV: Challenges from a DSO perspective



Small scale PV: Challenges from a DSO perspective

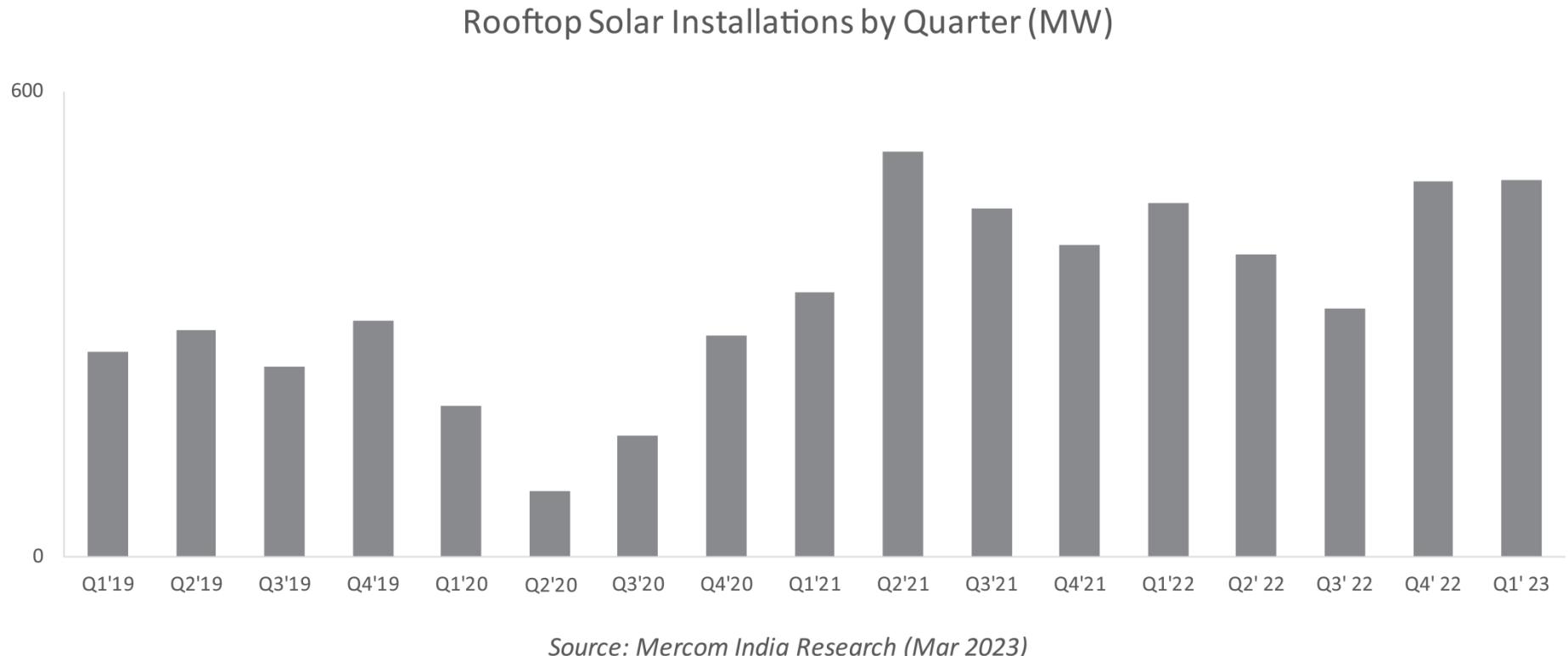
- Economic feasibility for the roof-top owner
- Very fast installation
- Easy grid connection



© giz

Very fast ramp-up of installations

Small-scale PV Development in India

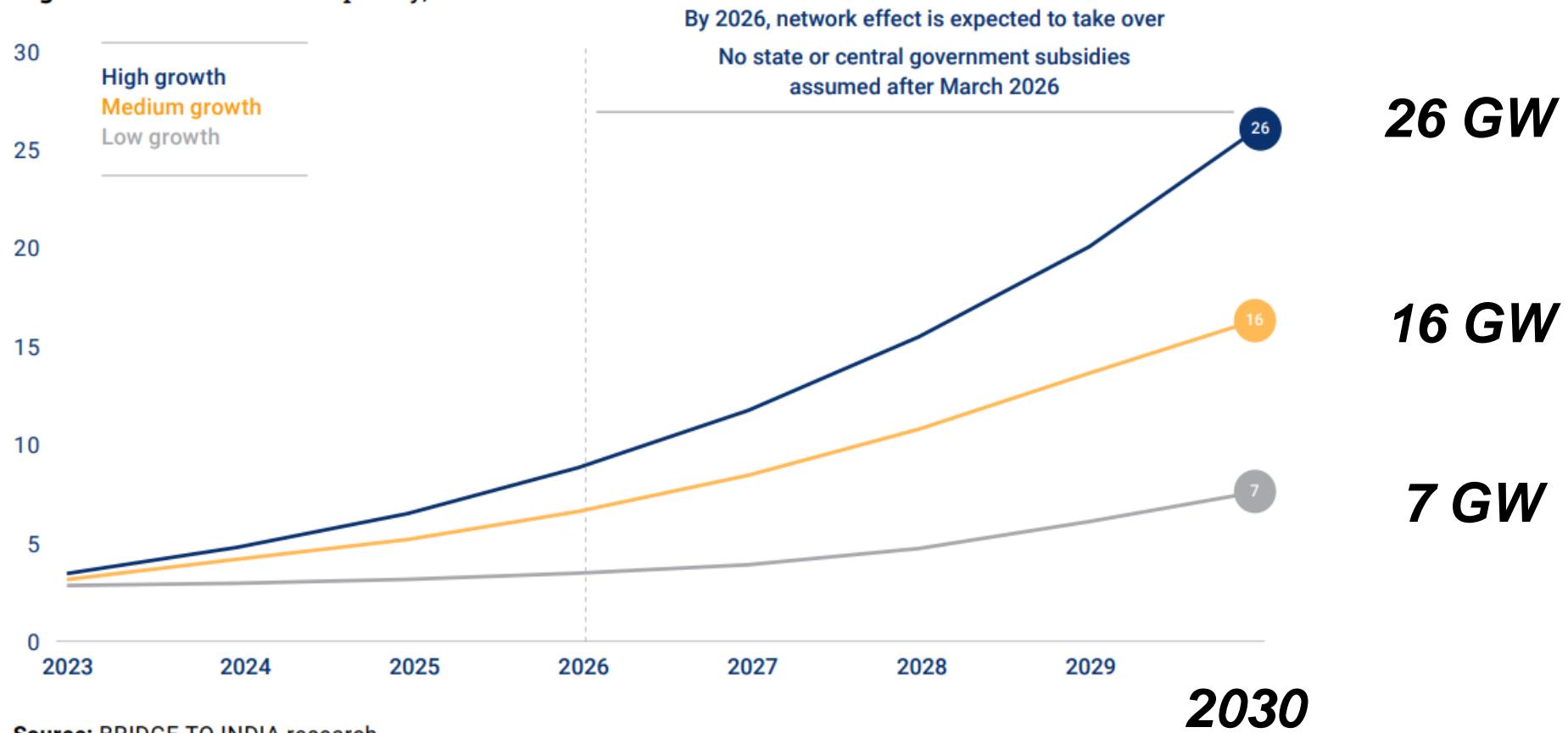


Adding about 400 MW every 3 month!

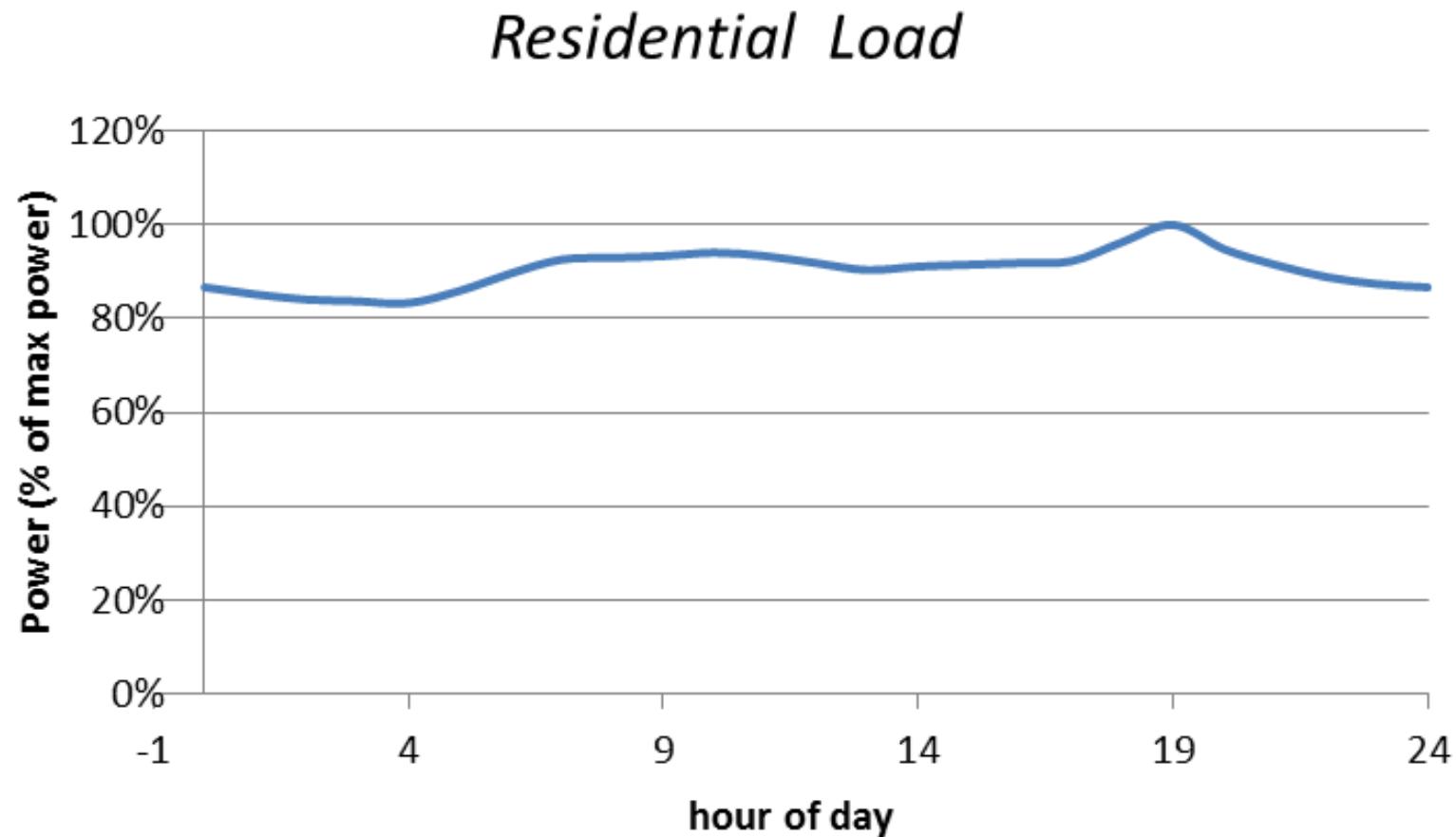


Small-scale PV Development in India, Perspective

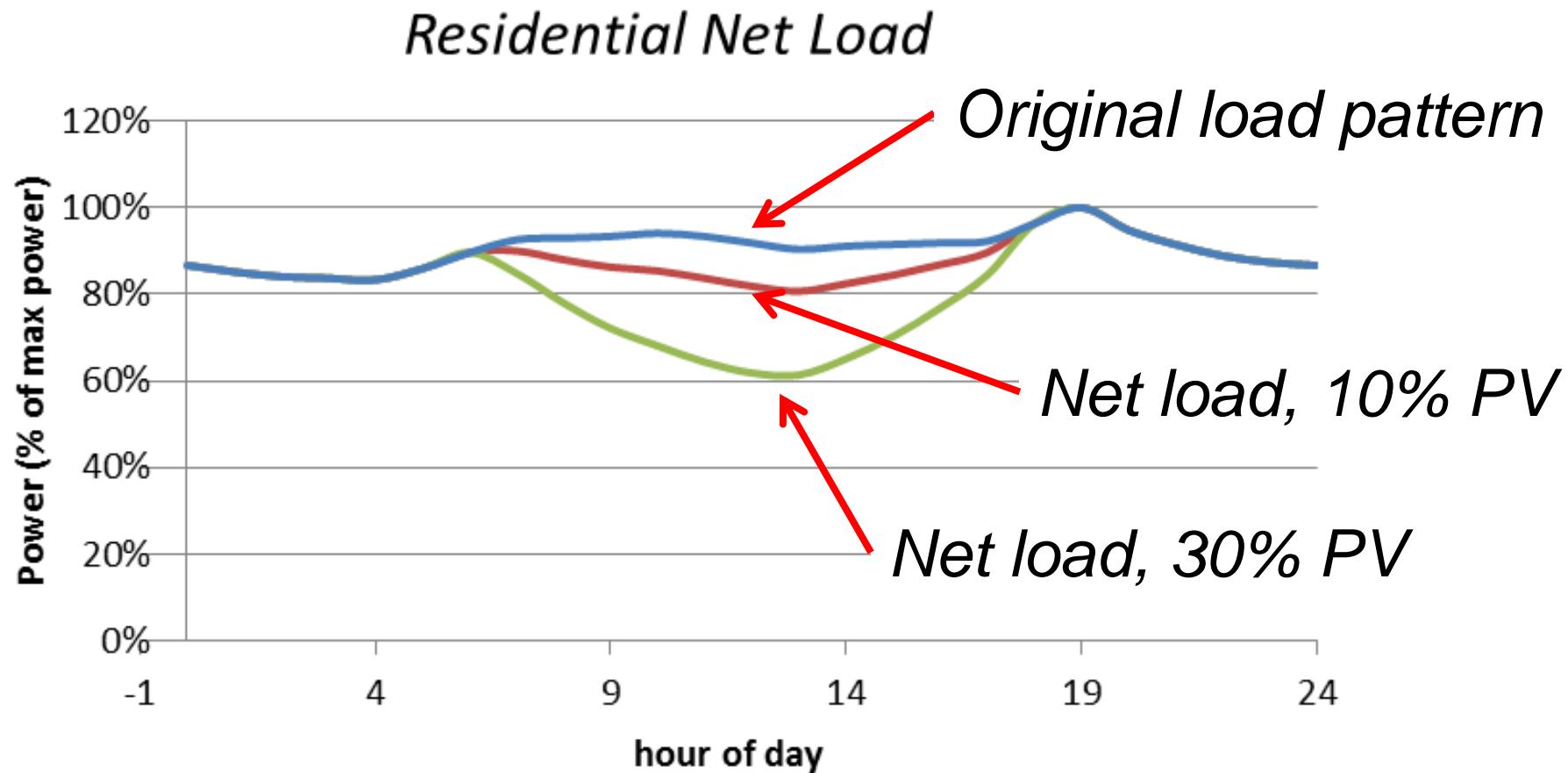
Figure: Total installed capacity, GW



Impact: Load patterns with big shares of PV

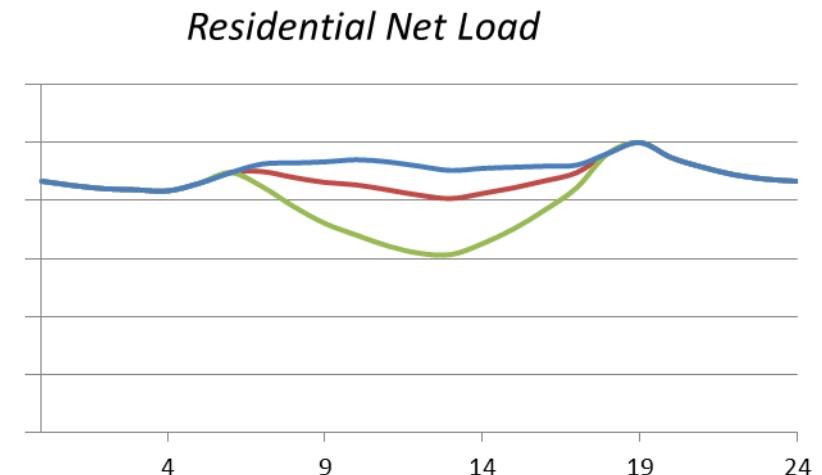


With big shares of PV: Net load pattern



Impact for DSOs: Negative load

- Roof-top PV feed-in is seen as negative load
 - No information about current production
 - No control over production
-
- Load forecasting is spoiled
 - Power purchase and market actions are facing an additional challenge

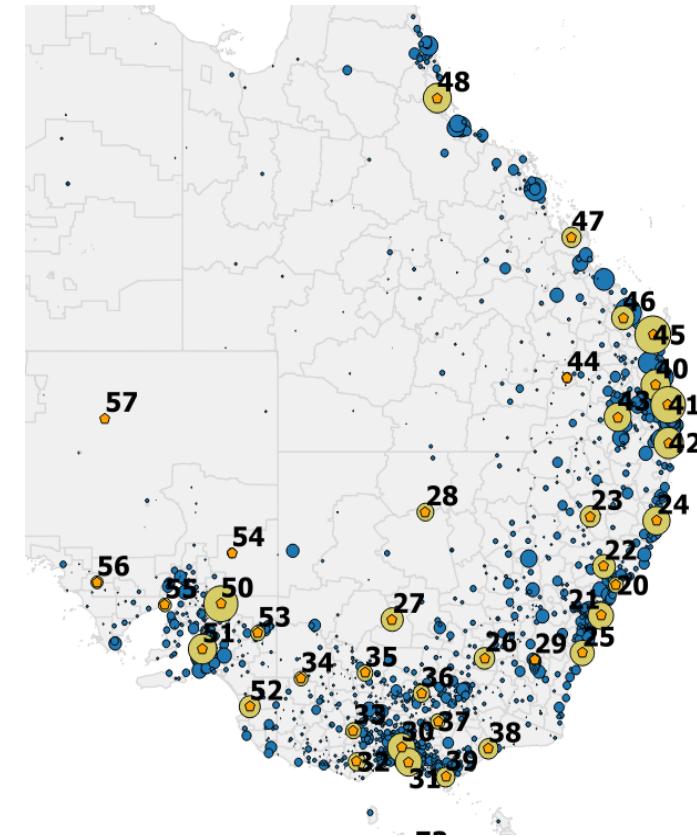


*Solution: Real -time Estimation and Prediction of
distributed PV Power Feed-in*



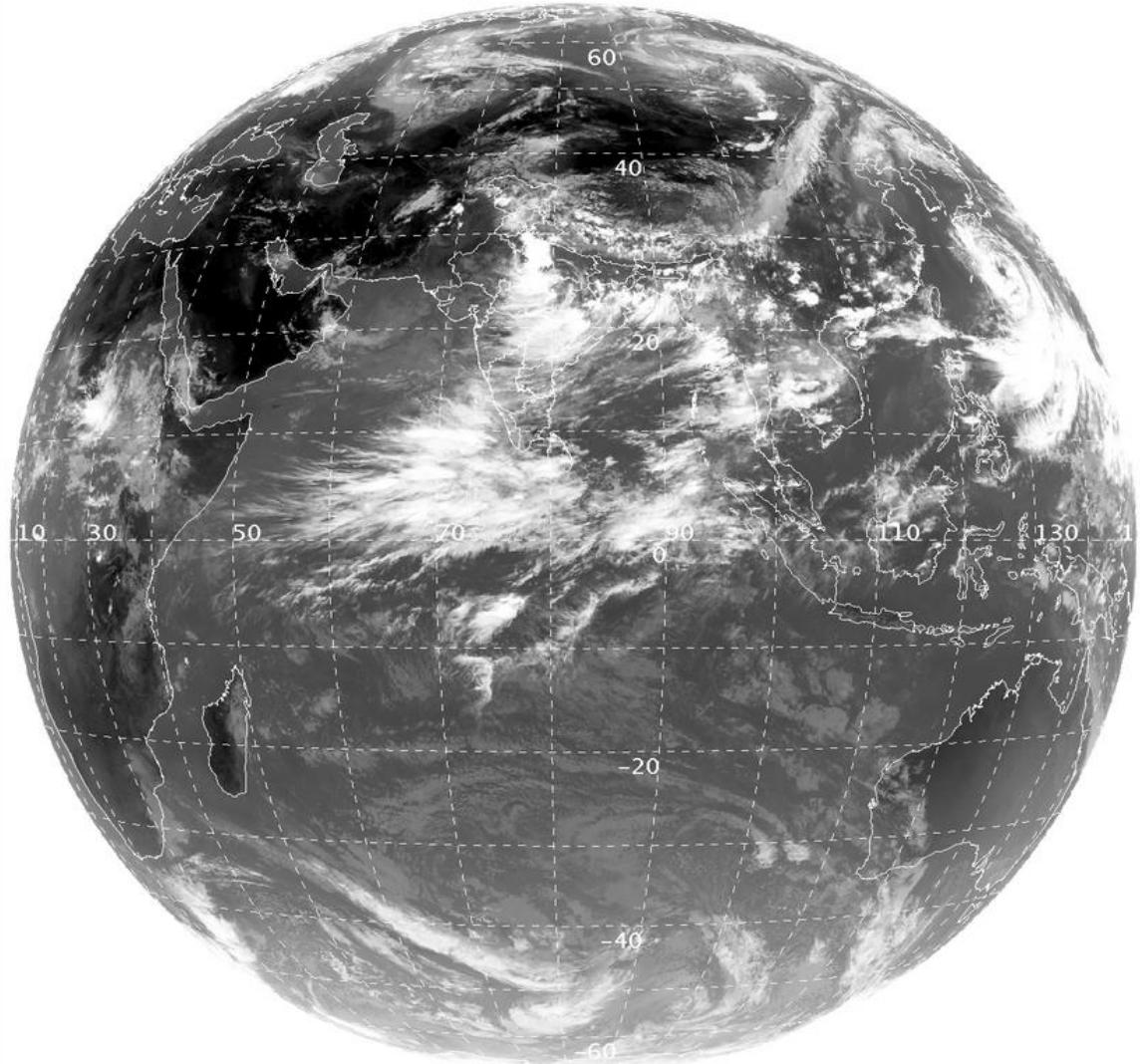
Real -time estimation of PV power feed-in

- Selected PV installations with on-line power measurement as reference stations
- Real-time satellite images as additional information
- **Real-time estimation of the current feed-in**
- **Short-term prediction of the expected feed-in**



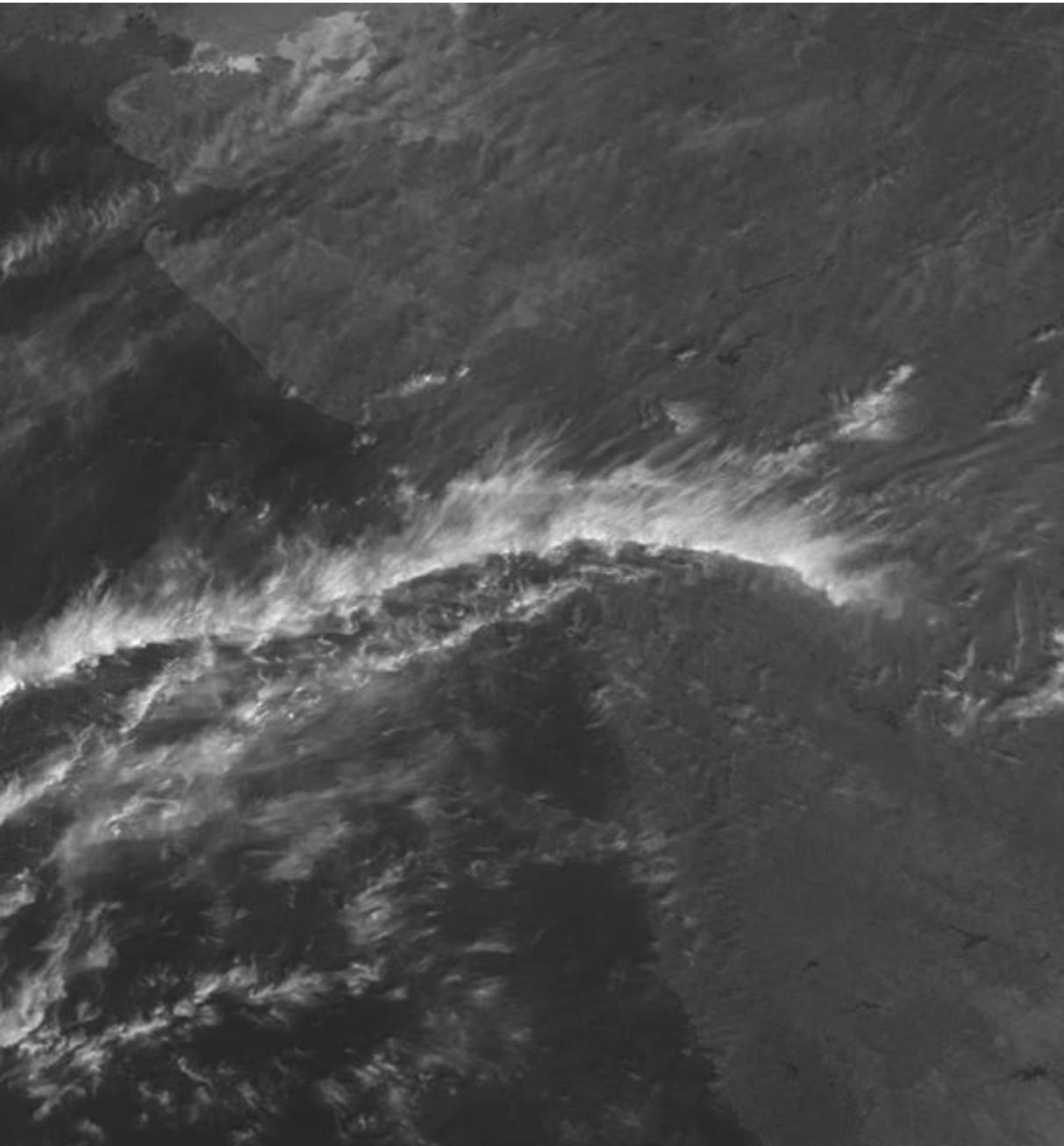


ISRO Satellite INSAT-3D



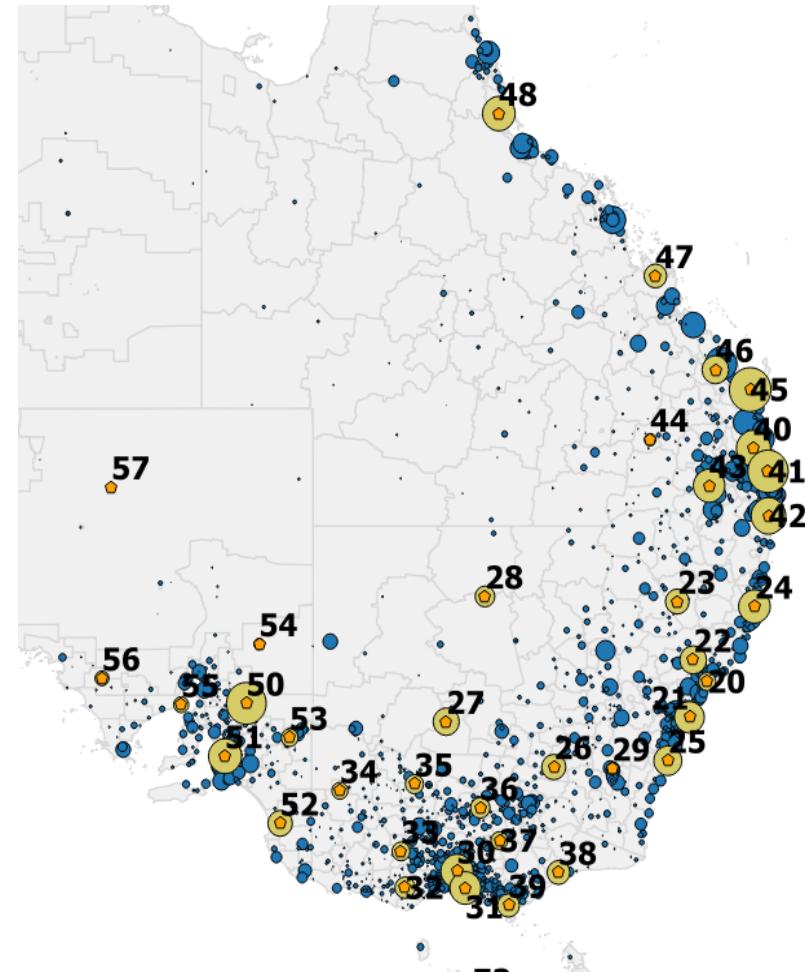
ISRO Satellite



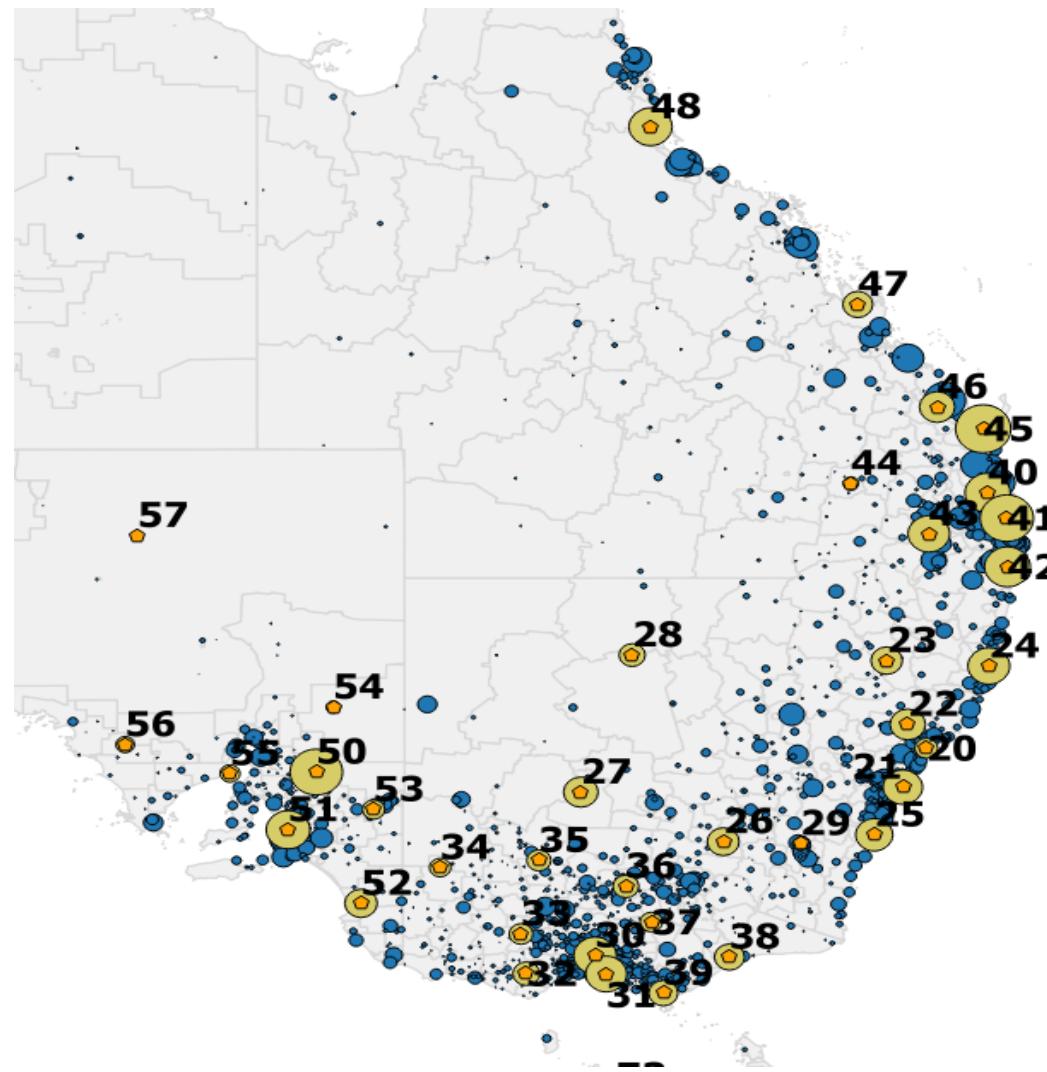


Our Reference System: Australian Energy Market

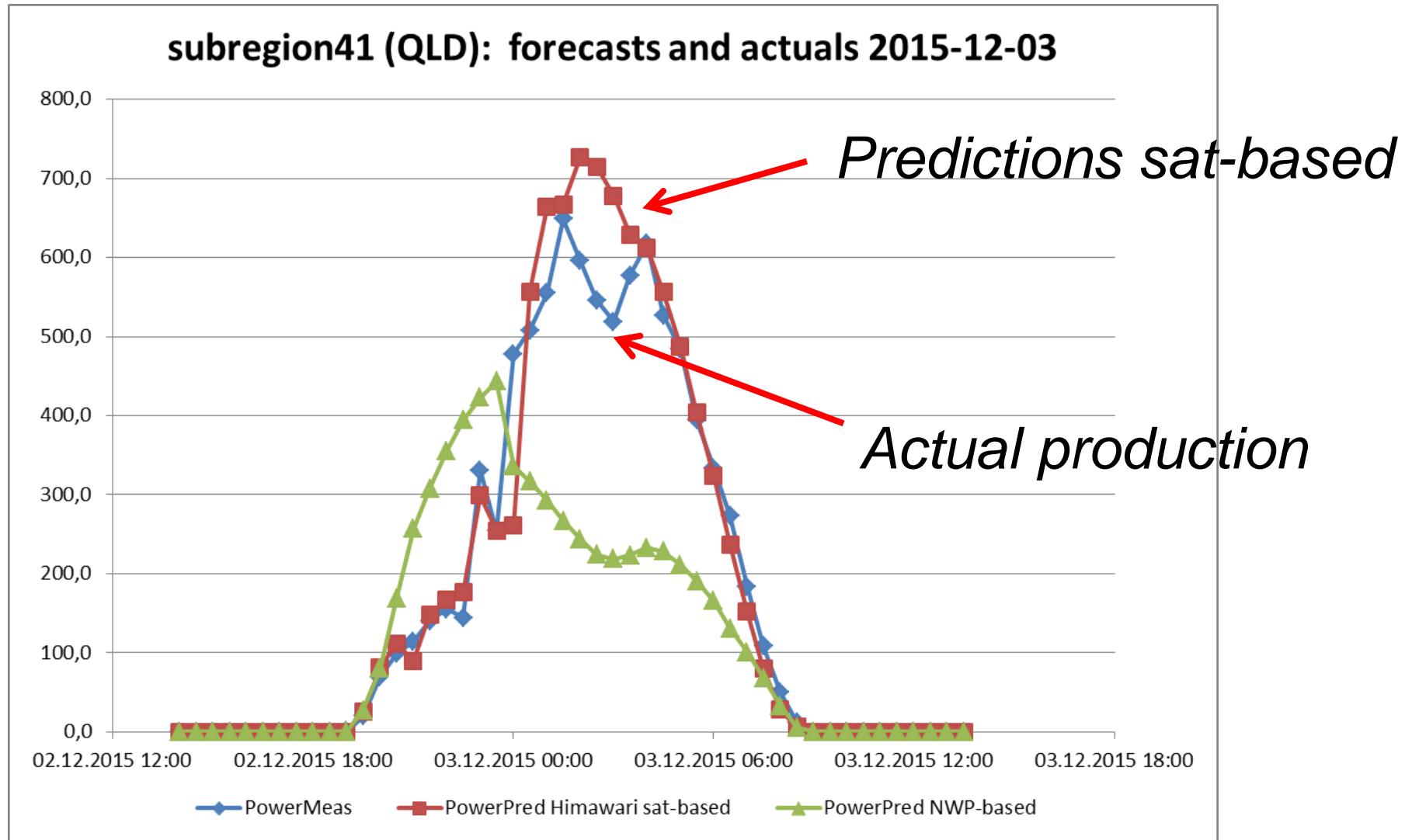
- Overspeed developed for AEMO
 - Running on-line since 2015
 - Including satellites
-
- Used as reference data of distributed PV power for the energy market
 - And for the DSOs of the respective cities



Forecasted Regions in Australia



Example: Using sat images for PV power forecasting



Summary: Solutions for DSOs with increasing PV shares

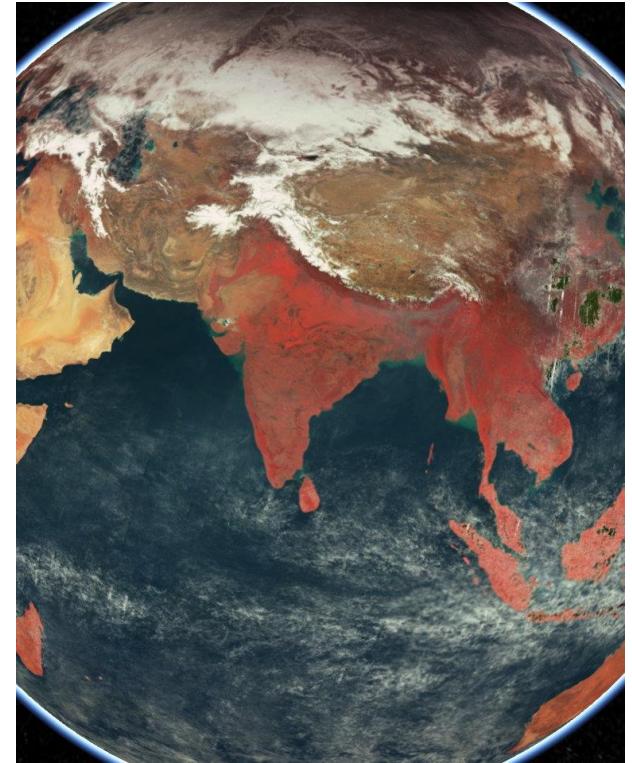
- On-line estimation and forecasts of distributed PV power as a service
- Including ISRO weather satellite data
- High accuracy
- Studies and advice how to build an on-line PV power forecasting system
- Advice how to optimise this system
- Advanced net-load forecasting with our partner ENFOR



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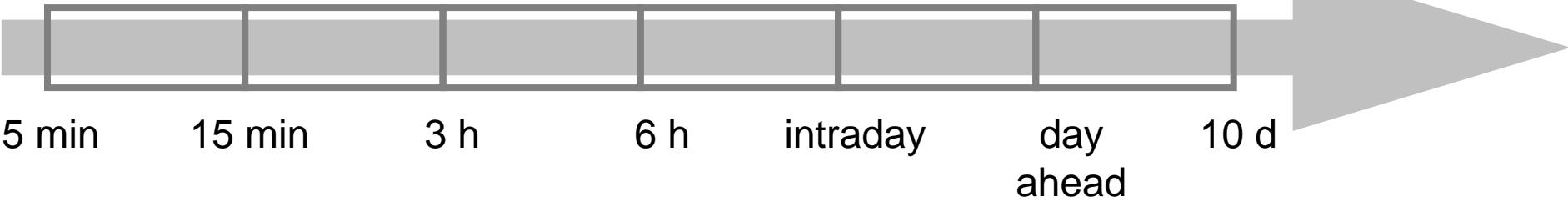




Prediction Principles: Short-term

Model types

Statistical models NWP + physical/statistical modelling



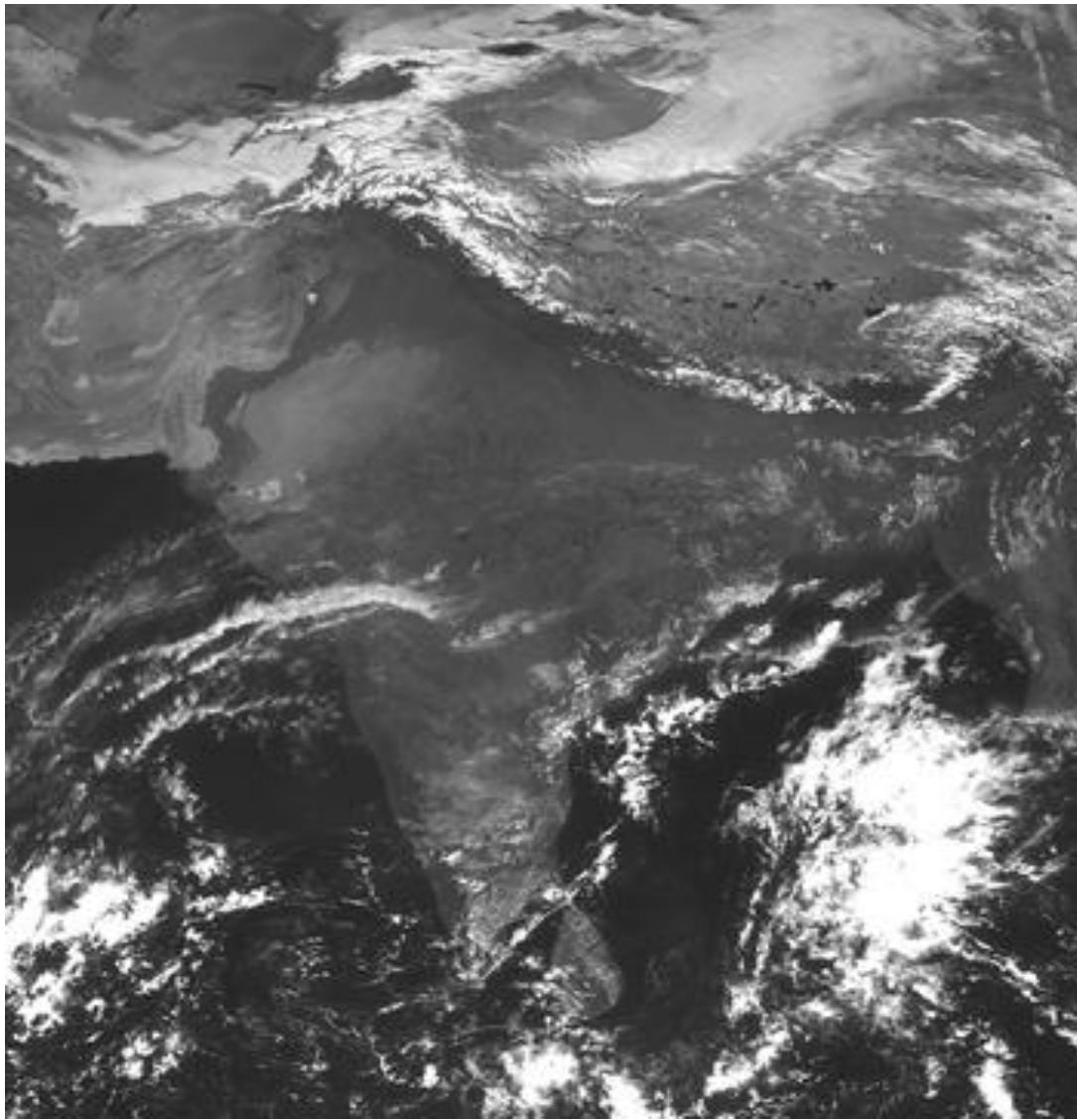
Input Data

Online SCADA NWP domain

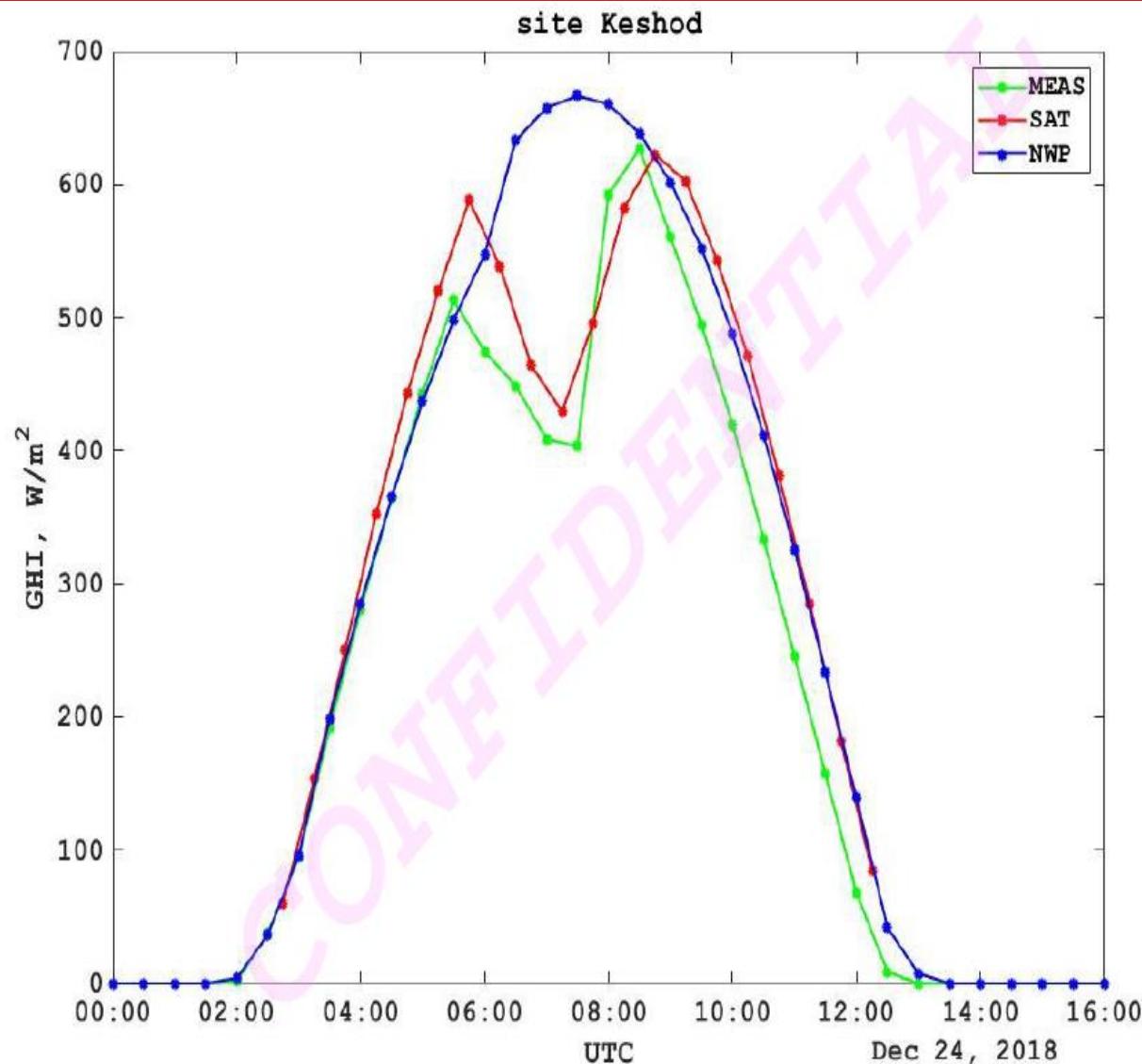
Sat images Historical SCADA







Validation sat-based predictions India



Advantages sat-based Solar Power Predictions

- Brings additional real-time information into the prediction process
- Improvements of short-term predictions (30 min to 2 hours)

Other Applications::

- Nowcasting if SCADA data is missing
- Replacing local irradiation measurement
- **Predictions for areas, like roof-top installations**
- **Nowcasting of distributed installations**



Other new developments Sky Cams/Sky Imagers



Video Skycam



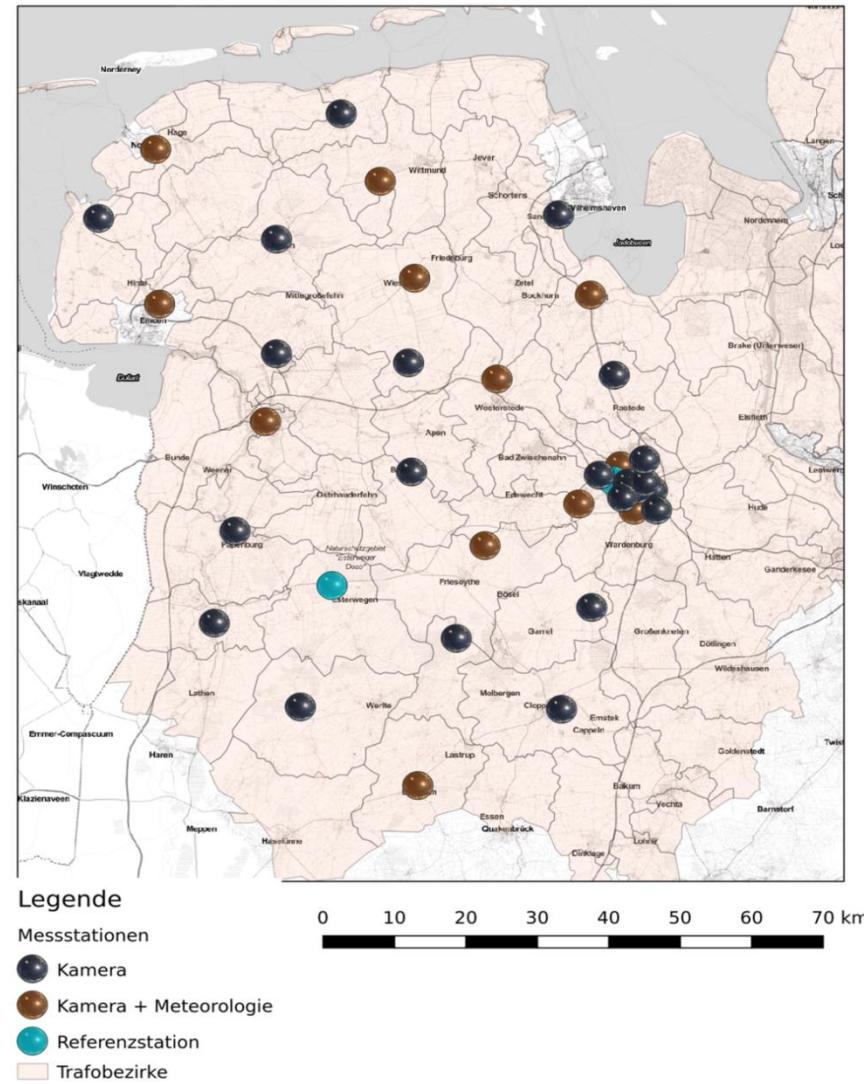
Potential Services for BSES

- Active in India since 2014
- Local Indian team
- Wind and solar power forecasting for BSES farms with ppa or via power exchange
- Estimation of current production of roof-top PV based on satellites for load forecasting
- Potentially: Setting up R&D projects in the future?

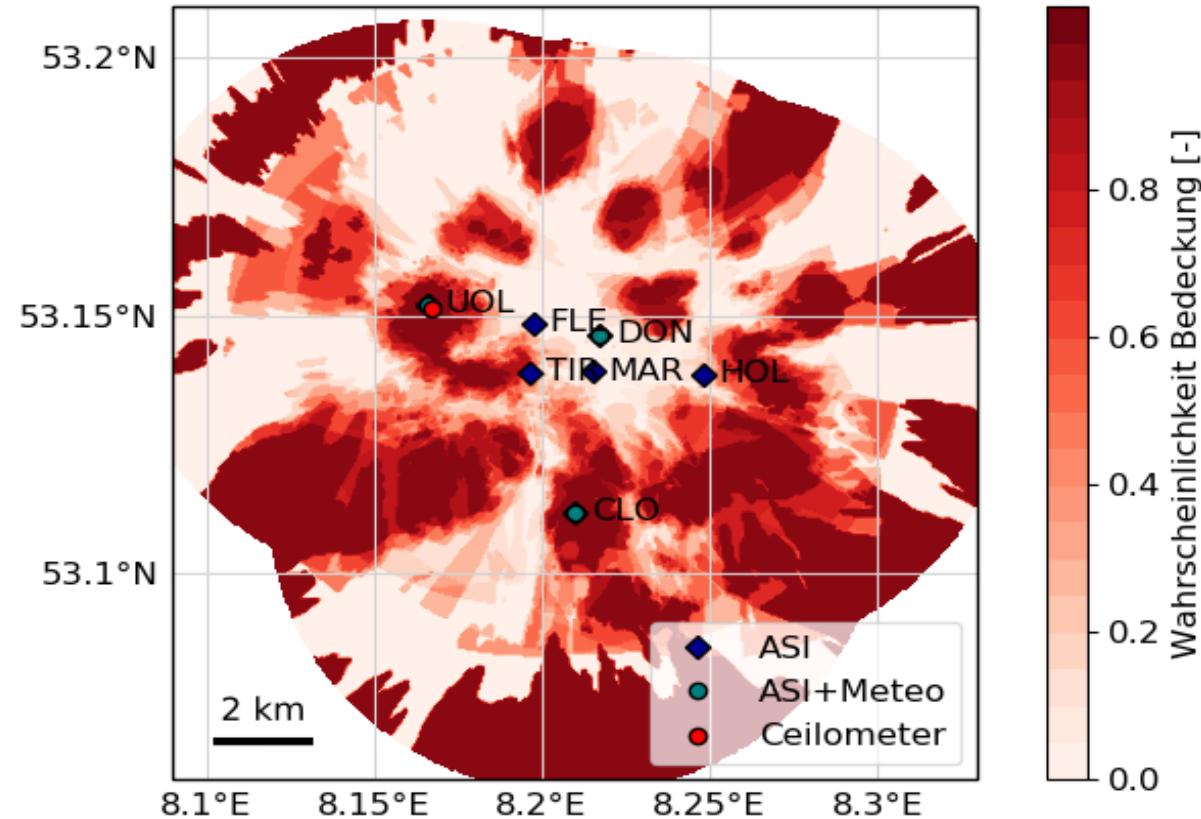




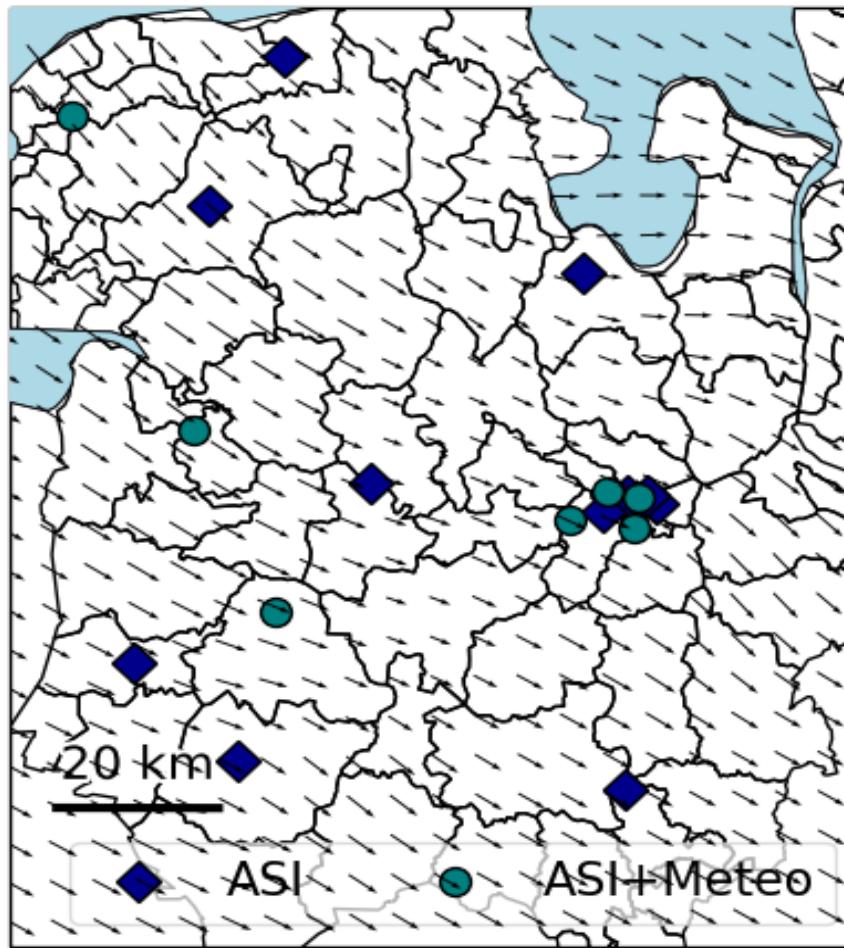
Network of Sky Cams/Sky Imagers: DLR/Uni Oldenburg



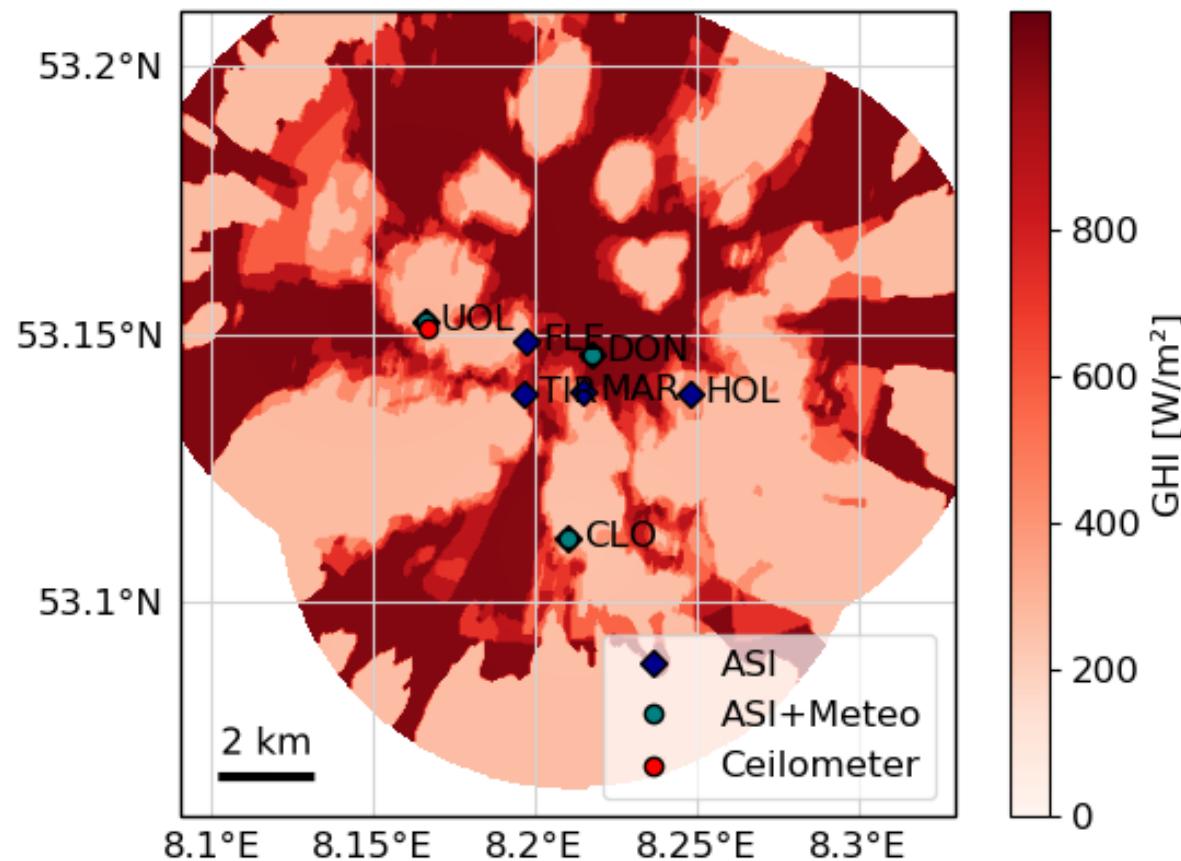
Map of Cloud Coverage



Vector Field of Cloud Motion

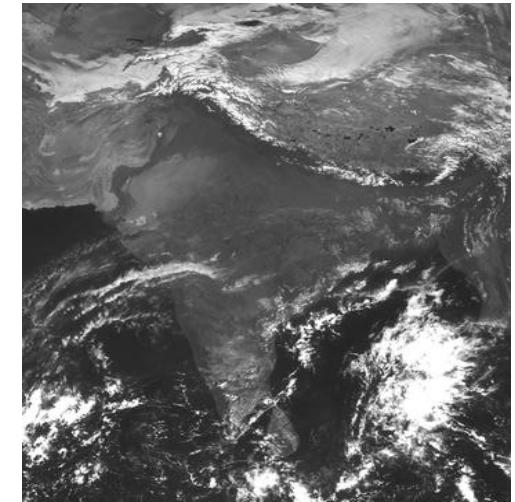


Prediction of Irradiation



Anemos Wind and Solar Power Predictions Summary

- Highly standardized software product for wind and solar power predictions
- World-leading prediction models
- Secured handling of information
- High-availability system
- Supports easy development, improvement and testing of prediction models
- Integrates new technologies like sat-based forecasting and sky cams
- Permanent R&D activities



Windenergy Consulting Onshore/Offshore

World-wide Prediction Activities

Wind and Solar Power Predictions for India

Overspeed: Project Team

The Perfect Wind and Solar Power Prediction



Wind and Solar Power Predictions for India



What we will have achieved: Forecasting Solution

- A Wind and Solar Power Forecasting Solution
 - Including models and infrastructure (Anemos platform)
 - With high-availability features
 - Ran and developed further by Adani
 - Including customised Dashboard GUI and OandM GUI
- Fully trained teams on OandM level
- Fully trained team for model development



What we will have achieved: Prediction Model Development Team

Prediction Model Development Team

- Fully trained in wind and solar power prediction modelling
- Capable of extending existing forecasting models (python)
- Capable of implementing own advanced prediction models in the future
- Capable to support 2nd level and 3rd level OandM if necessary



What we will have achieved: OandM Teams (1)

- OandM: Set-up Team
 - Set-up and roll-out of new farms
 - Collection of wind and solar farm static data and other configuration data
 - Able to train models for new farms



What we will have achieved: OandM Teams (2)

OandM: 1st and 2nd Level Support Team

- 24/7 monitoring of solution capabilities
- Trouble shooting for operational issues: Data feeds, system availability, prediction model availability, configuration issues

OandM: 3rd Level Support Team

- Monthly analysis of solution availability, accuracies and penalties
- Trouble shooting in case of unsatisfactory accuracies
- Proposing improvements for future development

The Perfect Prediction: Ingredients

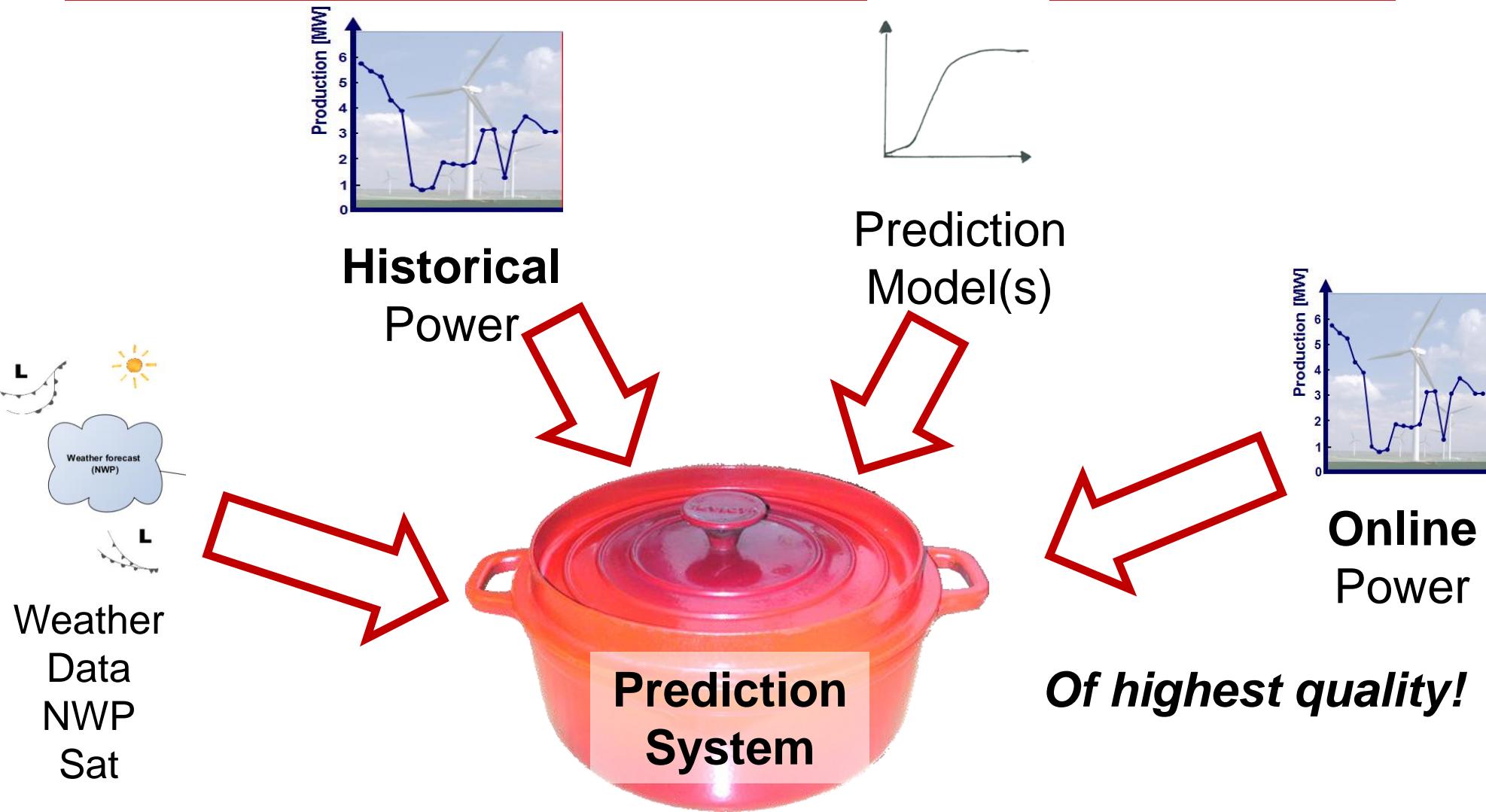


Chart Tables Download

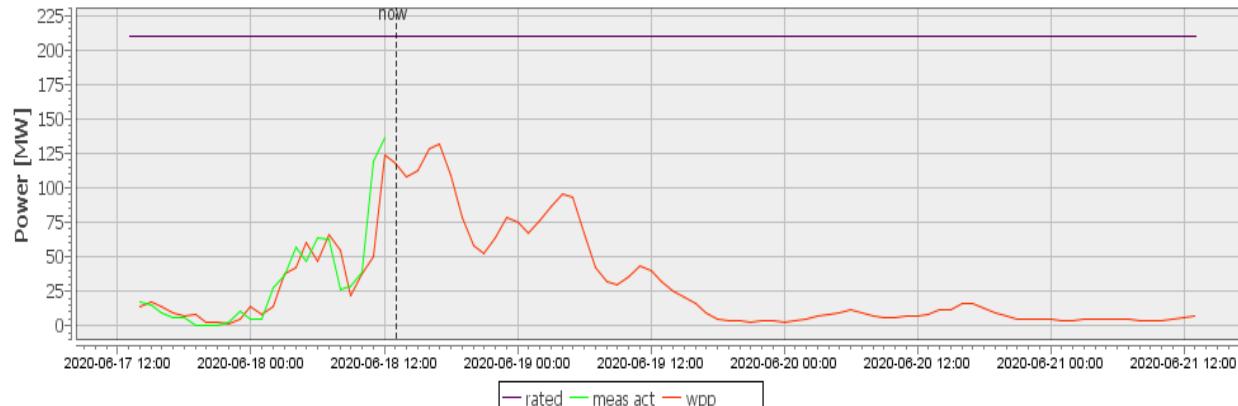
WPP power forecast wind farms

Chart: power forecast wind farms

 relative

minus 24 h

plus 72 h

Go

Site: WPP

Time: absolute

from

to

min. horizon (h)

Chart Tables Download

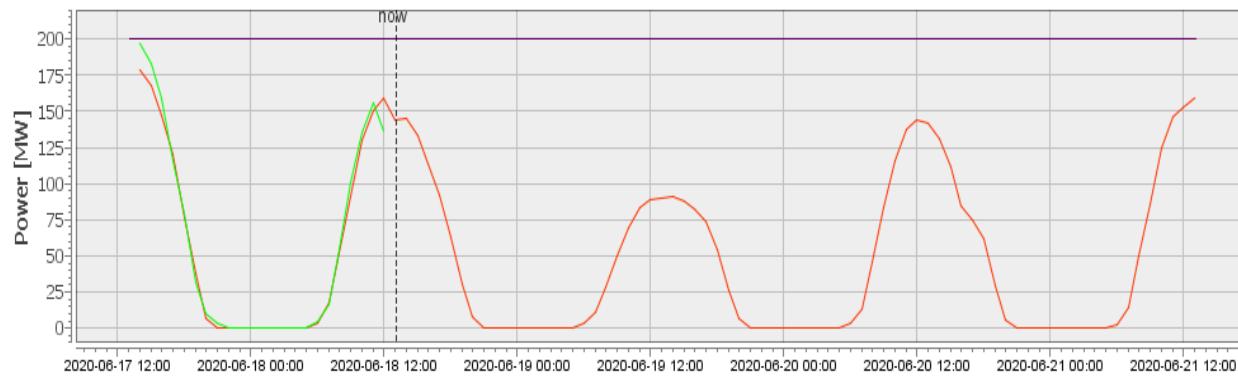
SPP power forecast solar farms

Chart: power forecast solar farms

 relative

minus 24 h

plus 72 h

Go

DUM 2023 - Distributed PV as a Challenge for DSOs

Tasks Outside Prediction Models

- Cyber security
- Data handling
- Redundancy
- Scheduling
- Logging
- Reporting
- GUILs

Error criteria vs. prediction horizon

Horizon: all horizon classes

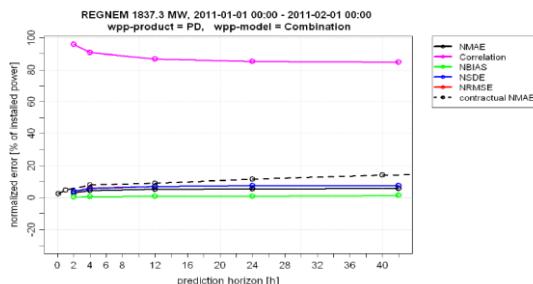


Table of error criteria versus prediction horizon

Horizon Class [min]	Horizon Class [h]	NMAE [%]	Correlation [%]	NBIAS [%]	NSDE [%]	NRMSE [%]
5 - 10	0.0833 - 0.167	1.08	99.5	-0.475	1.37	1.45
10 - 30	0.167 - 0.5	1.63	98.9	-0.033	2.09	2.19
30 - 60	0.5 - 1	2.5	97.4	-0.894	3.18	3.3
60 - 120	1 - 2	3.56	94.7	-1.22	4.5	4.66

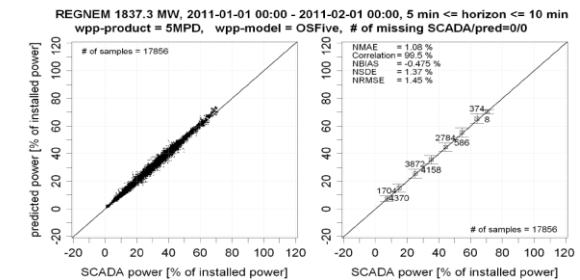
Error criteria one week moving average

Horizon: 30 - 60 minutes



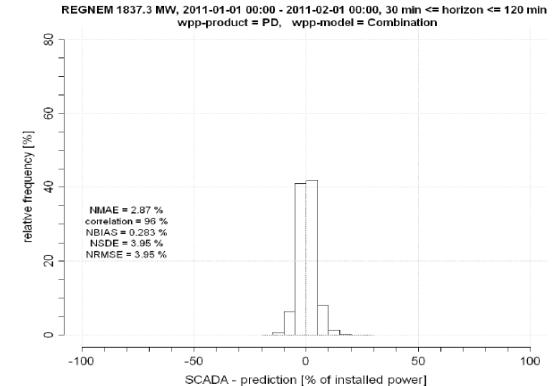
Scatterplot and bin averages

Horizon: 5 - 10 minutes



Error distribution

Horizon: 30 - 120 minutes



Overspeed: Project Team

Organigram Overspeed GmbH & Co. KG



Dr. H-P Igor Waldl



Thomas Pahlke



Team Forecasting

Team Energy Storages

Team Consulting



Team India



Team Members

- Dr. H-P Igor Waldl
 - Managing Director



- Felix Dierich
 - System Architect
 - Optimisation of Operations
 - Head Development



Team Members

- Christian Wichmann
 - Head OandM
 - System Designer and Developer



- Jakob Curdes
 - Cyber Security
 - IT Infrastructure



Team Members

- Barun Kumar
 - Business Development
 - Solar Power Modelling

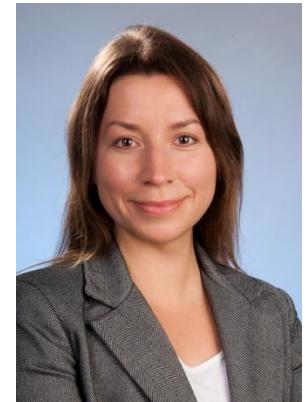


- Naveen Kumar
 - Solar Power Modelling
 - OandM



Team Members

- Dr. Elena Barykina
 - Solar Power Modelling
 - Sat-based Predictions
 - Data analyst



- Creighton Dement
 - Wind Power Modelling
 - Data Analyst
 - Data QA



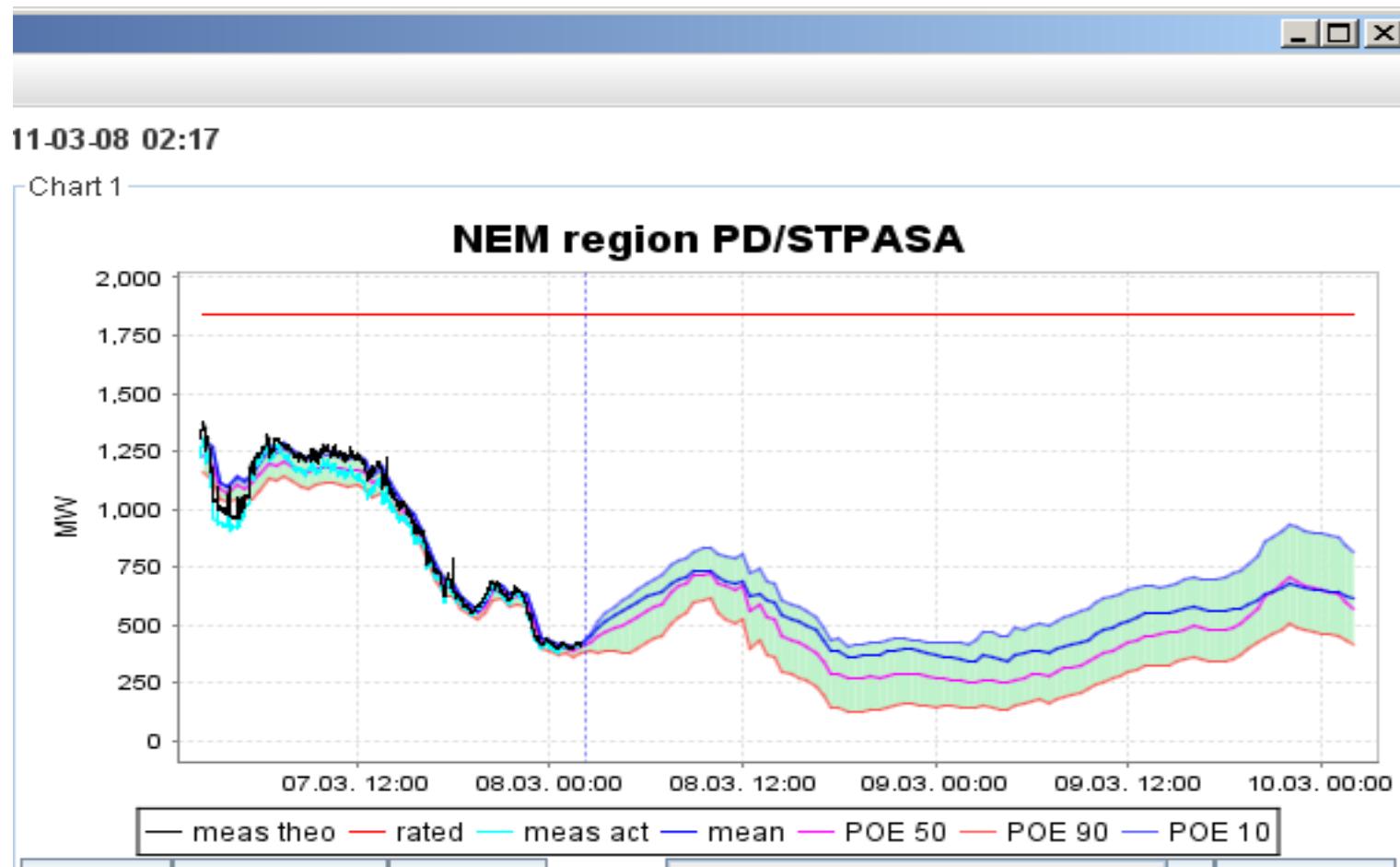
Best Practices

Best Practices: Australia

- 5 minute market
- Predictions from 5 minutes to multiple days ahead
- Strict rules about SCADA data to be provided
 - Power Production
 - Curtailment set point
 - Turbine/inverter availability
 - Average wind speed and irradiation for up-scaling
- ~~Probabilistic forecasting~~
- Ramp forecasts



Probabilistic Forecasting

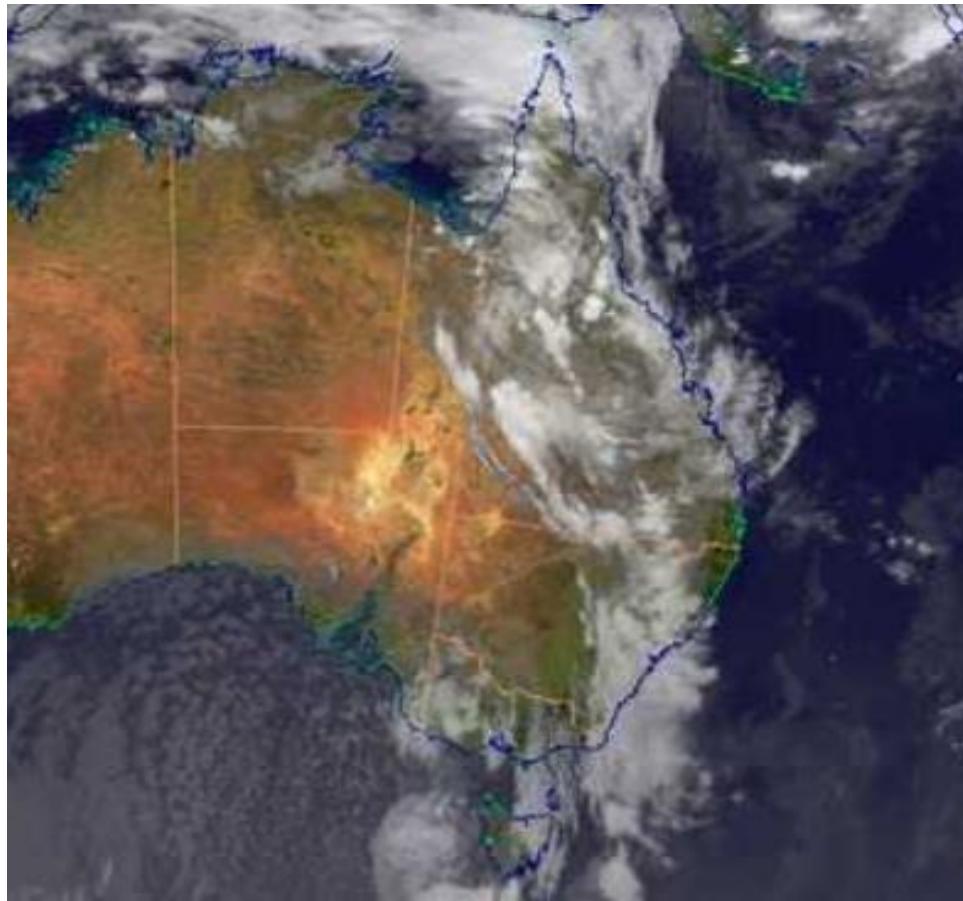


Best Practices: Australia ctd

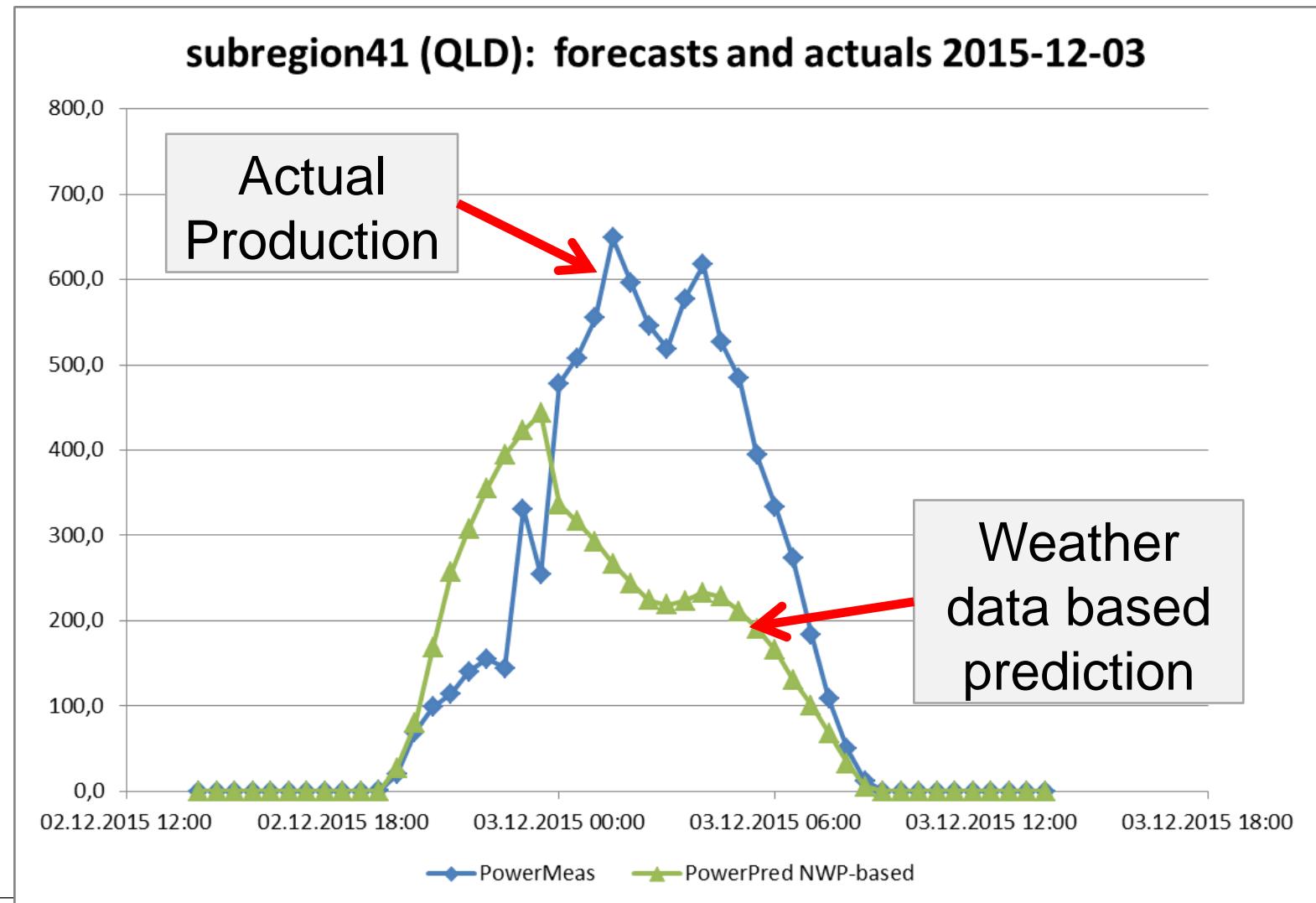
- Solar predictions using sat-based predictions
- Excellent measurement networks for estimation of distributed PV
- Extremely high quality management requirements
- Forecasting as infrastructure service by market operator AEMO
- Cooperation with local weather service (BoM)



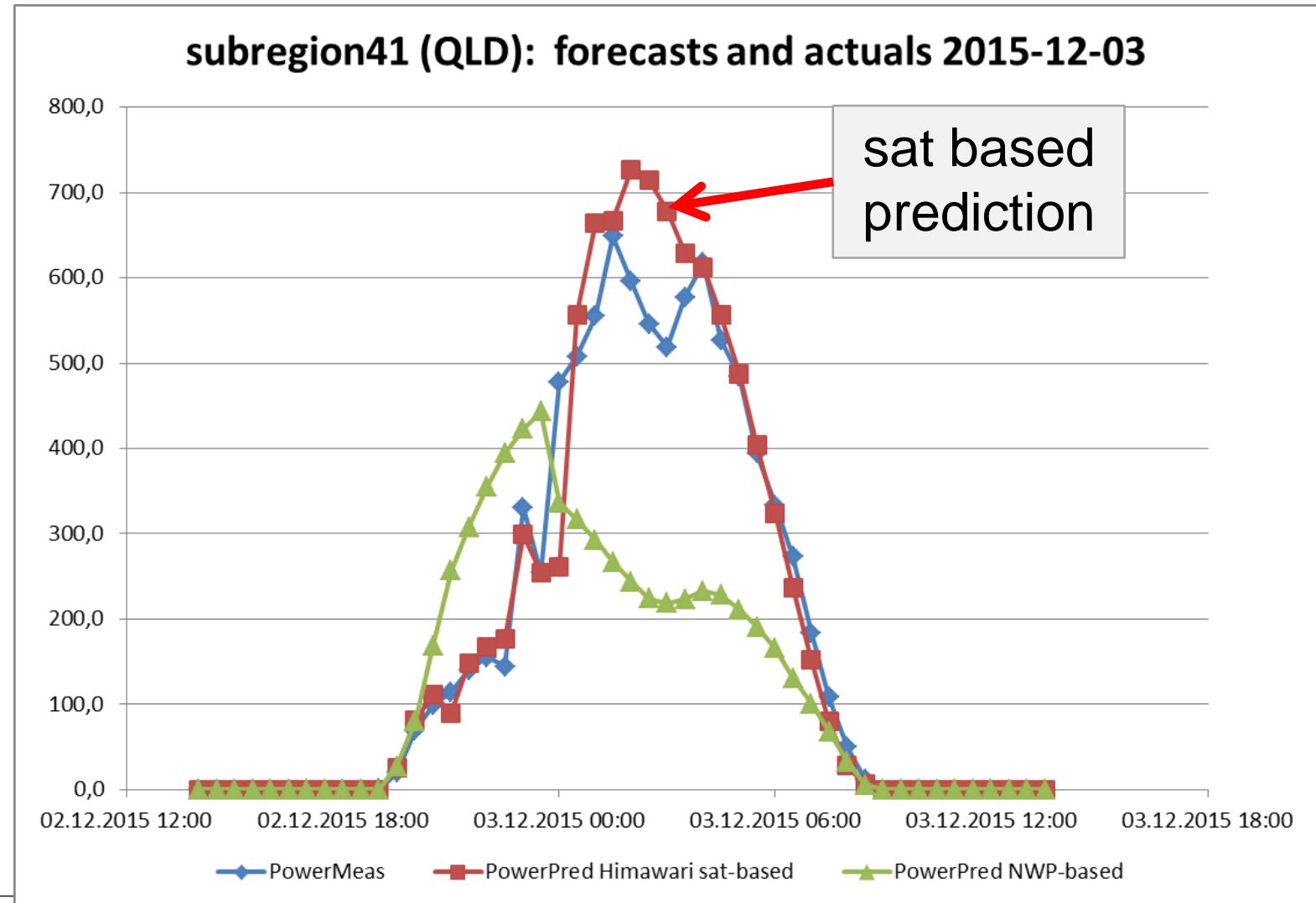
Big cloud field over south-east Australia



Example roof-top, NWP-based, Brisbane



Example roof-top, sat-based short-term, 1 hour ahead



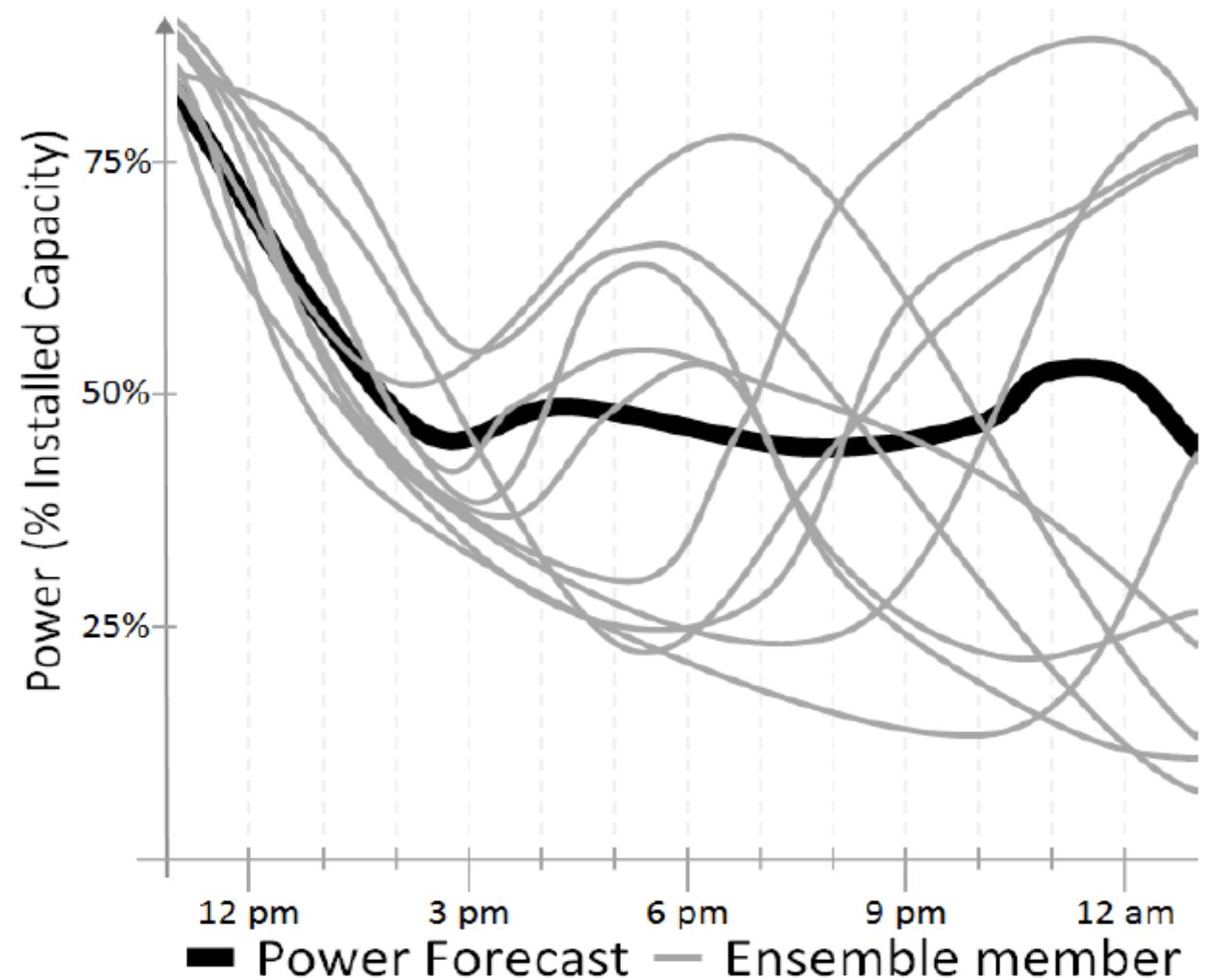
Best Practices: Ireland

- Good data quality
- Pooling in grid regions
- Forecasts from 15 minutes to several days
- Probabilistic forecasting
- Advanced ramp predictions based on ensemble predictions



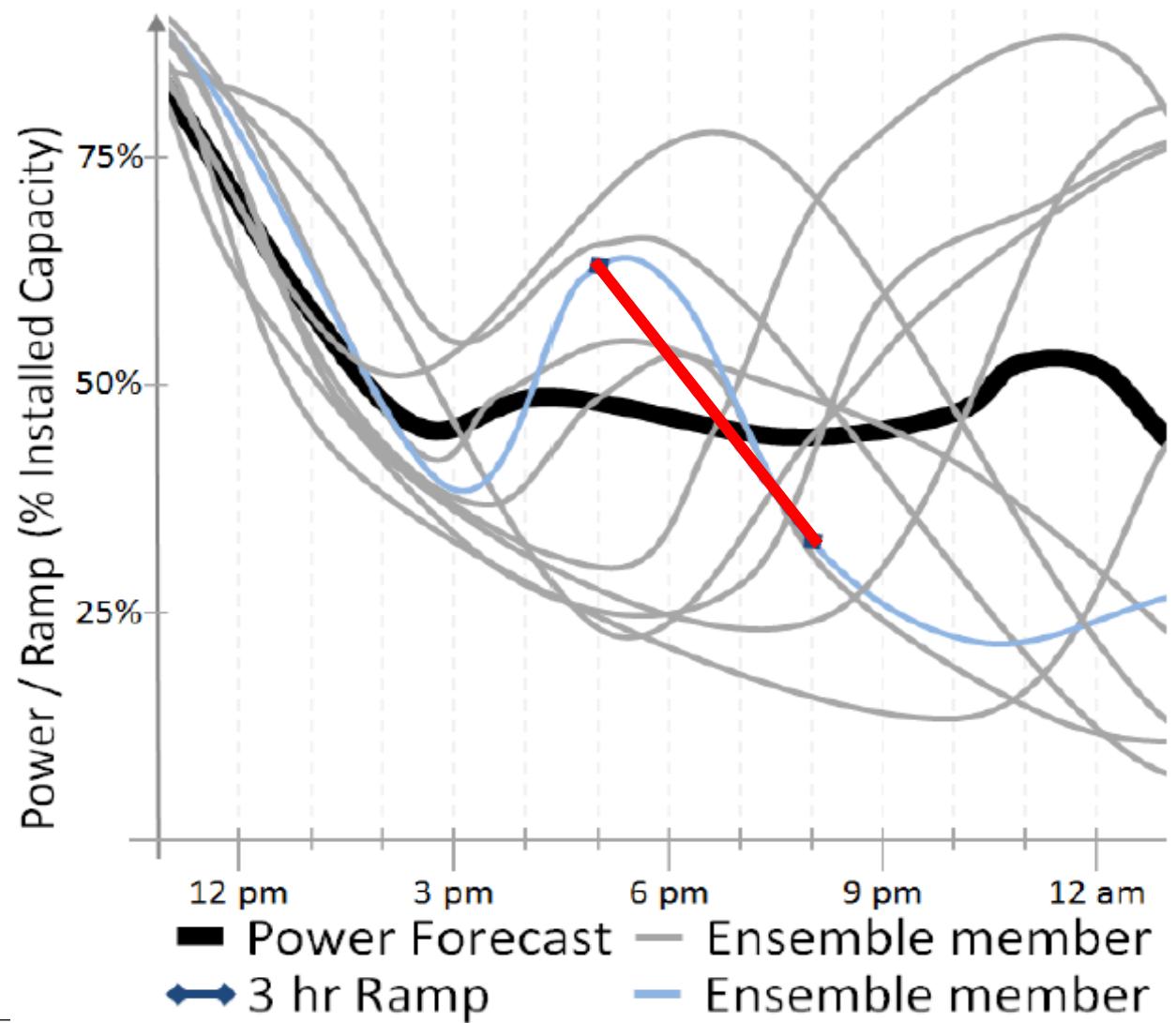
Ramp Forecast Product – Simplified Illustration

12-hour deterministic and
10 ensemble members /
scenarios



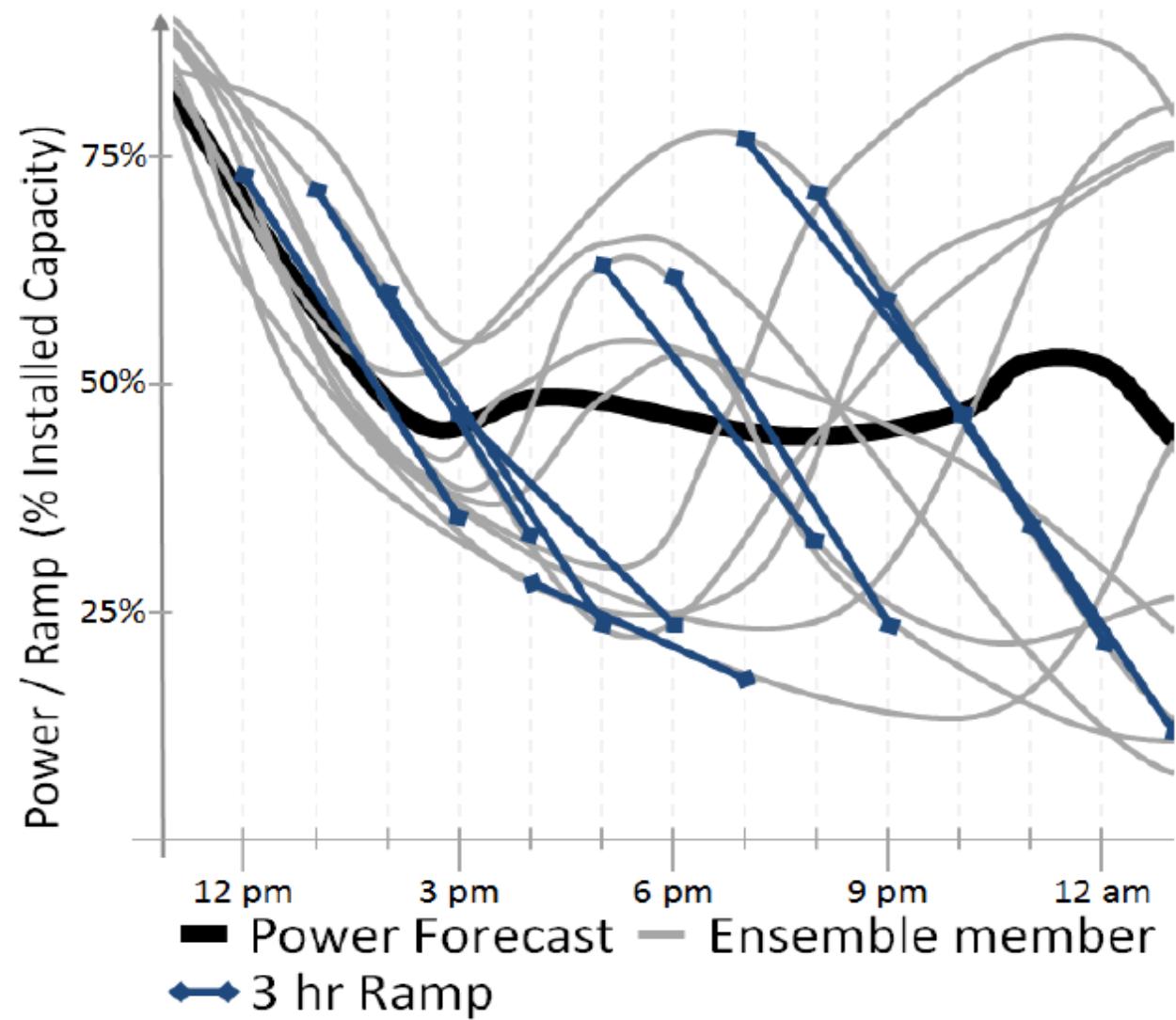
Ramp Forecast Product – Simplified Illustration

Maximum 3-hour ramp down may be calculated from ensembles



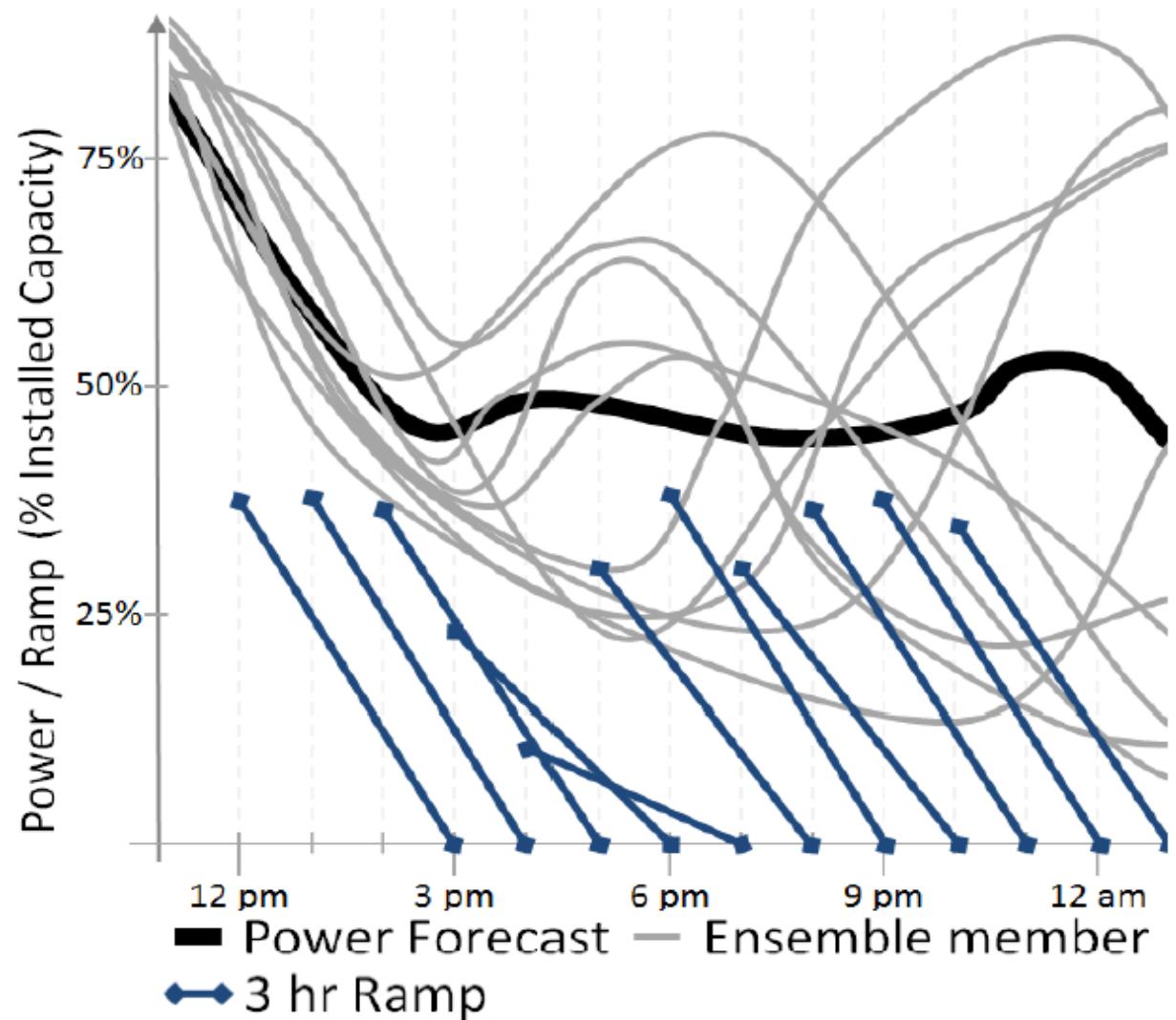
Ramp Forecast Product – Simplified Illustration

For each forecast interval,
maximum ramp down
calculated from ensemble
of forecasts



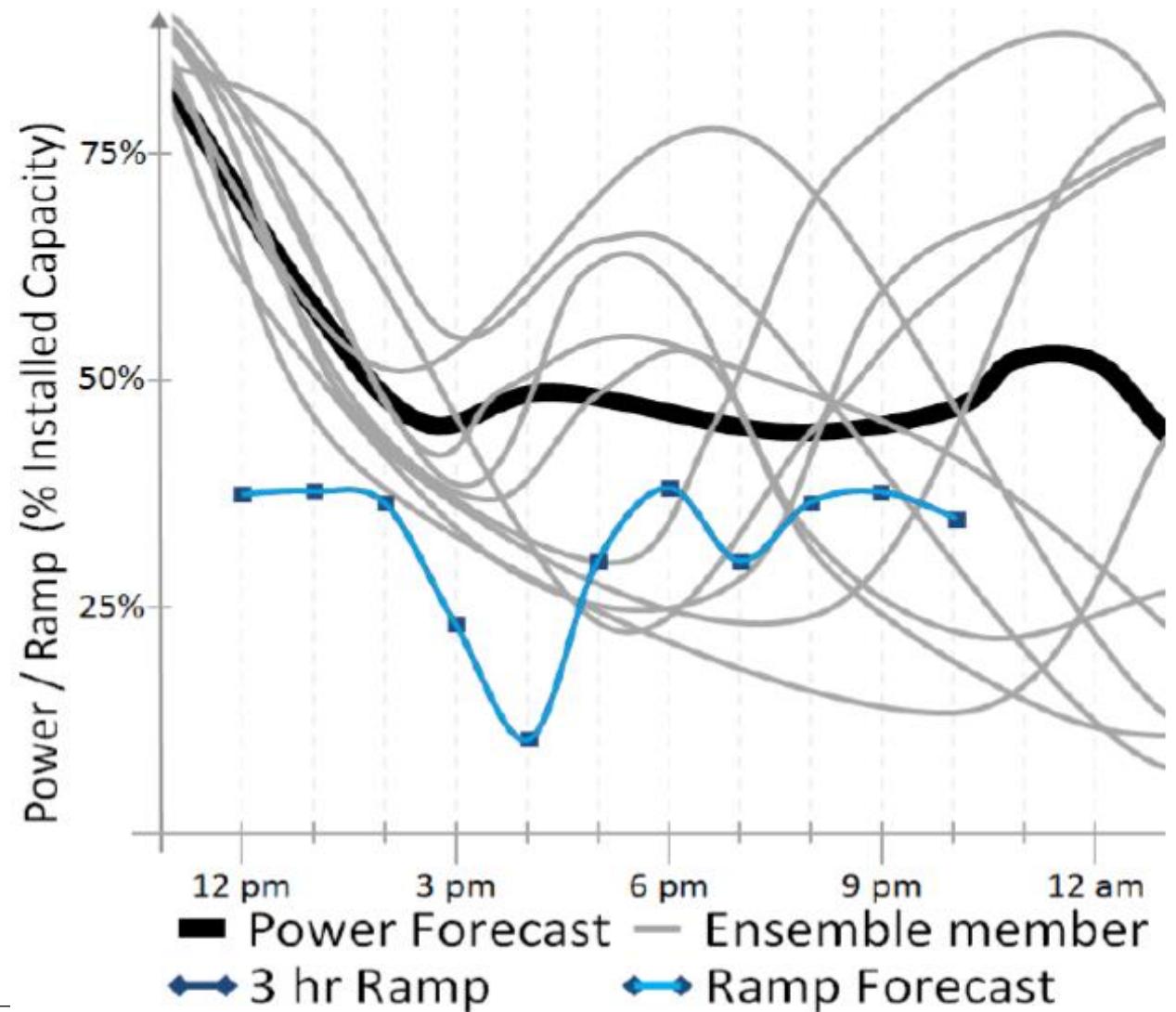
Ramp Forecast Product – Simplified Illustration

Composite of 3-hour maximum ramp down assigned at each forecast time step



Ramp Forecast Product – Simplified Illustration

3-hour ramp forecast generated



Best practices: Germany

- Very flexible pooling of wind and solar farms possible
- One hour to day-ahead predictions
- No penalties
- But: obligation to hedge deviations to production schedule
- Hedging by aggregator or by grid operators via market
- Current R&D: Measurement Networks for short-time solar forecasting



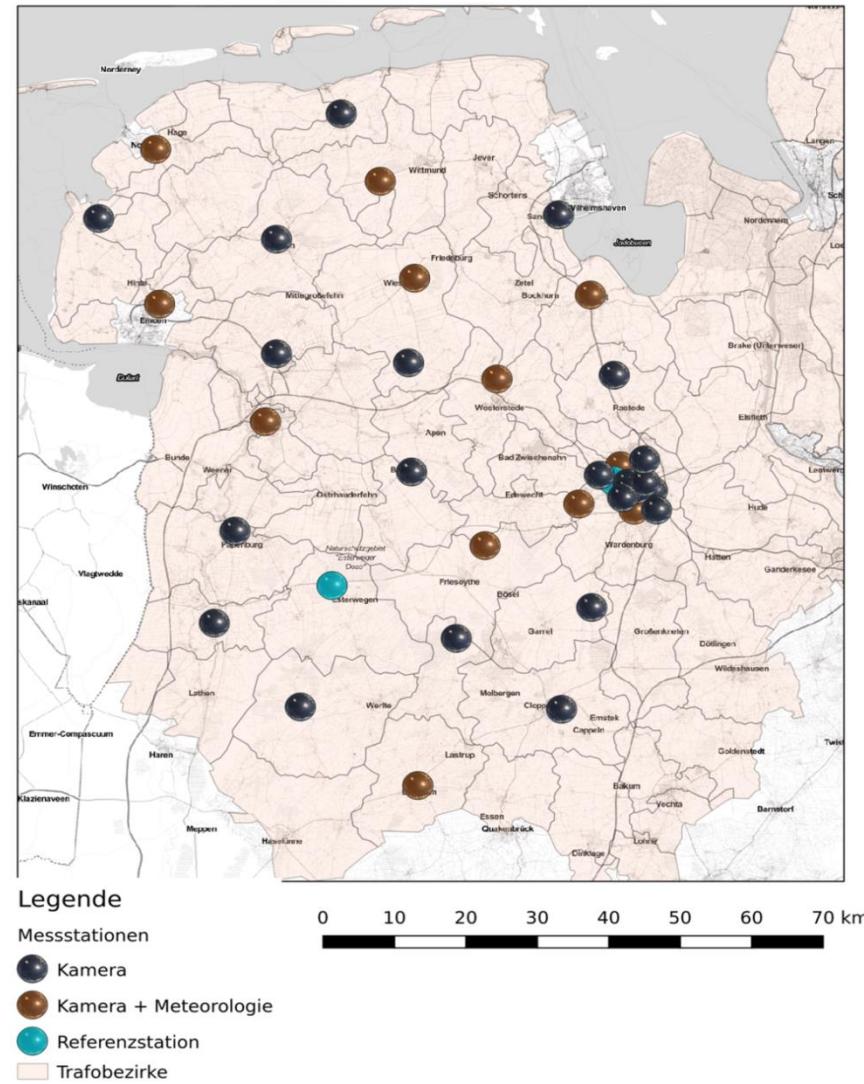
Sky Cams/Sky Imagers



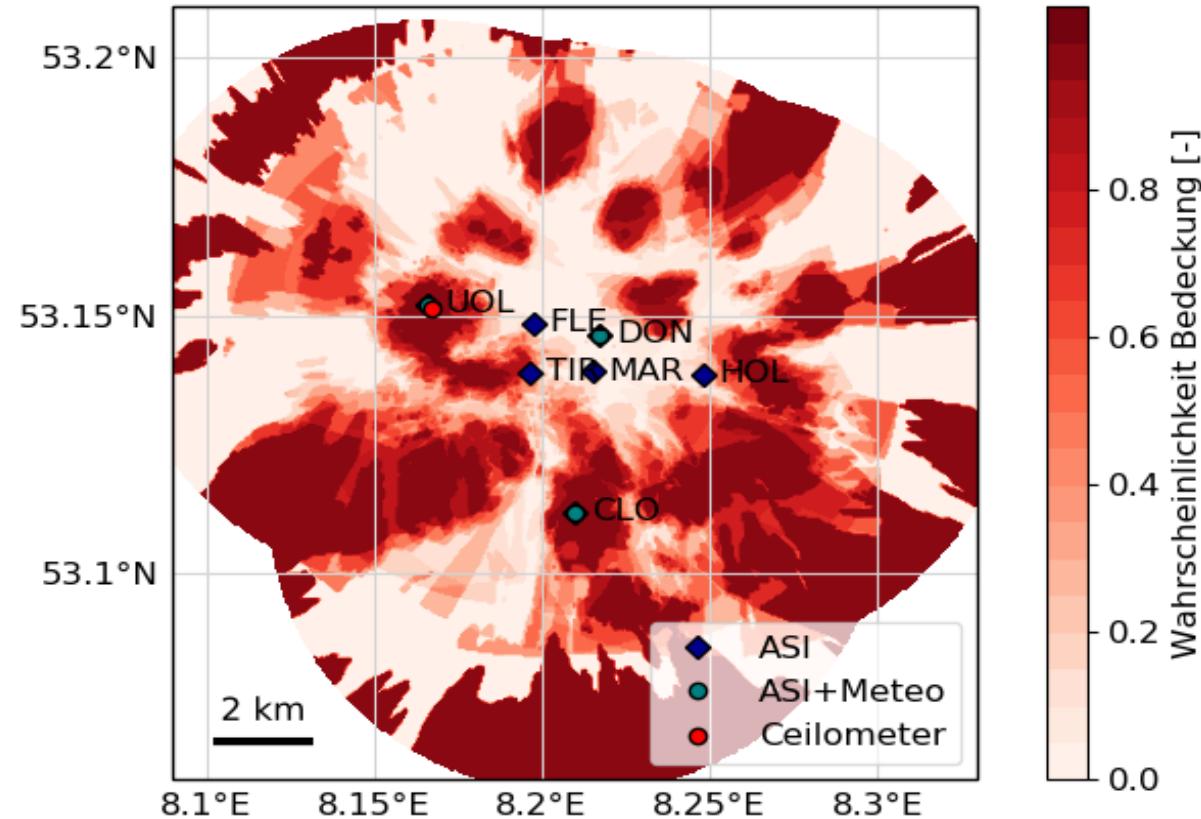
Sky-Cam Area Networks



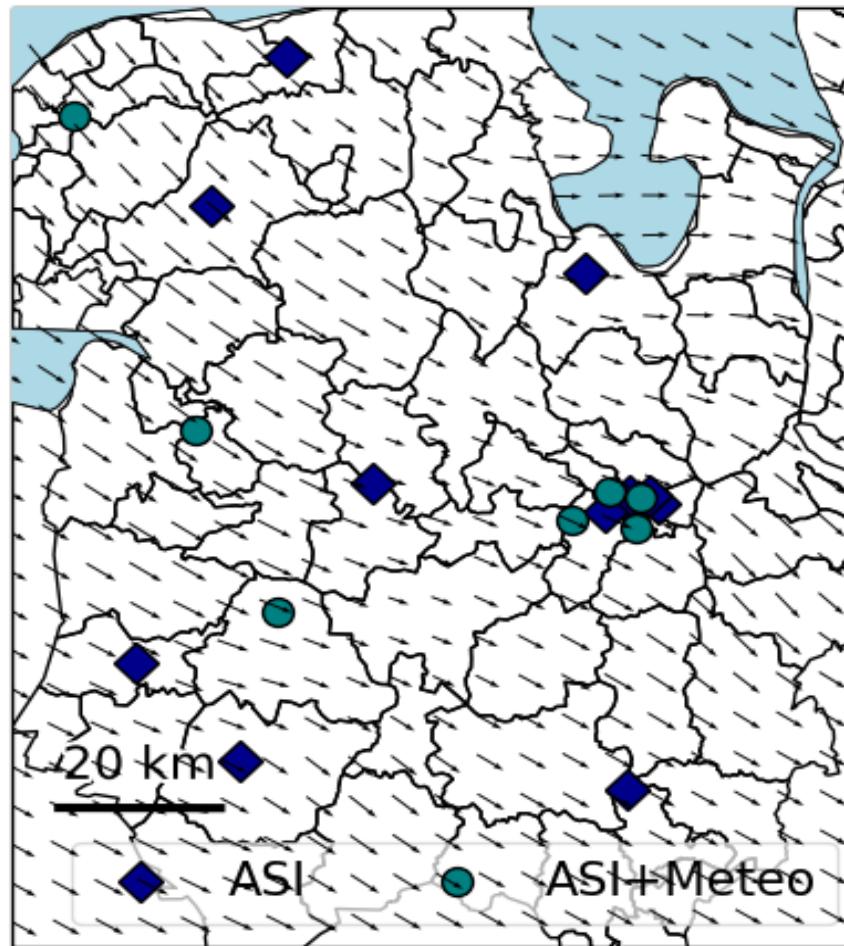
Network of Sky Cams/Sky Imagers: DLR/Uni Oldenburg



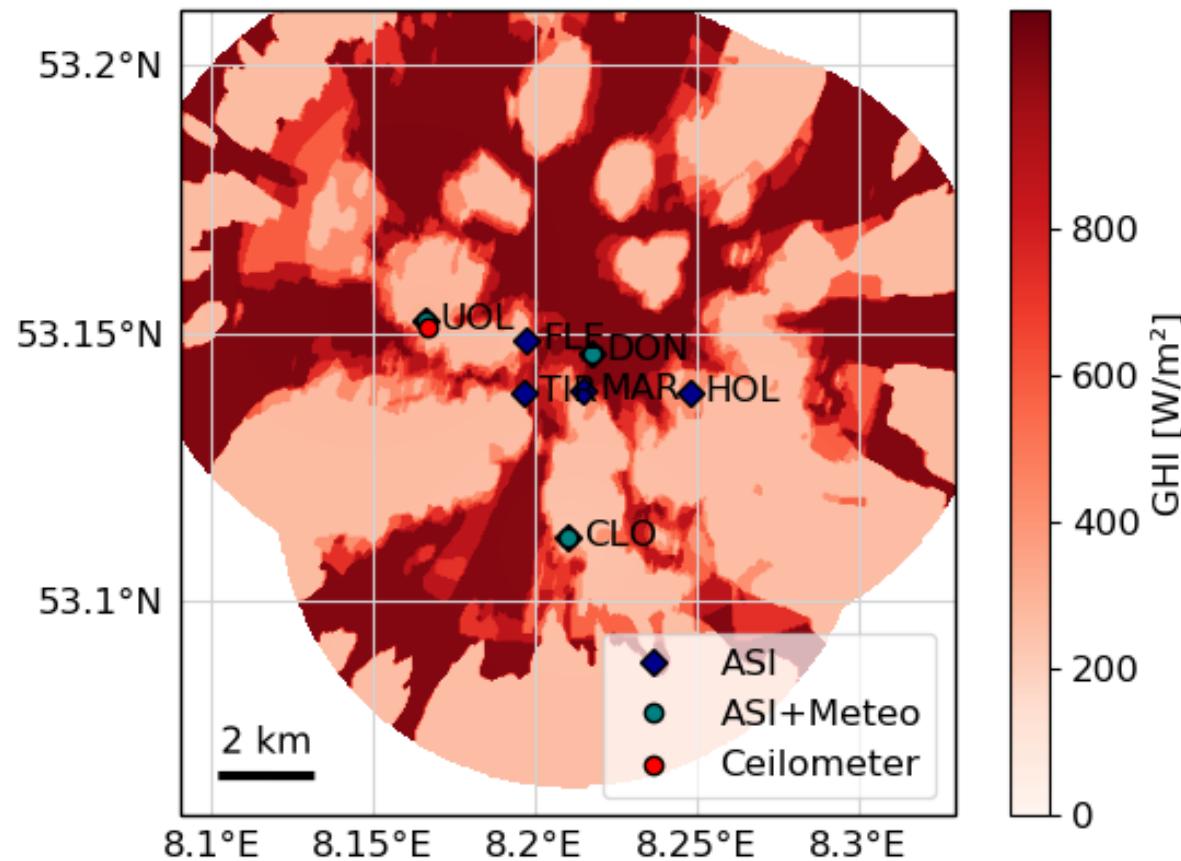
Map of Cloud Coverage



Vector Field of Cloud Motion



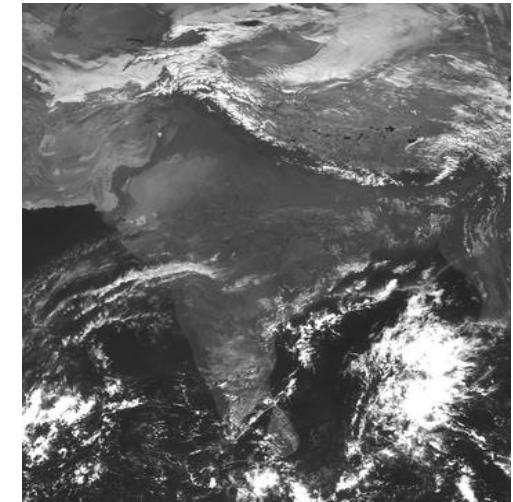
Prediction of Irradiation



Summary Anemos Prediction System

Anemos Wind and Solar Power Predictions Summary

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Windenergy Consulting Onshore/Offshore

World-wide Prediction Activities

Wind and Solar Power Predictions for India

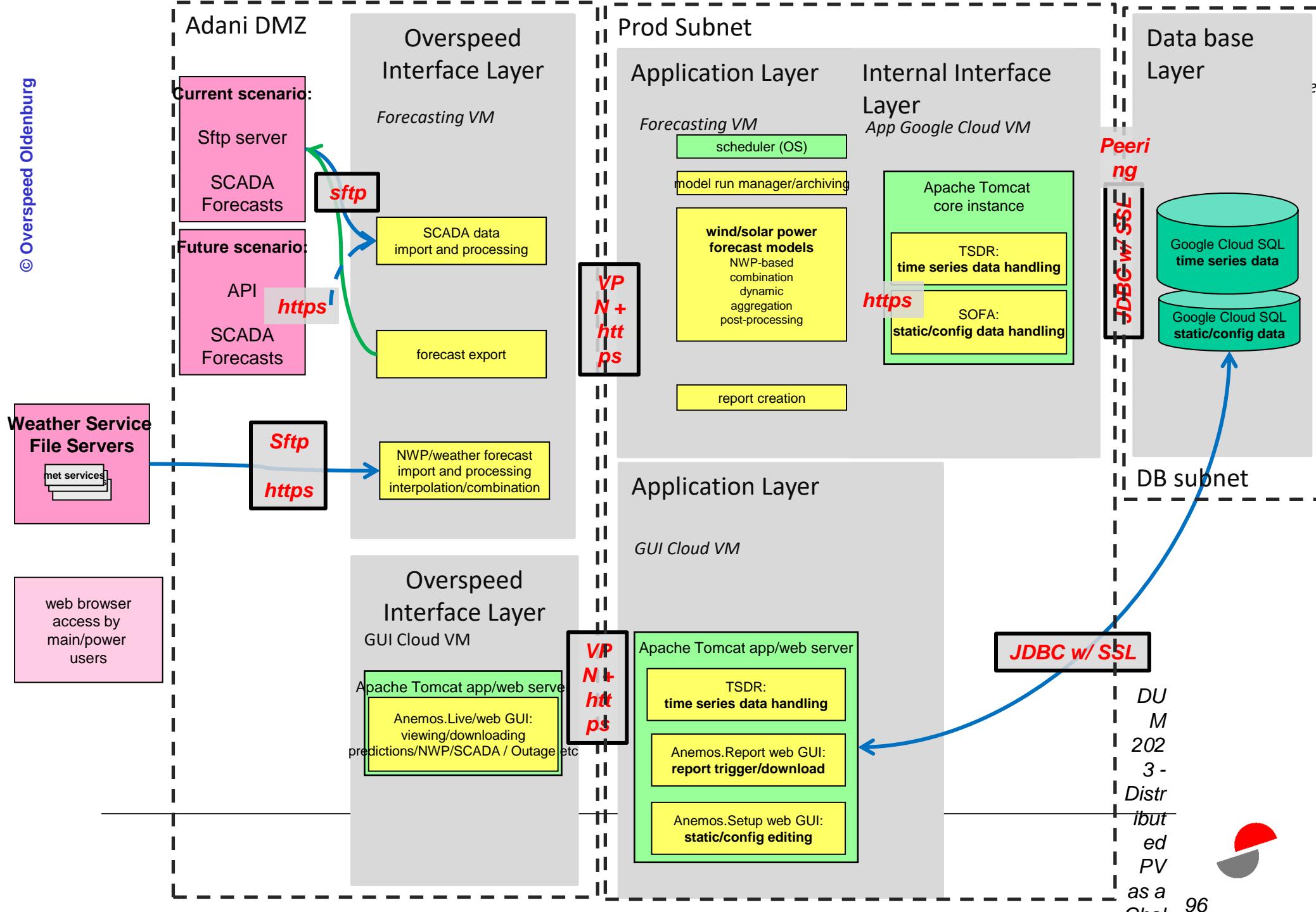
Overspeed: Project Team

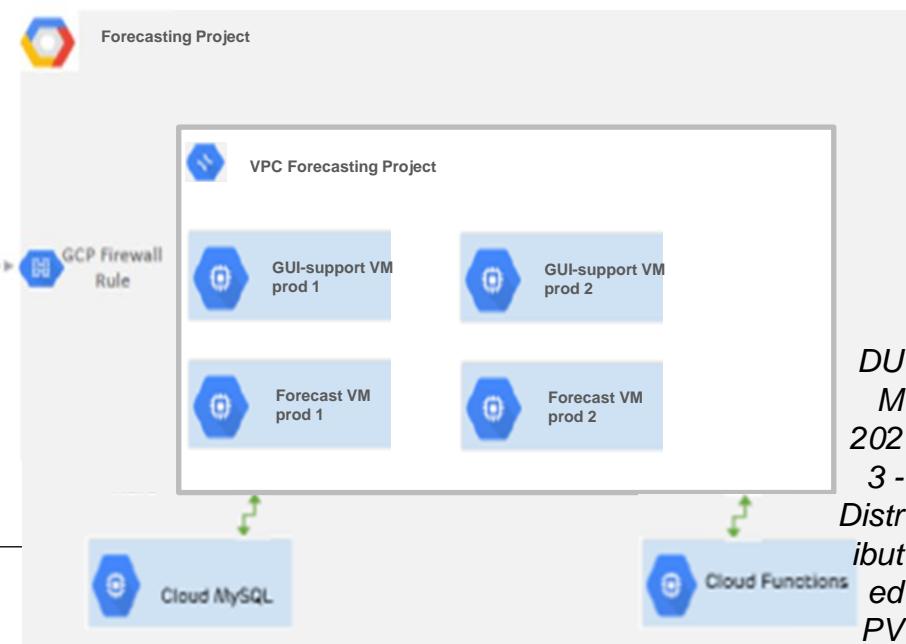
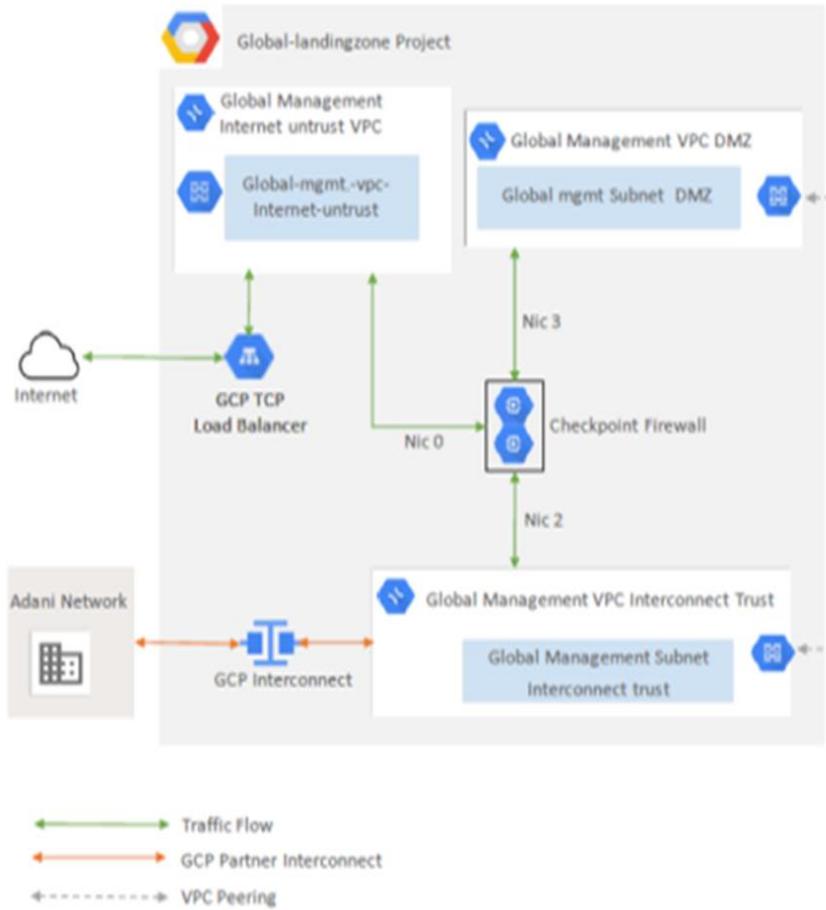
The Perfect Wind and Solar Power Prediction



Additional Slides





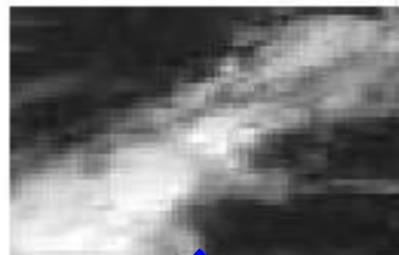
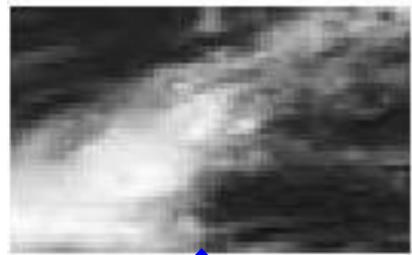


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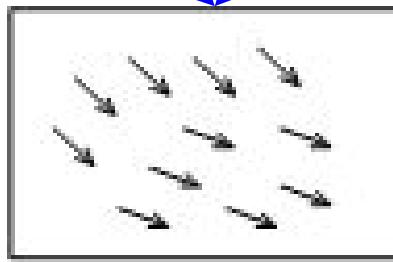
as a
Cloud



Cloud motion vectors



Consecutive satellite images



Motion Vector Field



**Cloud prediction
→ Irradiation**







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What we will have achieved: OandM Teams (2)

OandM: 1st and 2nd Level Support Team

- 24/7 monitoring of solution capabilities
- Trouble shooting for operational issues: Data feeds, system availability, prediction model availability, configuration issues

OandM: 3rd Level Support Team

- Monthly analysis of solution availability, accuracies and penalties
- Trouble shooting in case of unsatisfactory accuracies
- Proposing improvements for future development

Project Structure: Building blocks for the Forecasting Solution

- Prediction system and platform
- The Overspeed Anemos Prediction System: Platform and Prediction Models
- Customization of the Anemos System
- Integration of data feeds (Adani wind/solar farm production data, NWPs)
- Integration into Adani's IT cloud solution
- Customized GUI
- Support, supervision, and hand holding for Adani prediction model integration and development



Project Structure: Building blocks for the Forecasting Solution

- Trainings
- Operation and surveillance of the prediction system
- Set-up and management of static data like installed power, coordinates, power curves, ...
- Prediction model development and integration, including a development and testing framework
- Potential trainings about basics and details of wind and solar power modelling



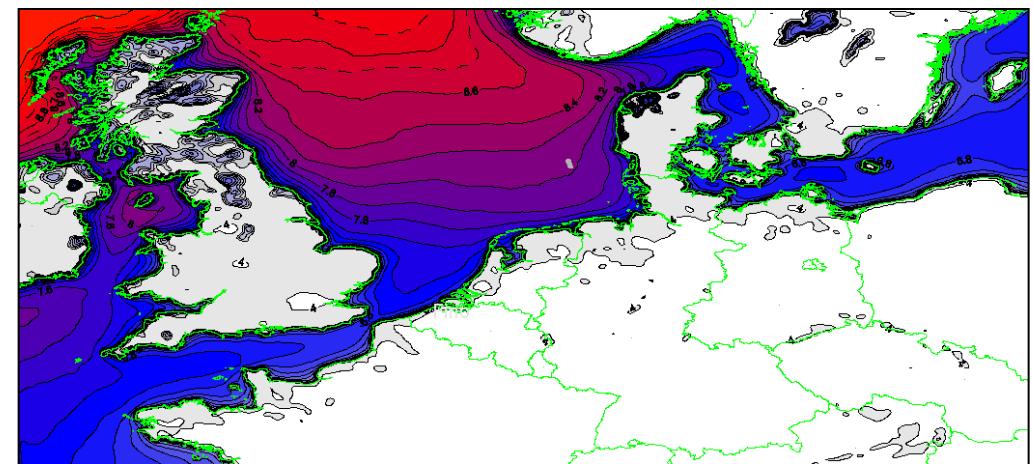
Customizations for Adani

- Customized GUIs
- Customized reporting
- Re-implementation of platform modules in Python
- Handling of NWP data via secured Overspeed servers
- Future interface to ENOC
- Benchmarking IBM Weather NWP data
- Support Adani in-house requirements for Cyber Security (3tier implementation)
- Vulnerabilities and security tests by external independent consultant

Wind Energy Consulting

Windenergy Consulting References

- Onshore
 - Germany, Spain, China, Greece, Turkey, Morocco, Brasil, Argenta, Portugal, Sri Lanka, India, ..
- Offshore
 - Germany, Poland, Portugal, India



Project Development/Design Sandbank24

- Planning from scratch (North Sea)
- Consulting, Research and Development
- Offshore wind farm with
72 turbines, 288 MW
- 100 km from coast line
- Permission application
- Environmental study management

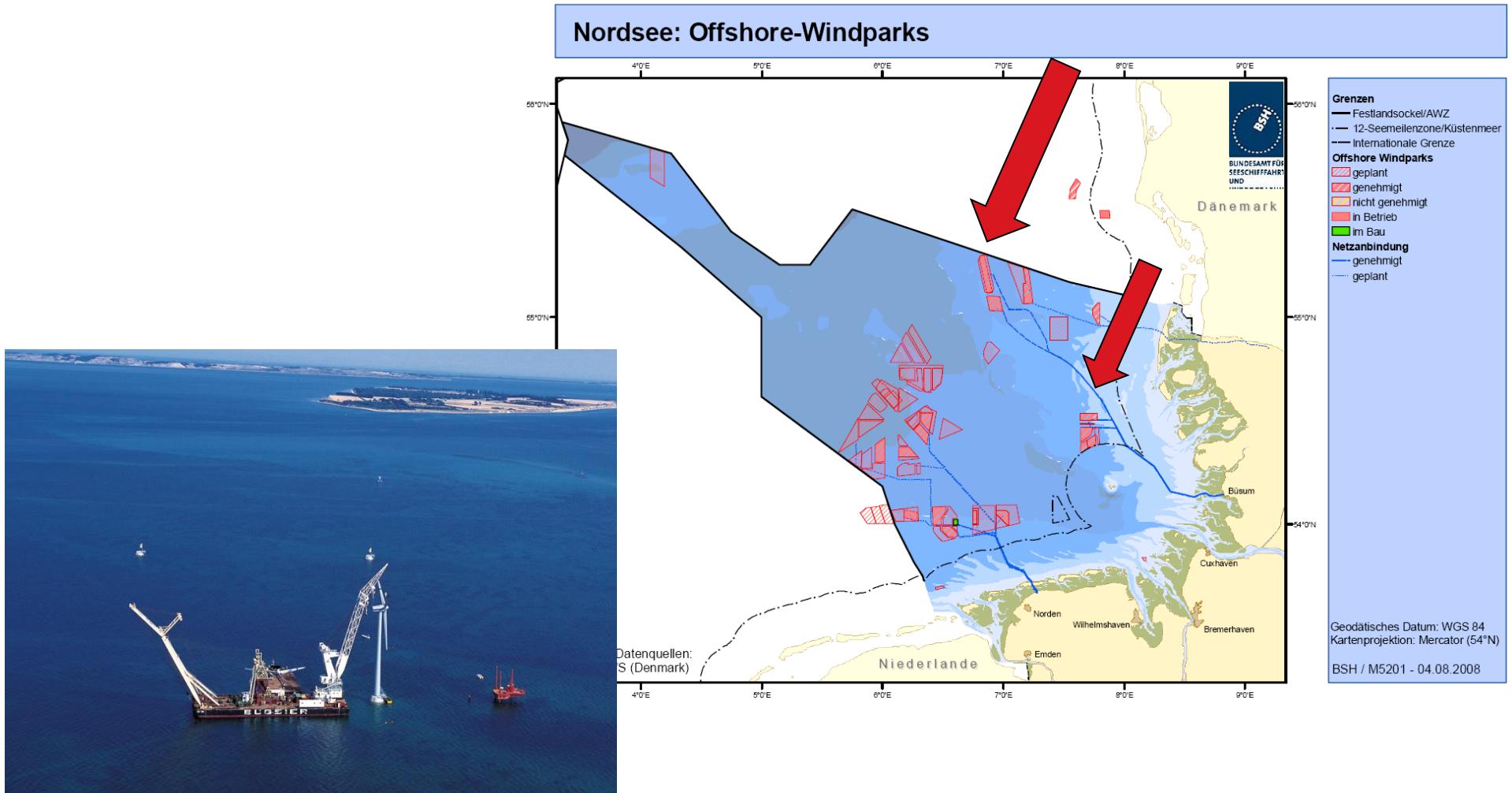


Project Development/Design Sandbank24

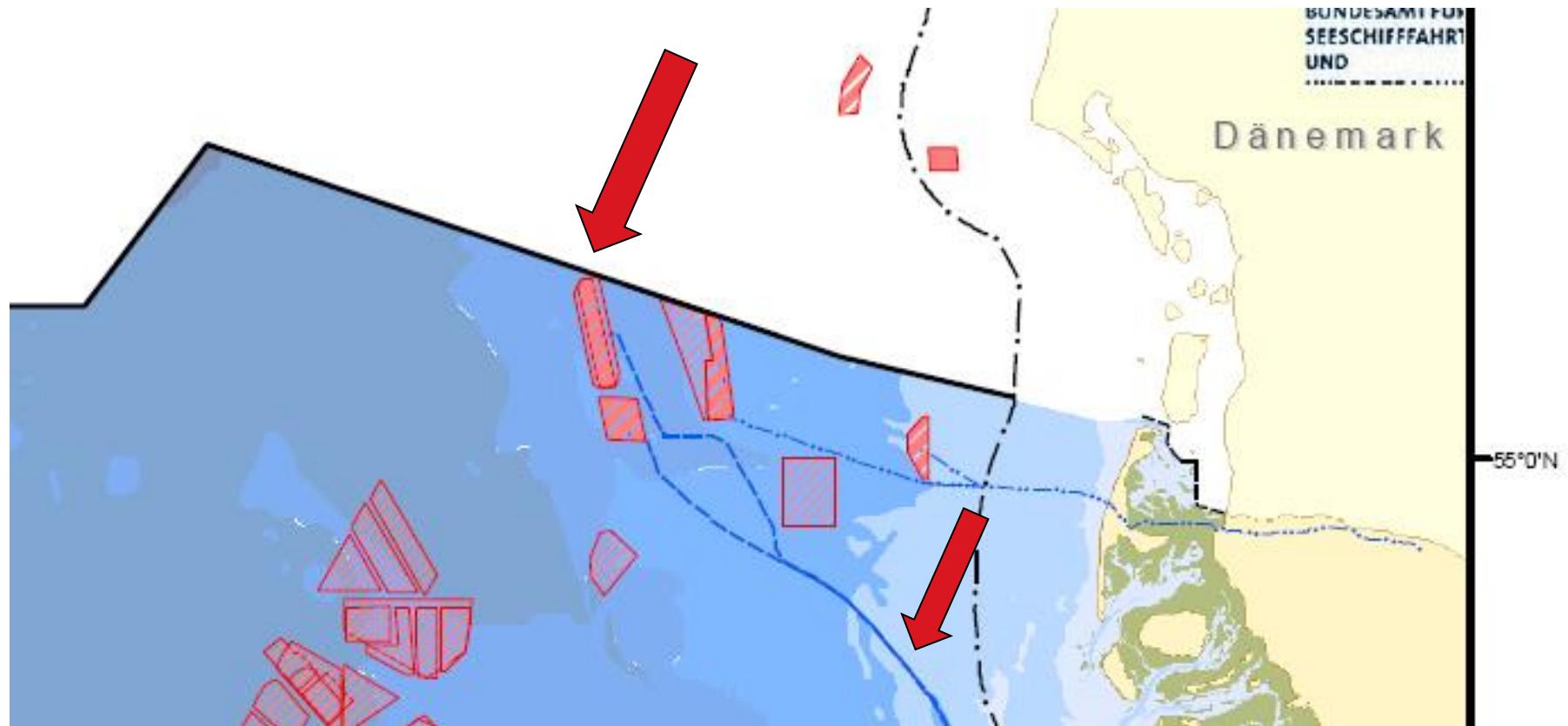
- Wind Potential & Energy Production
- Wind farm layout
- Energy transmission system selection und optimisation (HVDC)
- Internal electrical system
- Detailed layout
- Cost optimisation
(planning and implementation phase)



Offshore Wind Farm Sandbank 24



Offshore Wind Farm Sandbank 24



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Project Development/Design Sandbank24

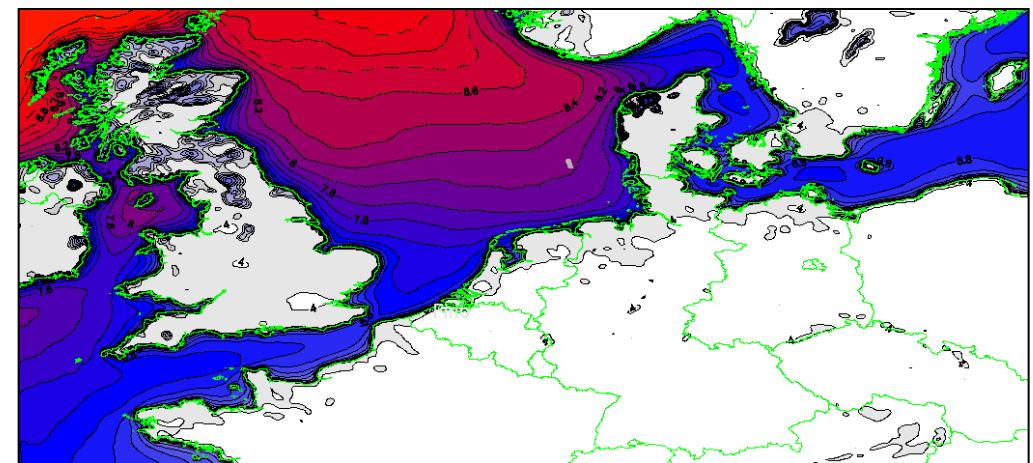
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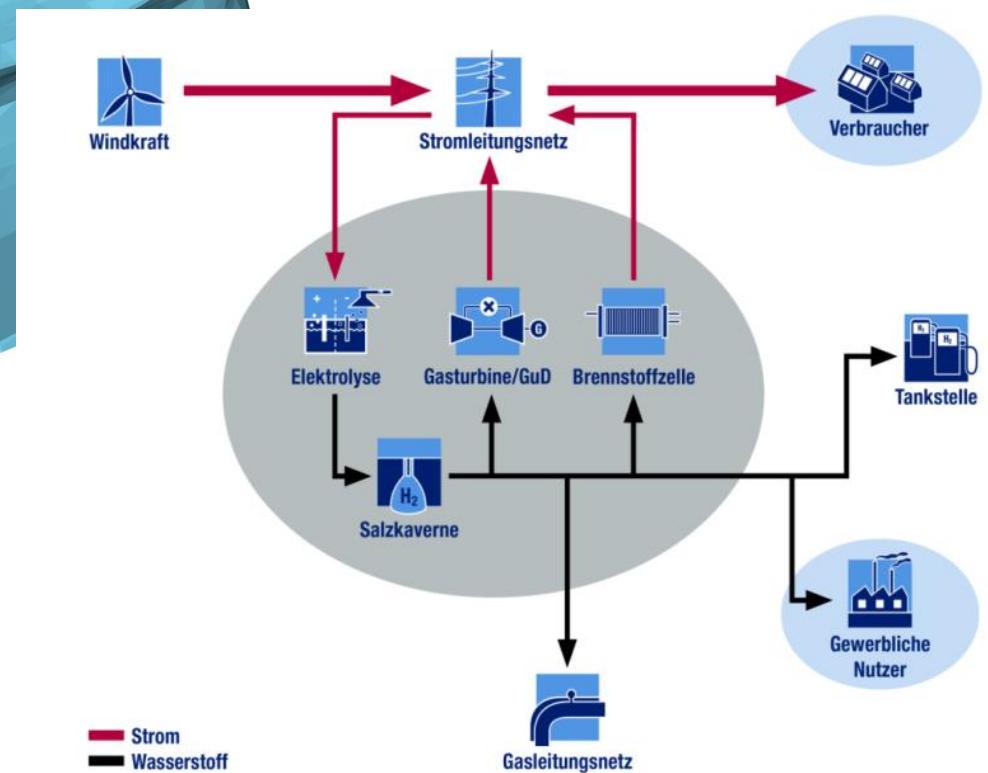
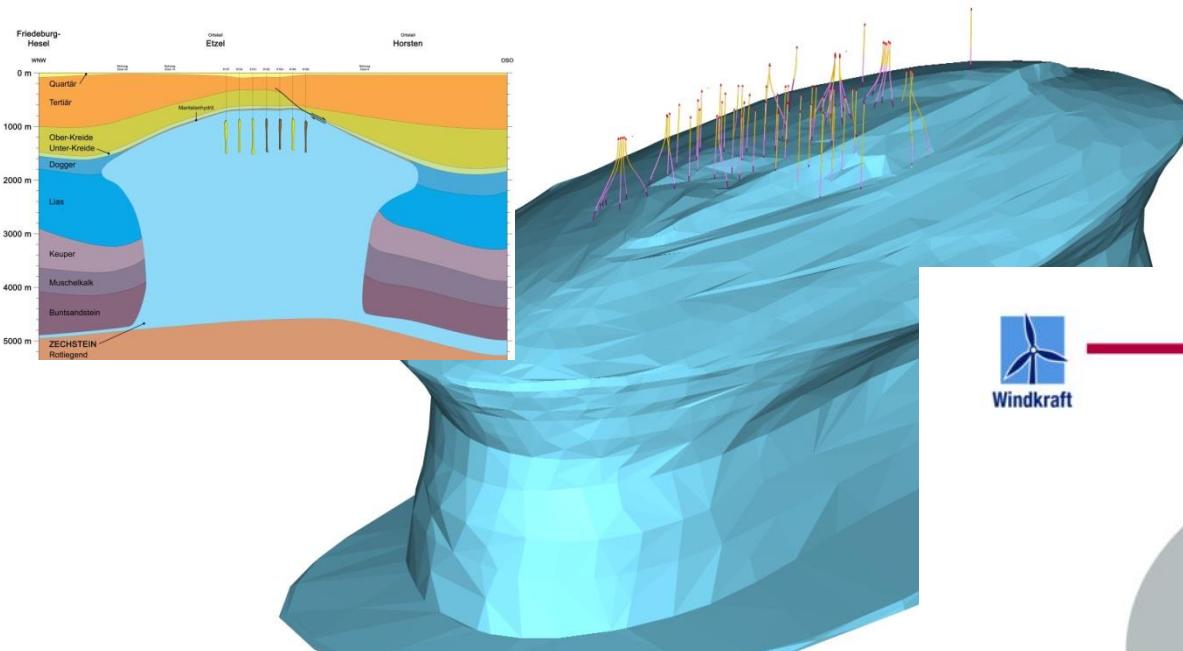
Storages and Systems: Hydrogen

Hydrogen Applications

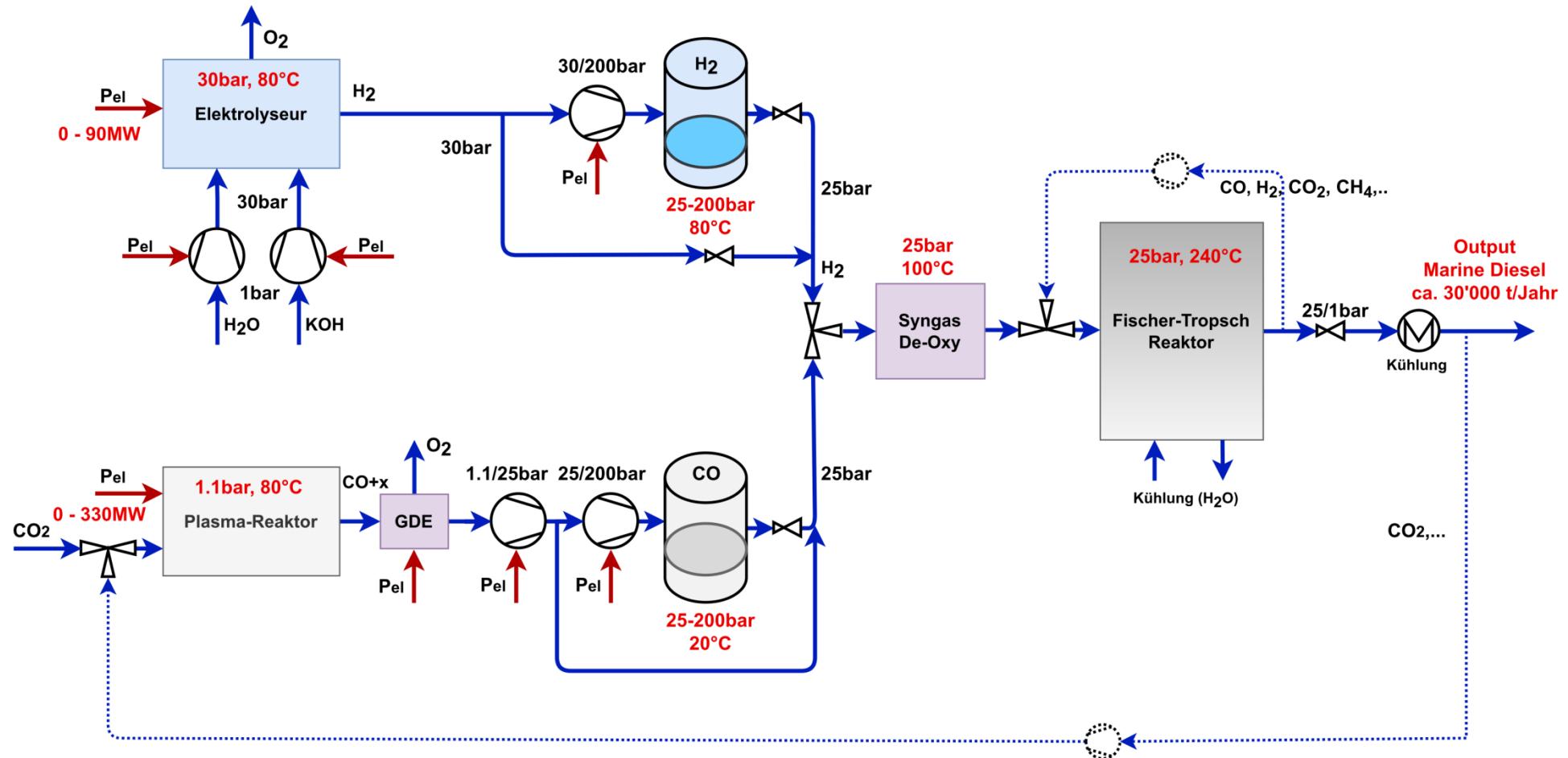
- Seasonal storages
- Supply for chemical industry
- Transportation



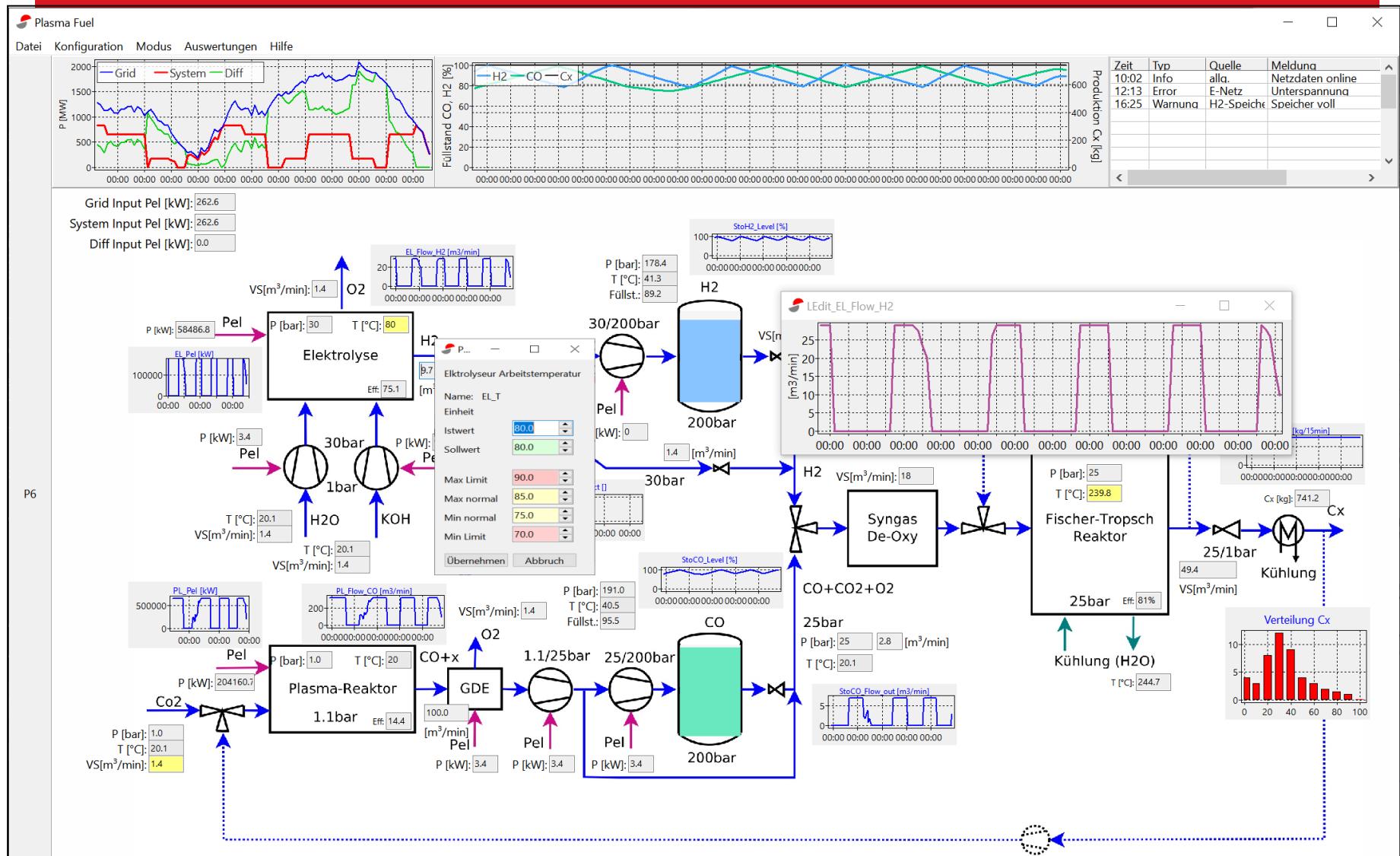
Underground storage for hydrogen



Power2Fuel System



Control and Optimization Power2Fuel



World-wide Prediction Activities

Anemos Wind and Solar Power Predictions?

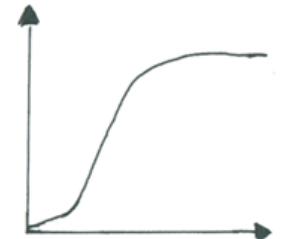
- Leading edge research and development

since 1994



- Prediction models

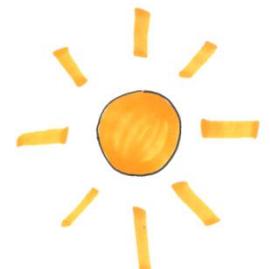
since 1996



- Wind and Solar Power Prediction System

- Commercial wind & solar predictions

since 1997

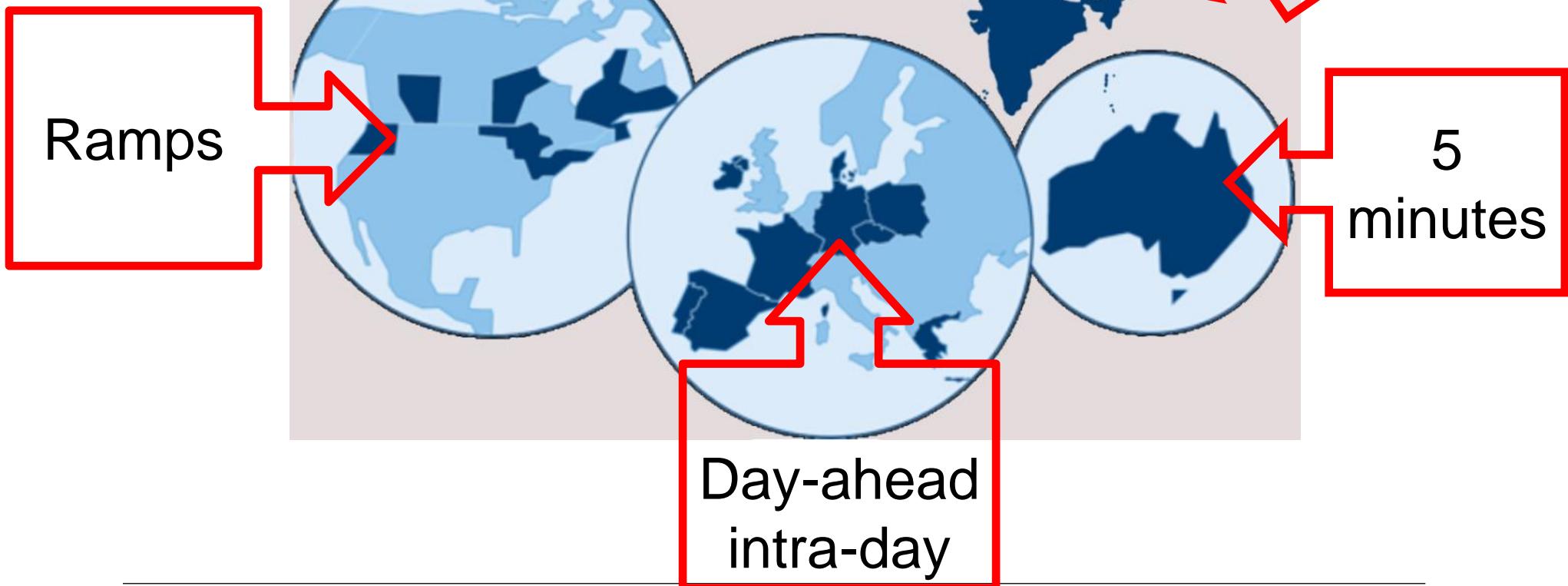


The Anemos Wind and Solar Power Prediction System

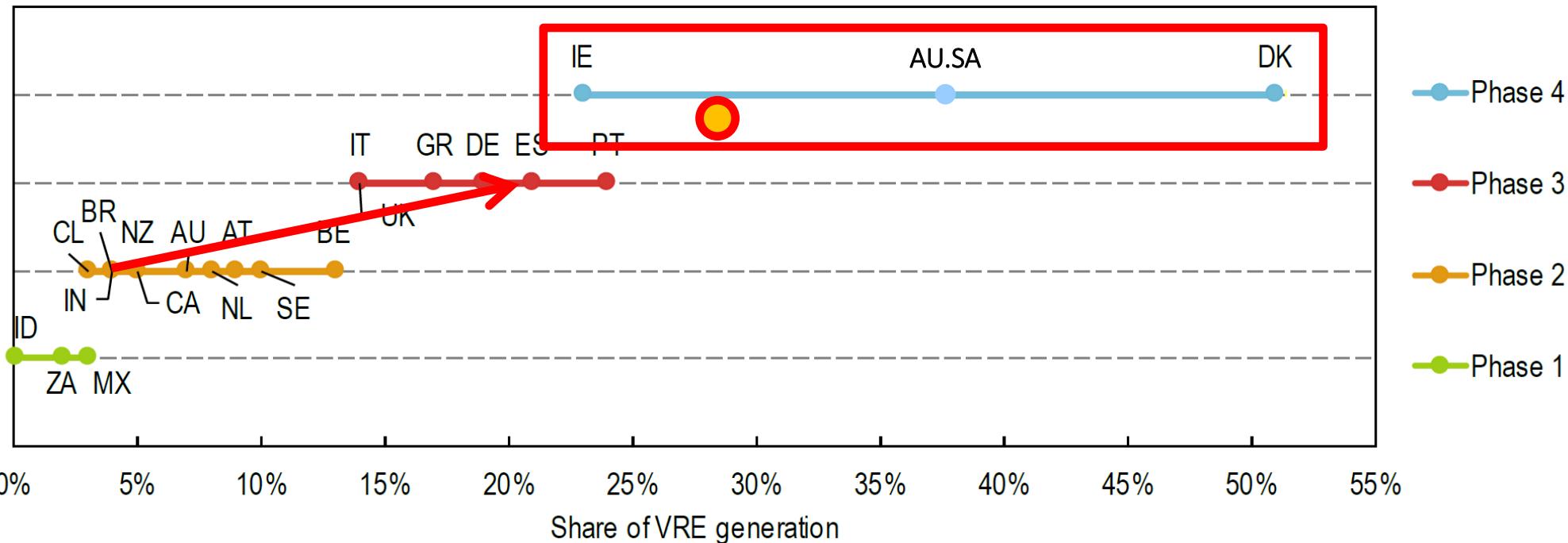
- Highly standardized software product
- World-leading prediction models
- Secured handling of information
- Data exchange is handled in a Service Oriented Architecture
- Easy implementation of server mirroring/redundancy and load balancing
- High-availability system (AEMO Australia: 100.000% availability since 2008)



Typical Prediction Applications



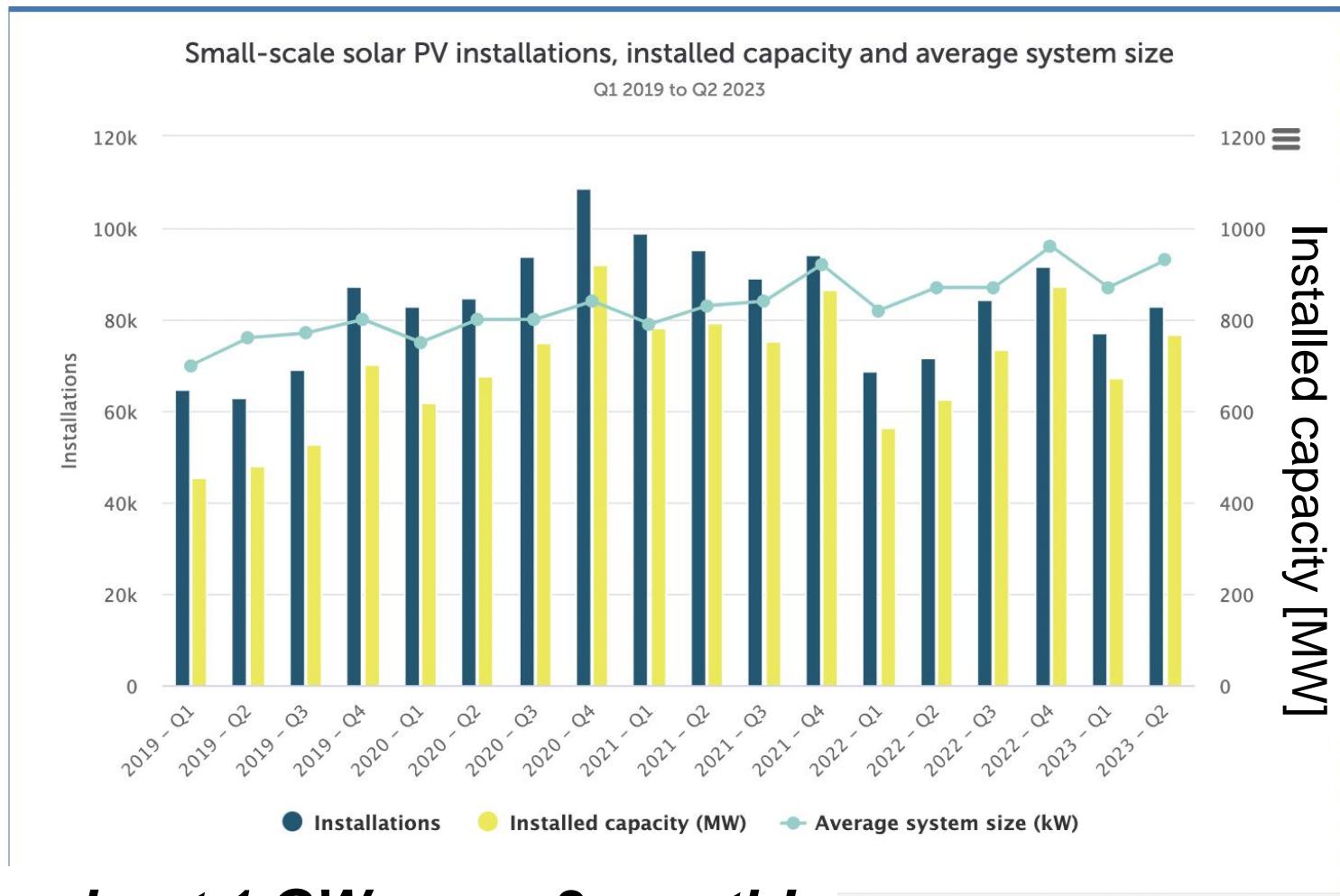
Anemos Reference predictions for high-penetration countries



Source: Adapted from IEA (2016d), *Medium-Term Renewable Energy Market Report 2016*



Example: Small-scale PV in Australia



Adding about 1 GW every 3 month!

