Solar forecasts and their integration in the management of energy systems

Elke Lorenz
TwinSolar Workshop
DTU Riso, 21.08.2023
www.ise.fraunhofer.de

Agenda TwinSolar Workshop on Solar Forecasting

Morning

	Morning
09:30	Introduction and Overview of solar irradiance forecasting models (Elke Lorenz)
10:00	NWP and satellite-based solar forecasting (Elke Lorenz)
10:30	**Coffee Break**
10:45	High-resolution shortest-term forecasting with all sky imagers (Nils Straub -> Elke Lorenz
11:30	From irradiance to PV power forecasting (Elke Lorenz)
12:00	**Lunch**

Agenda TwinSolar Workshop on Solar Forecasting

Morning

12:00	**Lunch**
13:00	Recap and questions (Elke Lorenz)
13:15	Use of probabilistic forecasts for energy management in La Reunion (Josselin Le Gal La Salle)
13:45	Forecast based energy management (Arne Gross)
14:30	**End of workshop**

Agenda TwinSolar Workshop on Solar Forecasting

Concept

Presentations: 30 – 45 Minutes

Questions and/or small tasks for the audience during presentations

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Agenda TwinSolar Workshop on Solar Forecasting

Concept

Presentations: 30 – 45 Minutes

Questions and/or small tasks for you during presentations

Please do not hesitate to ask and comment

- **if you want more details**
- **if something is not clear for you**
- **If you have any comments**

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Introduction, motivation and overview of forecasting models

Elke Lorenz
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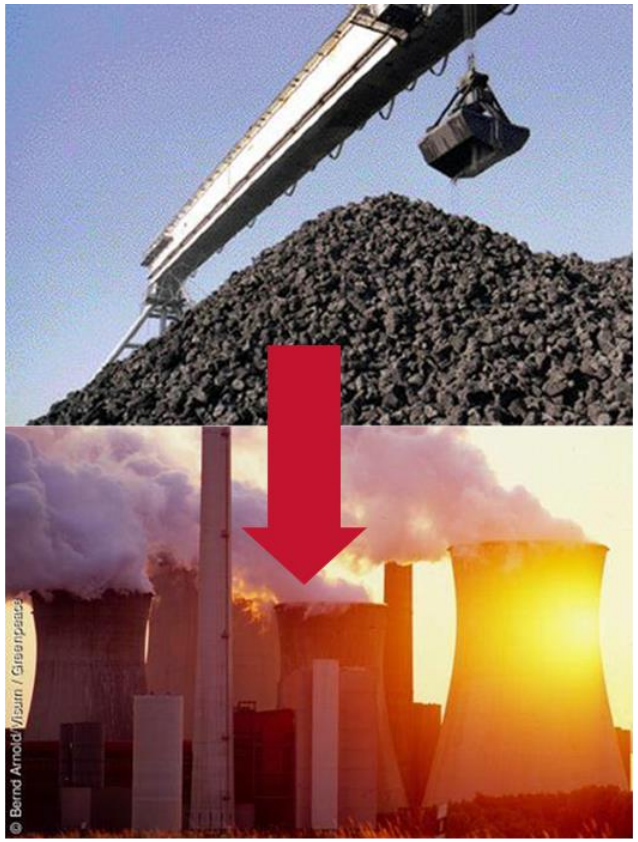
Agenda

1. Motivation
2. Applications
3. Overview of forecasting models

Why solar forecasting?



Source: Heinemann, Energy Meteorology Lecture WS16/17

Conventional power plants:

- Controllable
- Demand driven:
  adaptation to given load profiles easily possible
  with a suitable mix of power plants

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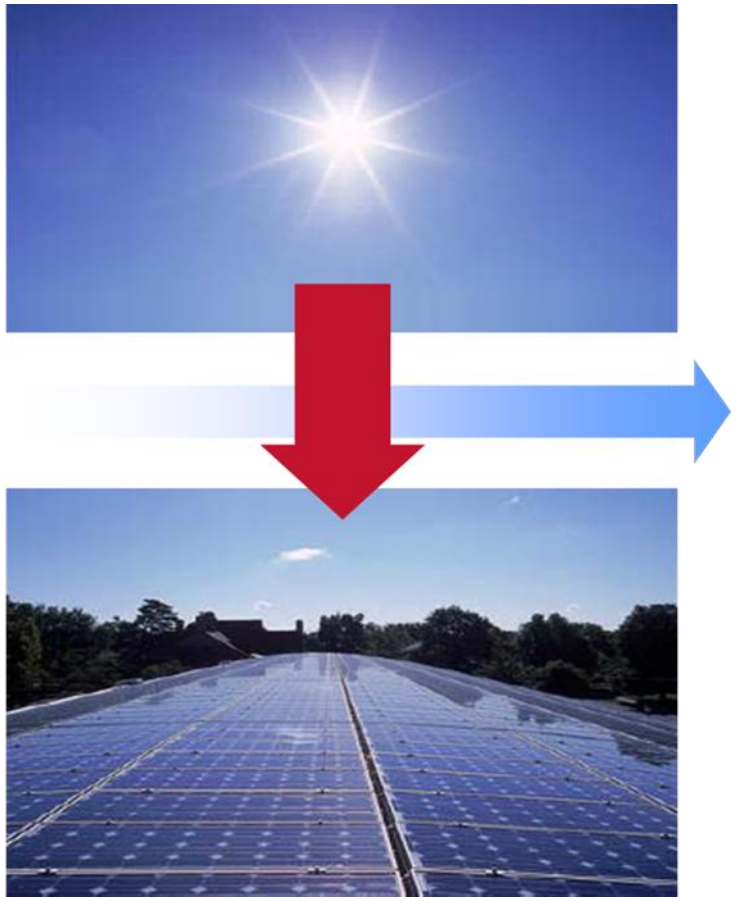
Why solar forecasting?



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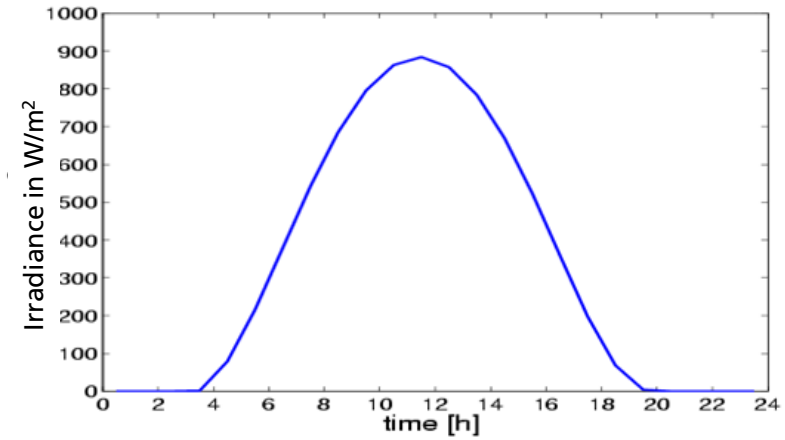
Solar energy

- Supply driven
- Deterministic daily and seasonal course of irradiance



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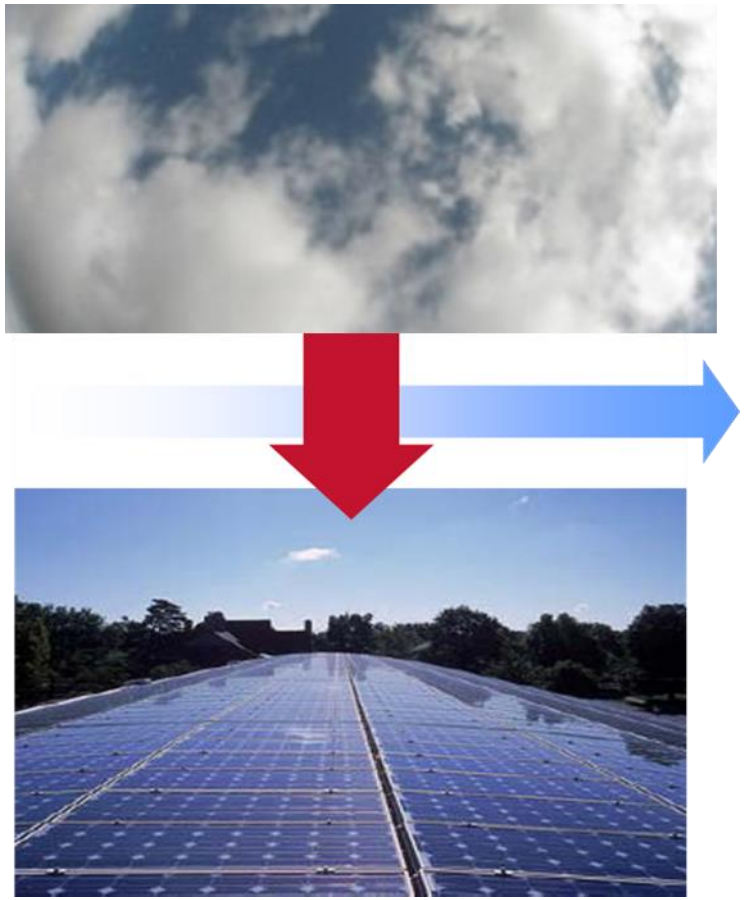
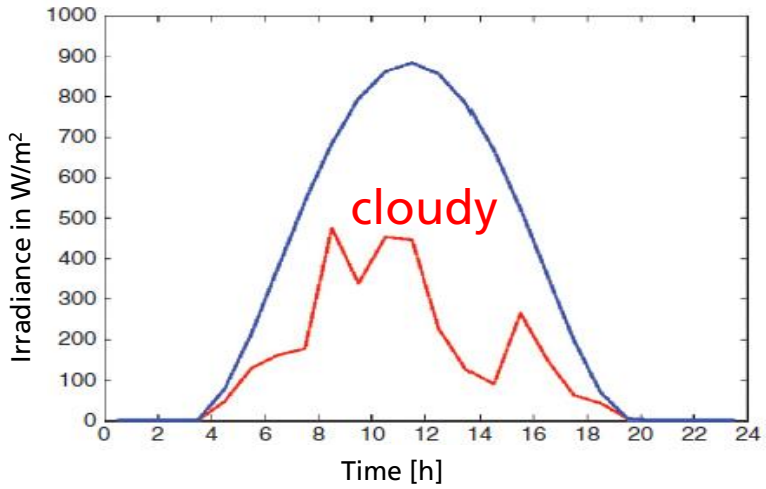
Why solar forecasting?



Source: Heinemann, Energy Meteorology Lecture WS16/17

Solar energy

- Supply driven
- Deterministic daily and seasonal course of irradiance
- Weather dependent



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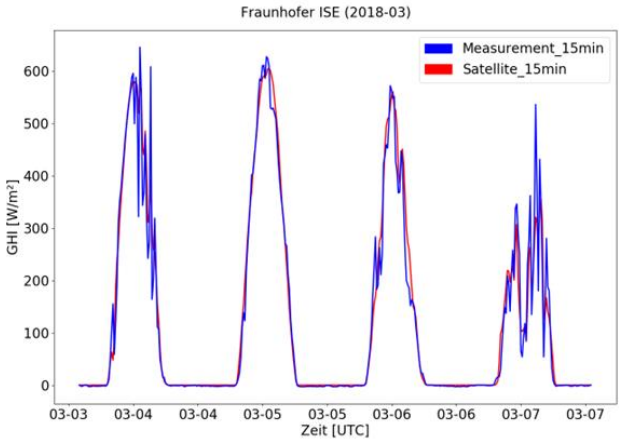
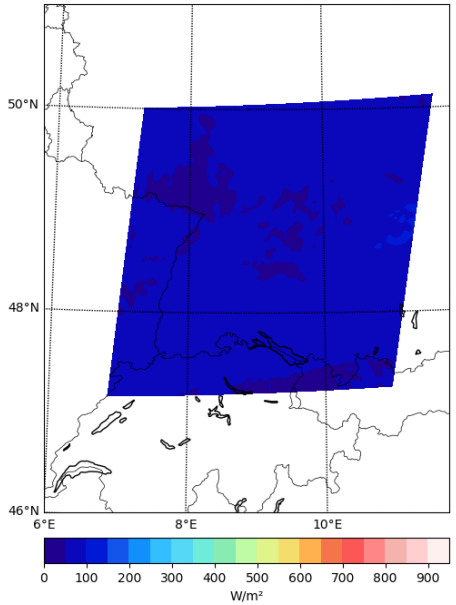
Variability of solar power

An important – and new – constraint for the future energy supply system is the **variability of production rates**.

temporal variability



spatial variability



Irradiance maps for state of Baden-Württemberg

Information on solar irradiance is essential

for efficient integration of solar energy to the energy supply syste

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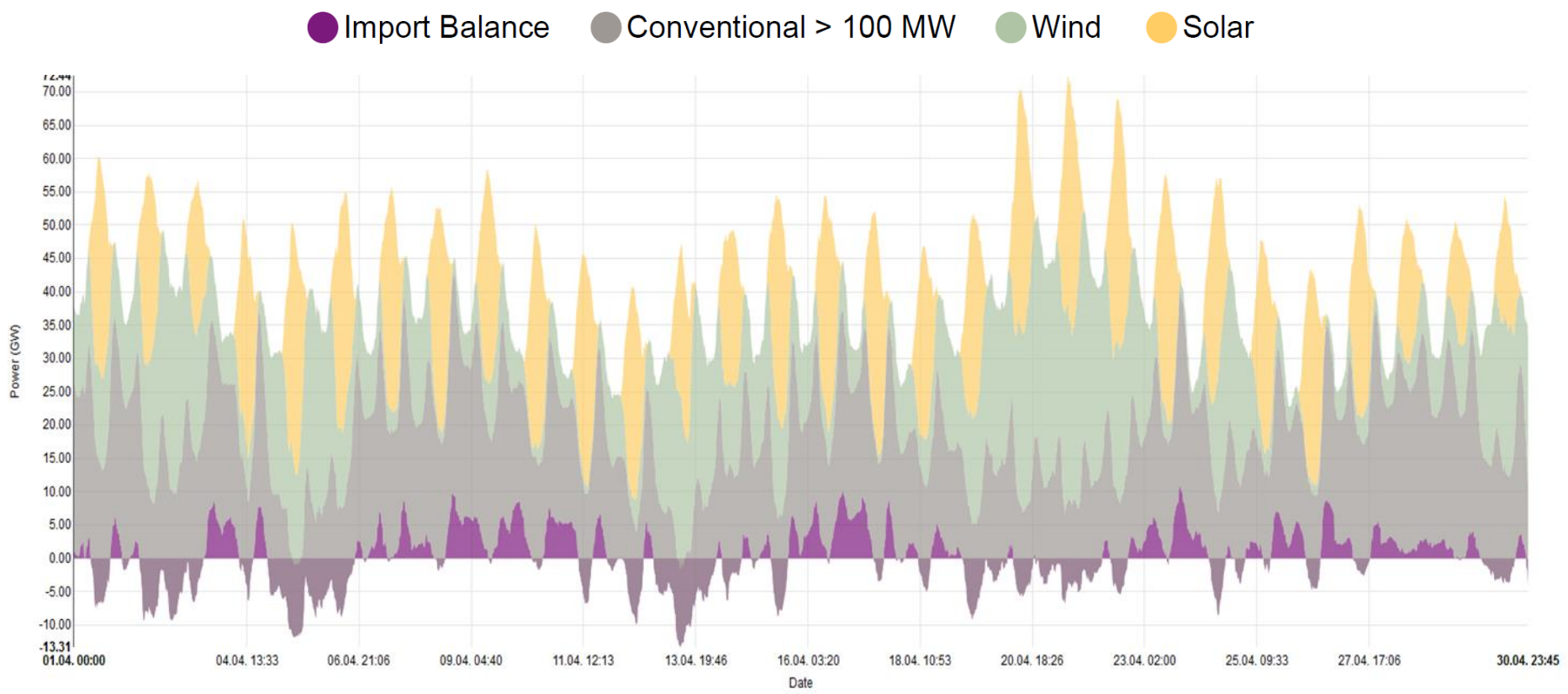
Contribution of PV power in Germany

Electricity generation in April 2020



Source: www.energy-charts.de
Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, EEX;

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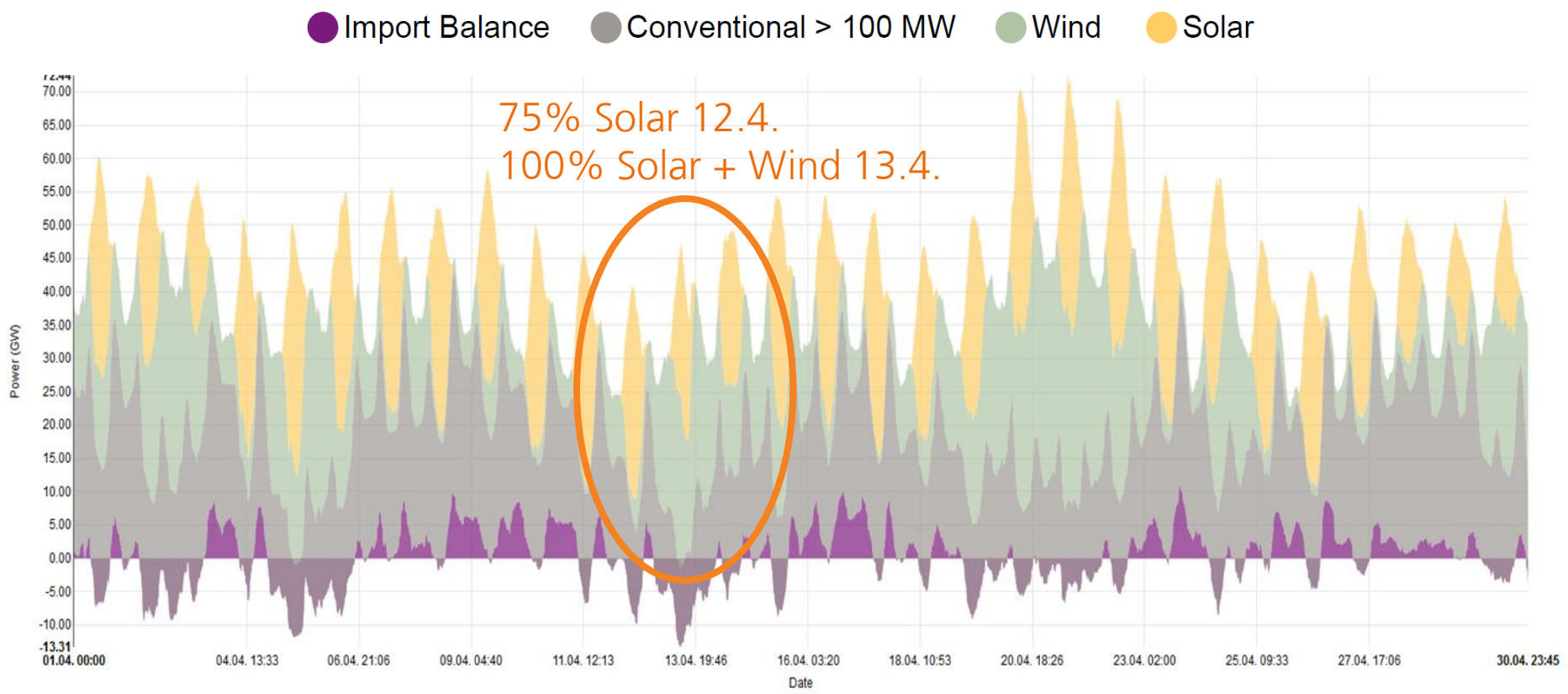
Contribution of PV power in Germany

Electricity generation in April 2020



Source: www.energy-charts.de
Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, EEX;

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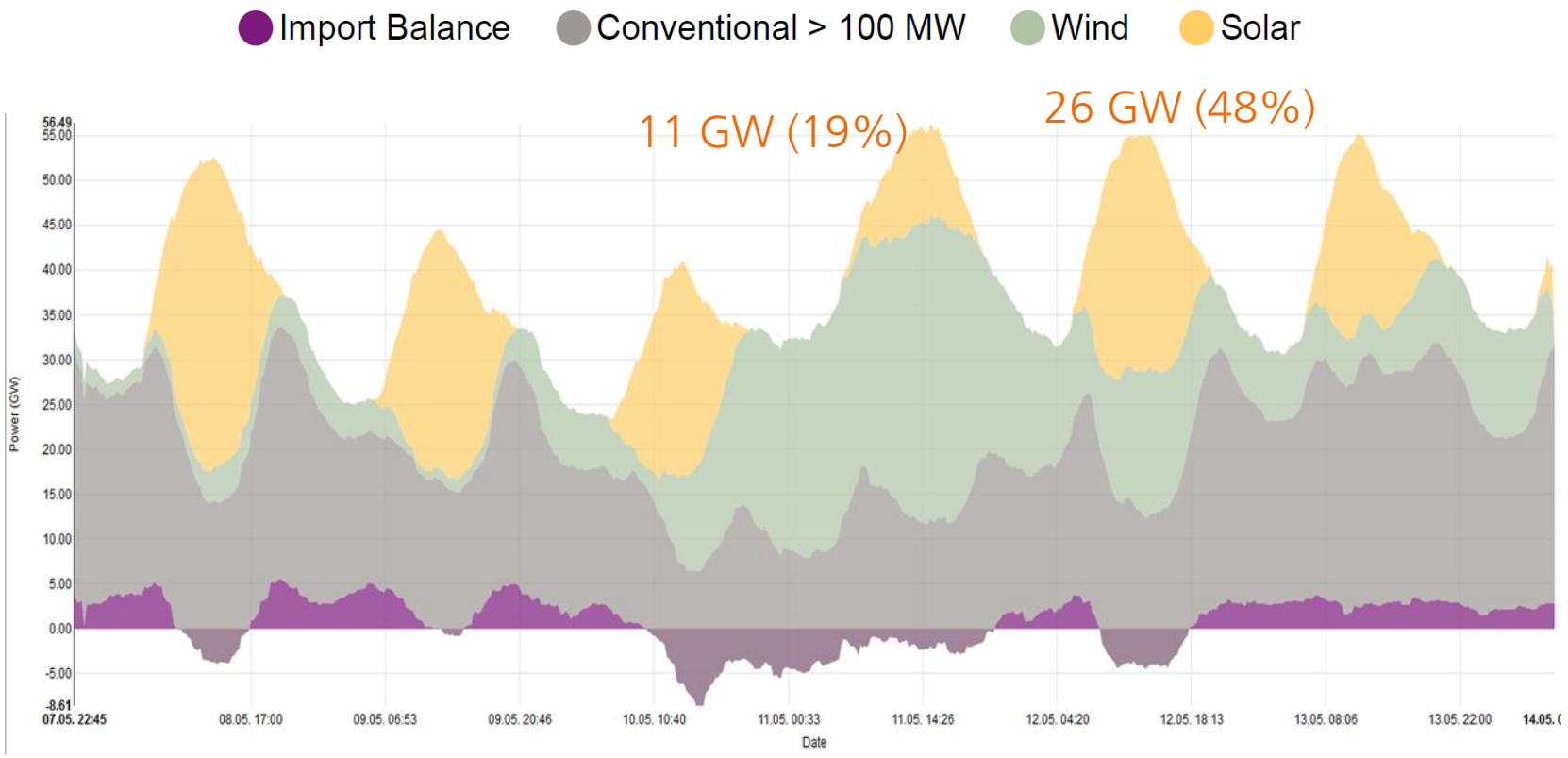
Contribution of PV power in Germany

Electricity generation in Mai 2020



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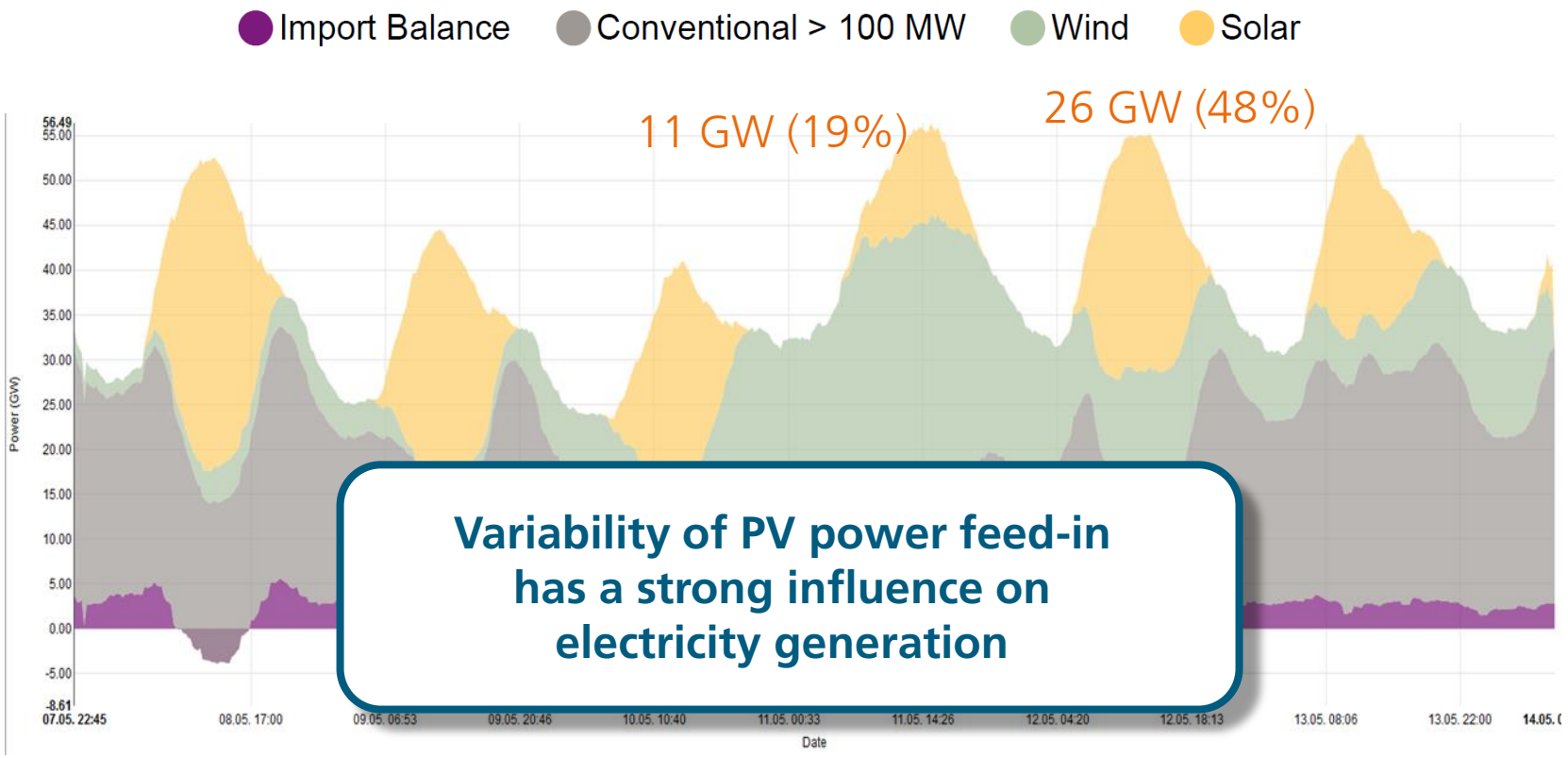
Contribution of PV power in Germany

Electricity generation in Mai 2020



Variability of PV power feed-in has a strong influence on electricity generation

Source: www.energy-charts.de
Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, EEX;

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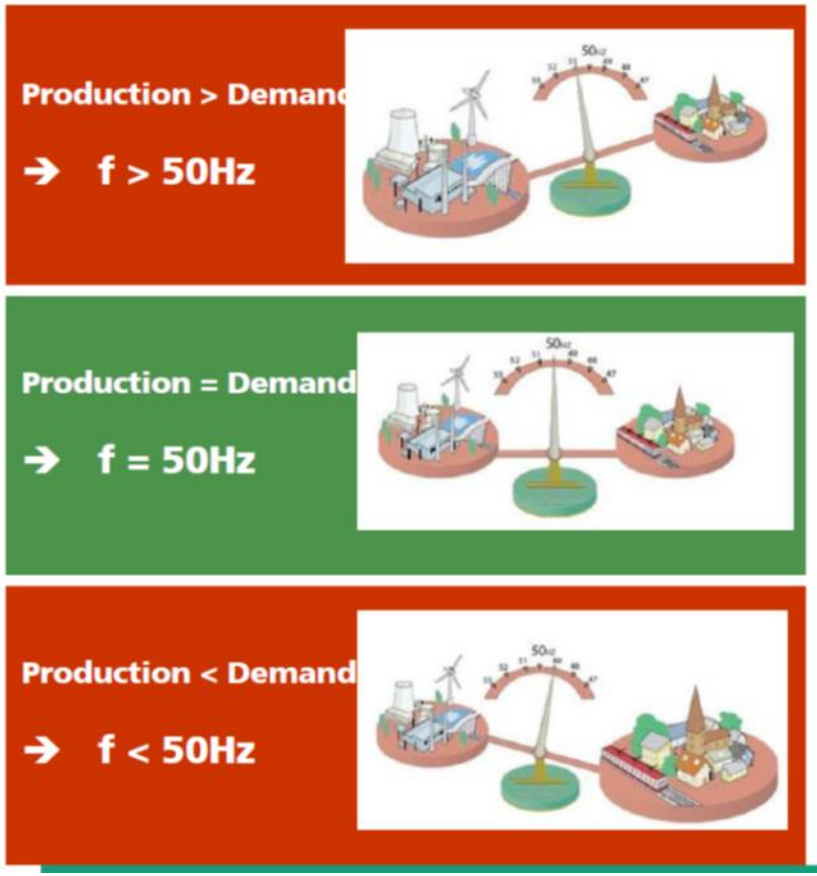
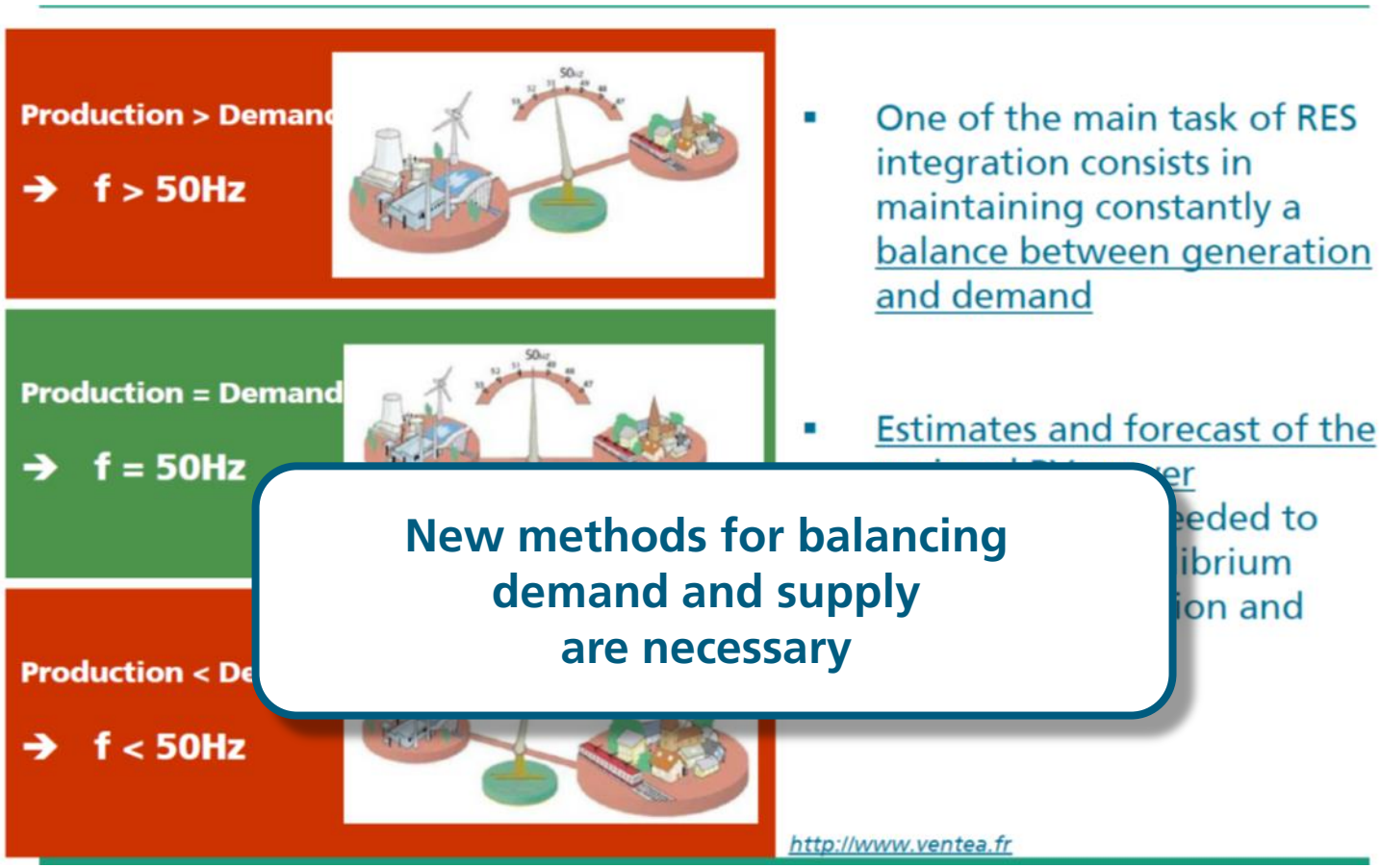
Balancing generation and demand



- One of the main task of RES integration consists in maintaining constantly a balance between generation and demand
- Estimates and forecast of the regional PV power generation are needed to maintain an equilibrium between generation and demand

Source: Y. M Saint-Drenan 2016

Balancing generation and demand



- One of the main task of RES integration consists in maintaining constantly a balance between generation and demand
- Estimates and forecast of the
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New methods for balancing demand and supply are necessary

Source: Y. M Saint-Drenan 2016

Grid integration of PV Power in Germany

Marketing at the European Energy Exchange

by Transmission System Operators

Regional forecasts

Von Francis McLloyd - Eigenes Werk, CC BY-SA 3.,://commons.wikimedia.org/w/index.php?curid=22232969

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Grid integration of PV Power in Germany

Marketing at the European Energy Exchange

By Transmission System Operators

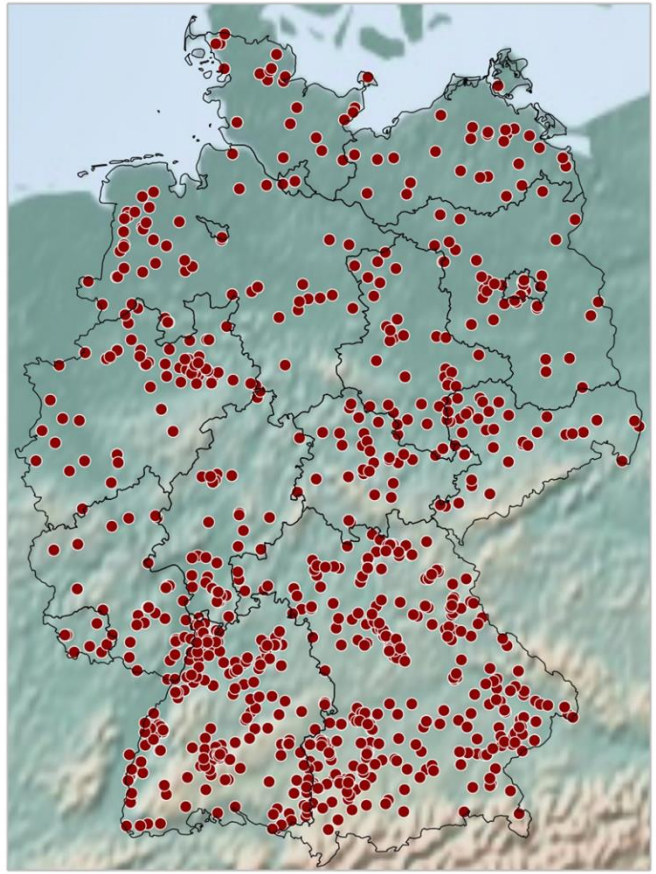
Regional forecasts

Direct marketing

Forecasts for single PV plants

Virtual power plants

Forecasts for clusters of distributed generation systems



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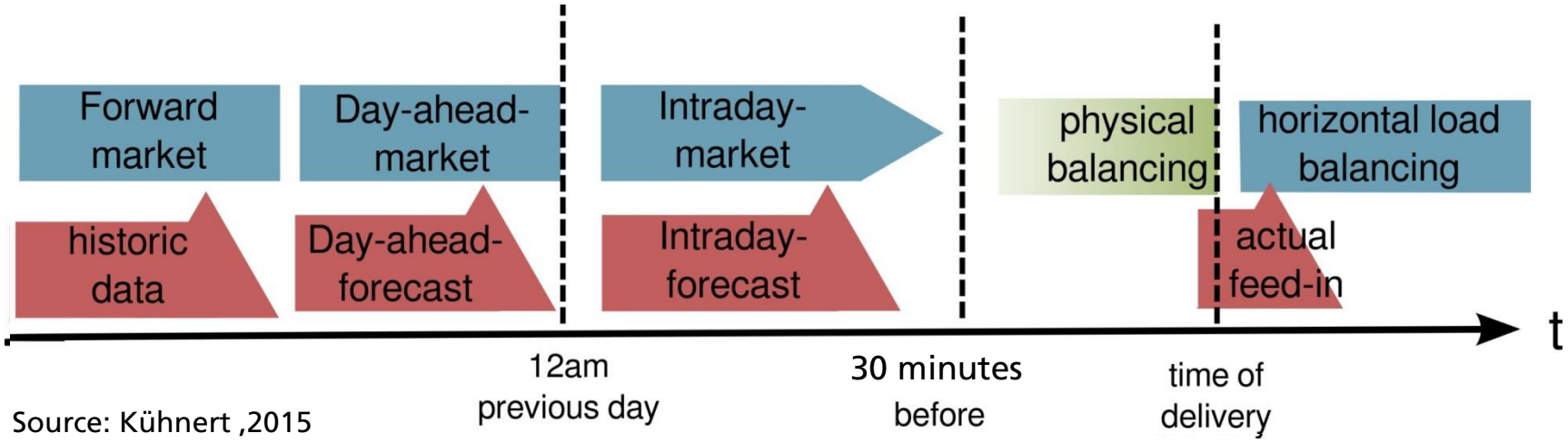
Grid integration of PV Power in Germany

Marketing at the European Energy Exchange

Energy trading and forecast horizons



Source: Kühnert ,2015

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Grid integration of PV Power in Germany

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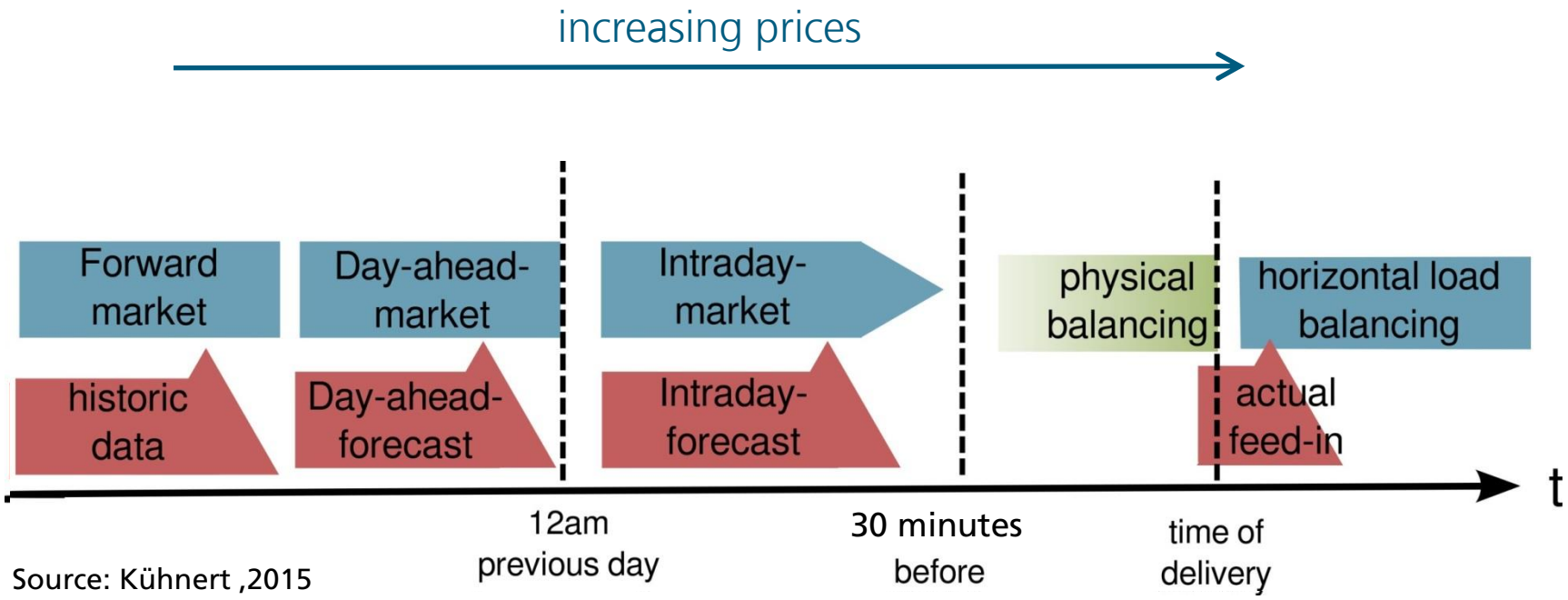
Energy trading and forecast horizons



Source: Kühnert ,2015

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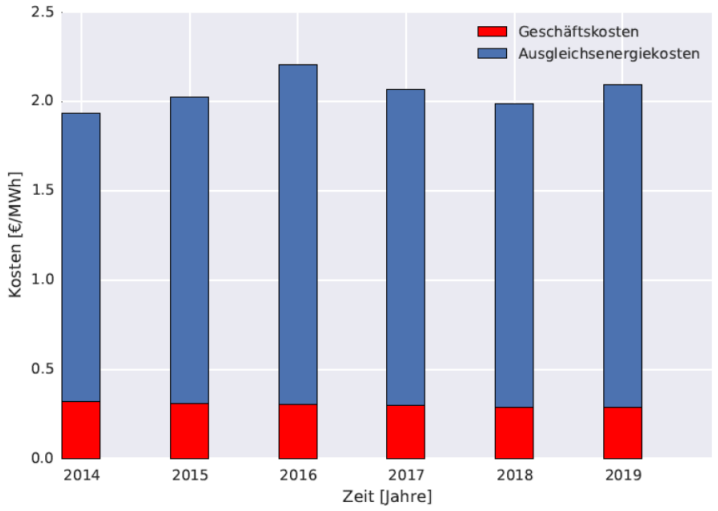
Costs for balancing power

FVEE – Jahrestagung 2016 : Forschung für die Energiewende – Die Gestaltung des Energiesystems

Cost distribution for direct marketing
Example: AMIRIS Simulation over 6 years



Business costs:
- Forecasts
- IT
- trading
- personell

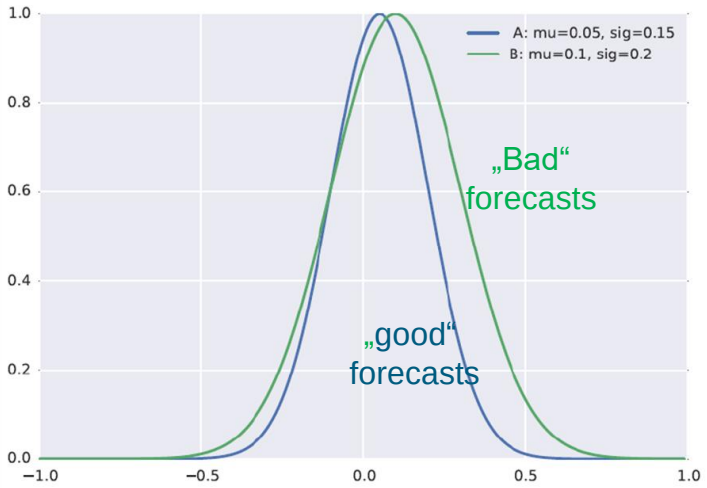
balancing costs

Source: Sehnke et al 2016, translated

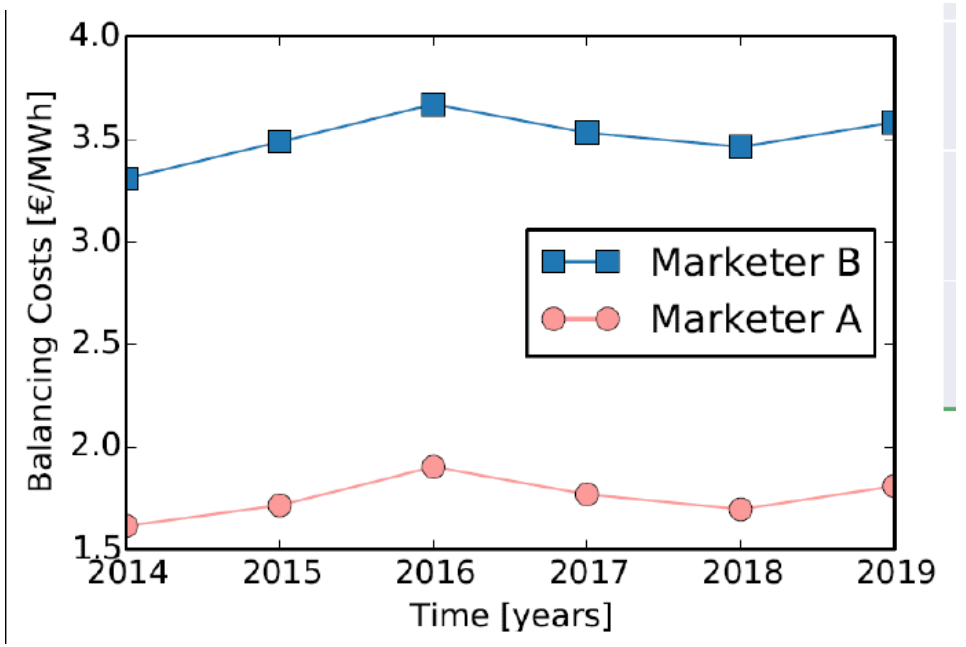
Costs for balancing power

FVEE – Jahrestagung 2016 : Forschung für die Energiewende – Die Gestaltung des Energiesystems

Influence of forecast quality on balancing costs
Example: AMIRIS Simulation over 6 years



- Artifical forecasts: Measurements + random errors with a normal distribution
- Mean values and variance describe forecast quality



Grid integration of PV Power in Germany

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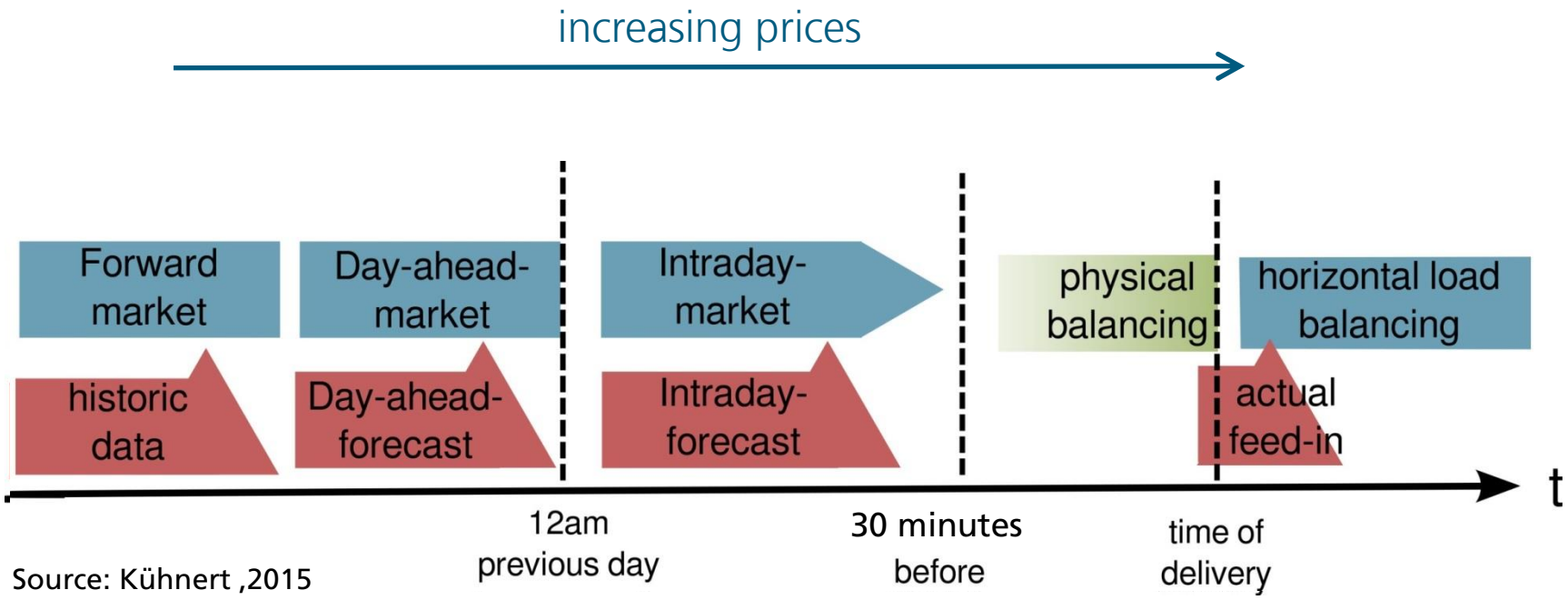

Source: Kühnert ,2015

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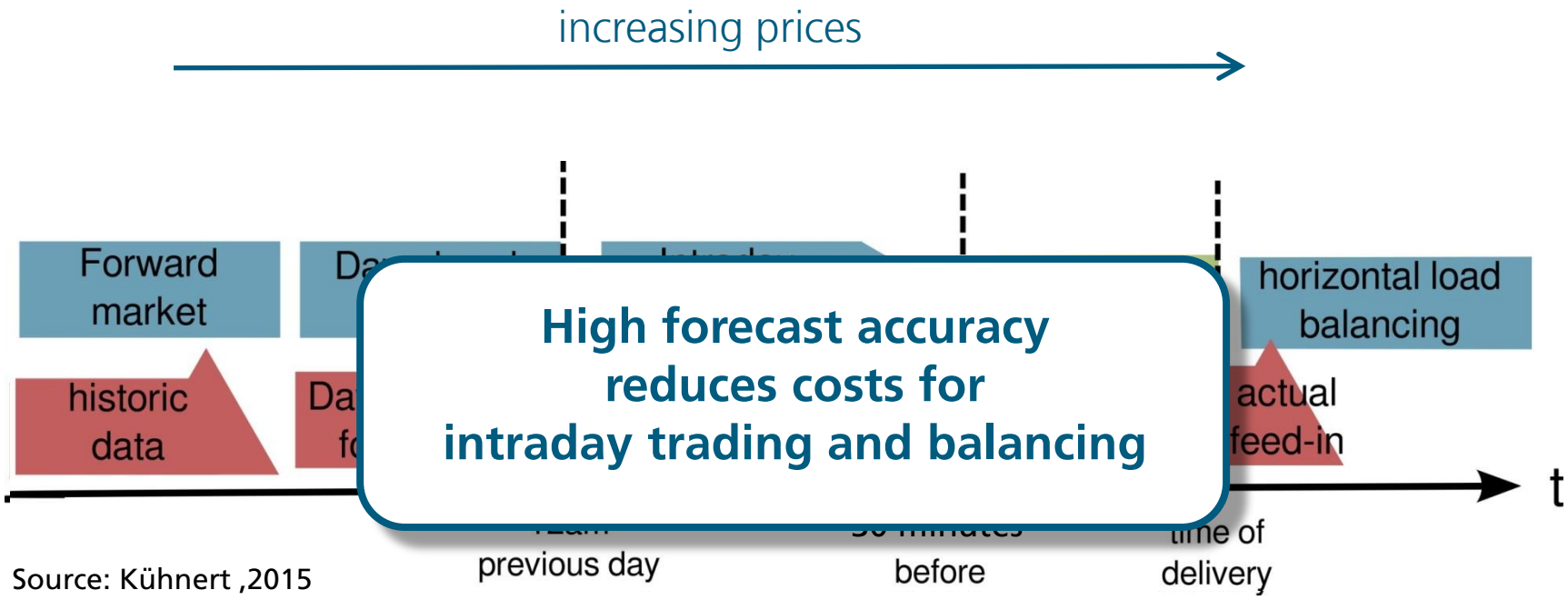

Source: Kühnert ,2015

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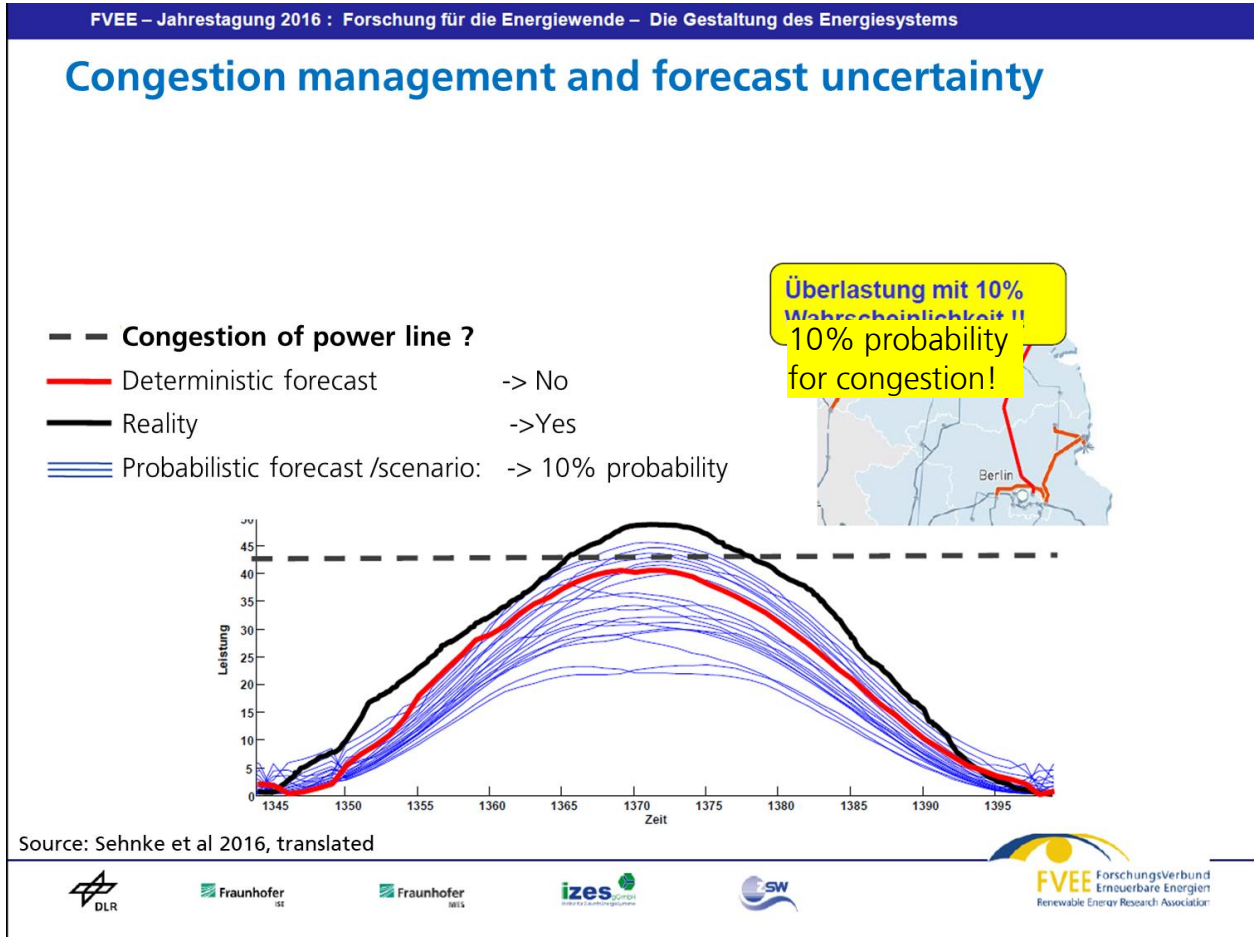
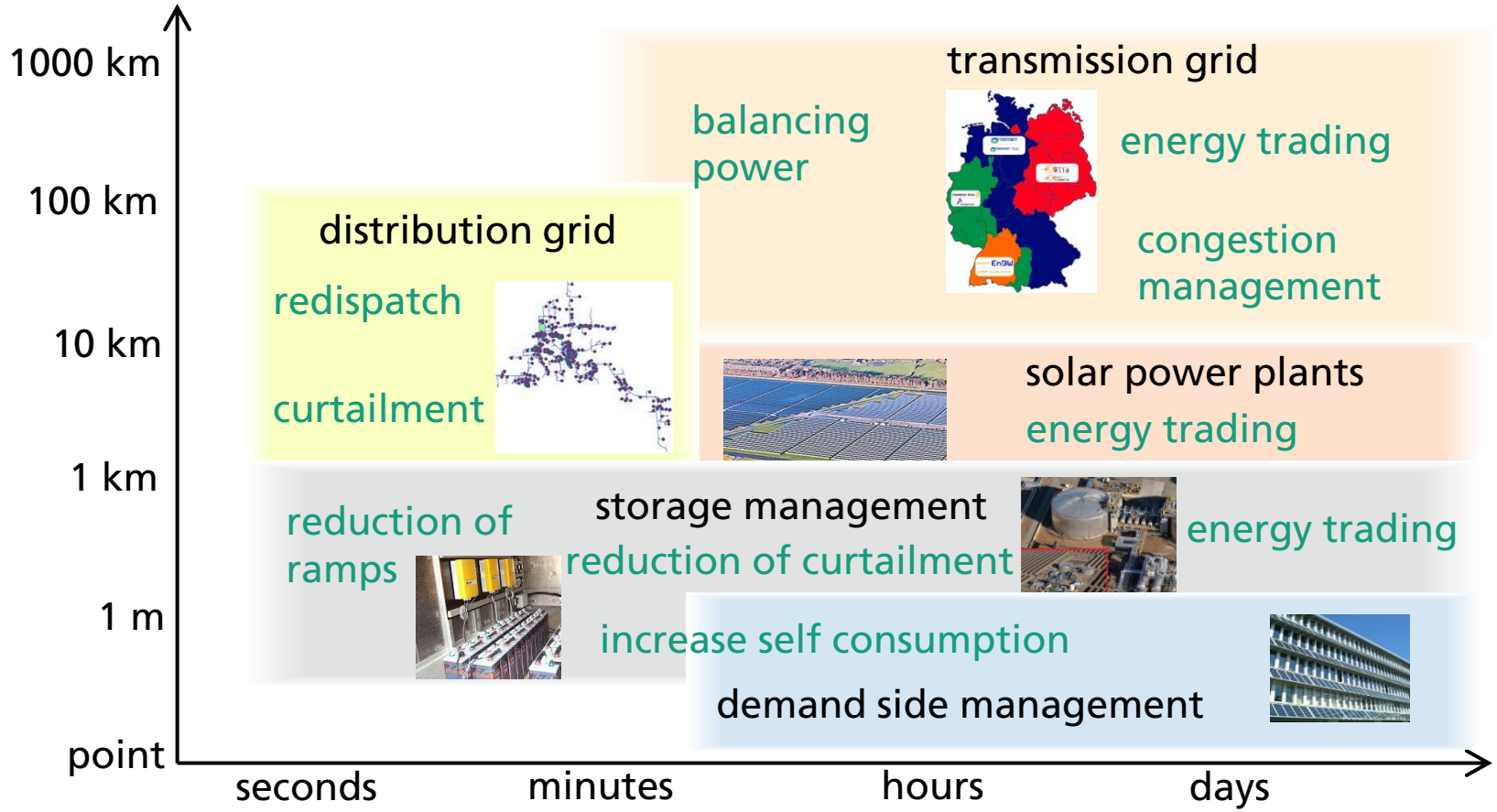
Congestion Magnagement



Solar power forecasting for energy management and system integration



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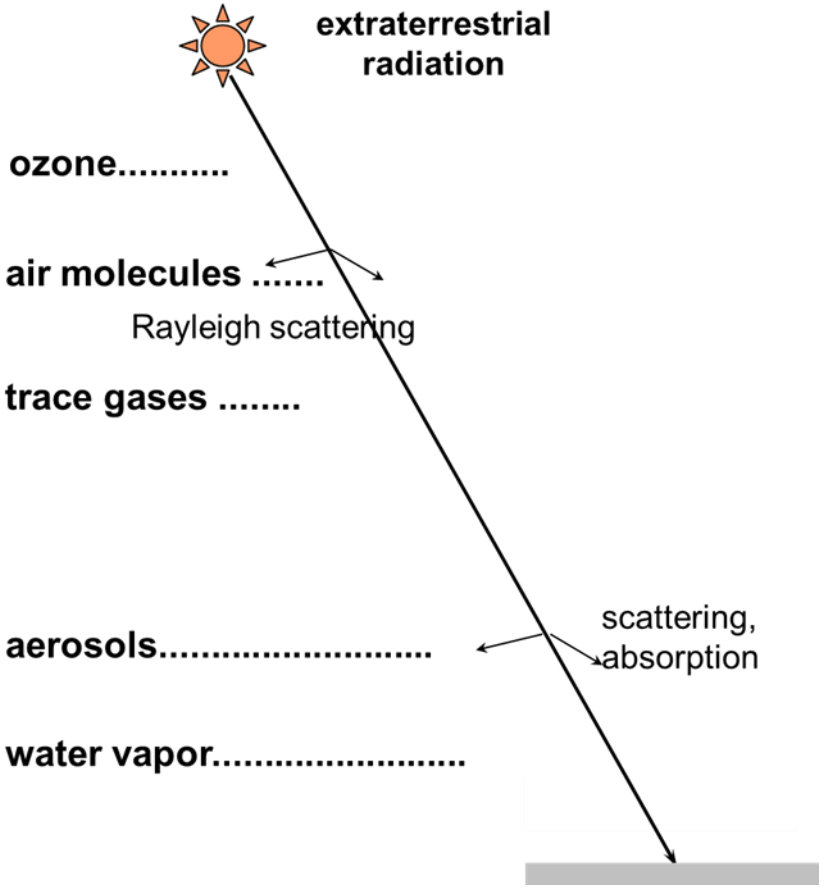
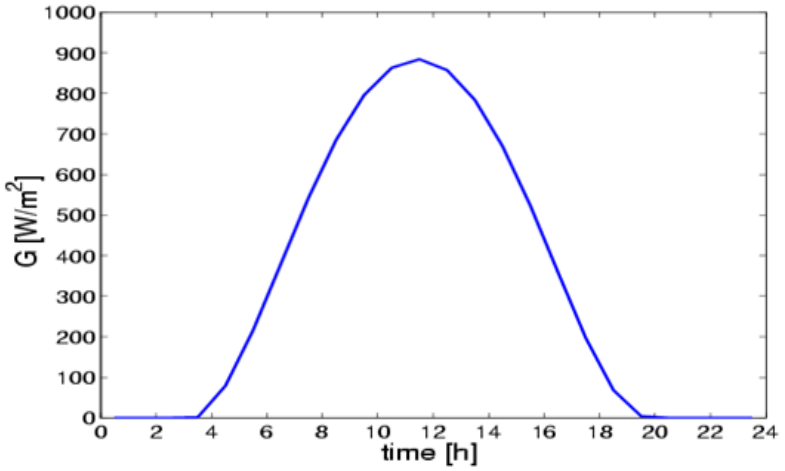
Satellite-based irradiance models

Surface solar irradiance and atmospheric processes



Clear sky irradiance

- Daily/Seasonal course
- atmospheric composition



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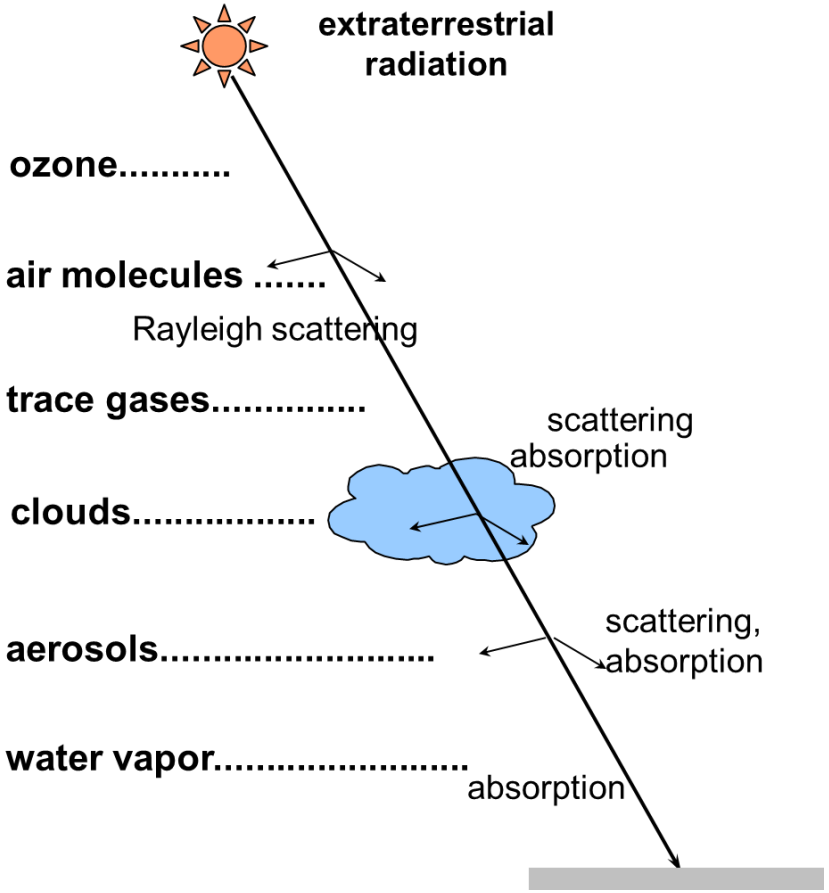
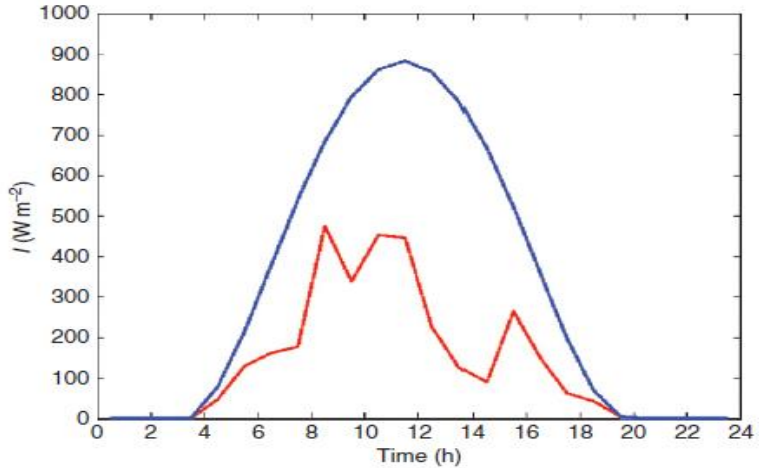
Satellite-based irradiance models

Surface solar irradiance and atmospheric processes



All sky irradiance, including clouds

- Strong impact on solar surface irradiance
- Highly variable



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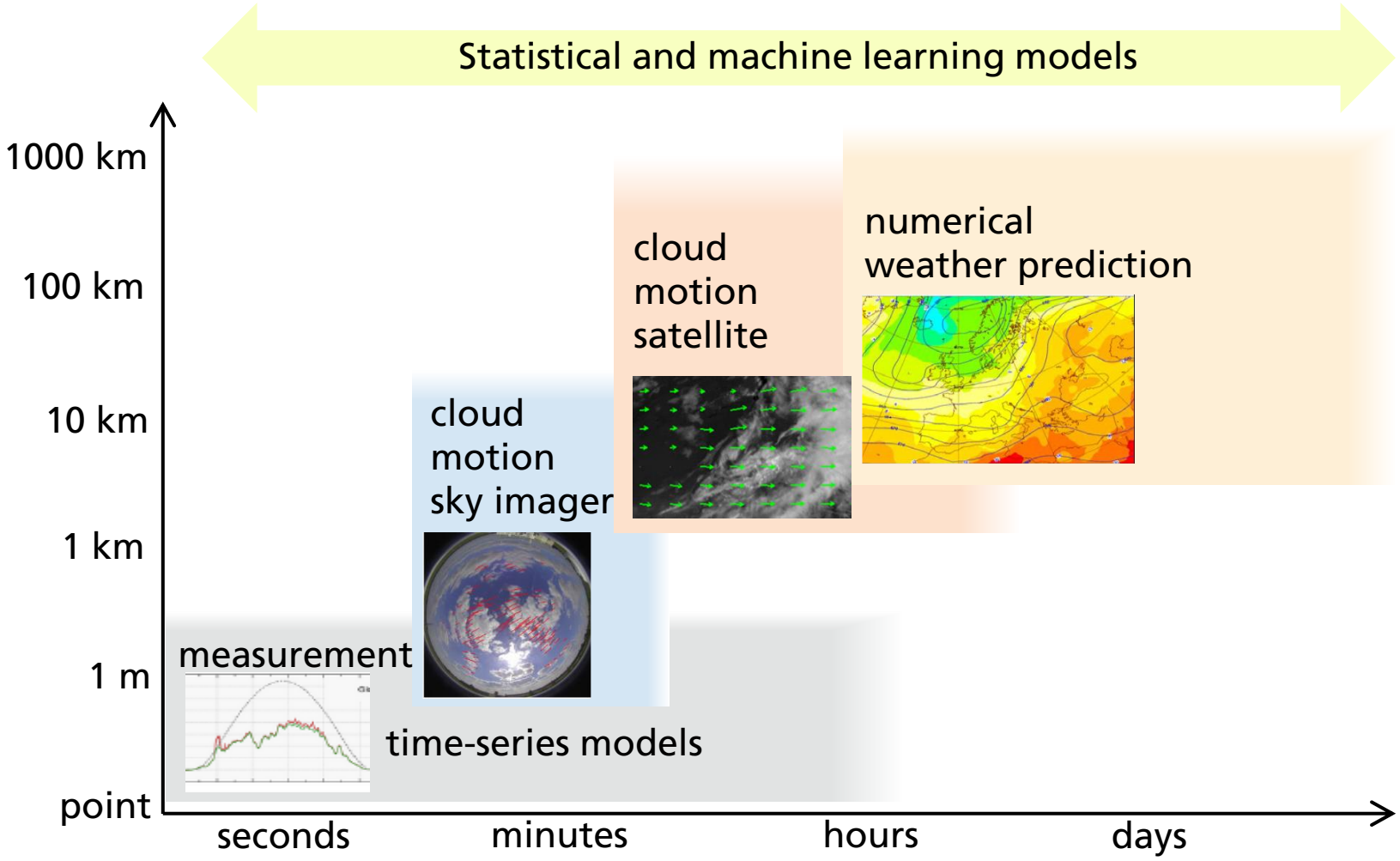
Overview of irradiance prediction models



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Temporal scales of forecasts

Temporal scales: Forecast horizon, Temporal resolution of forecasts,Update Frequency

Spaital sclaes: Spatial resolution, spatial coverage

How ist forecast horizon and spatio/temporal resolution related?

Check for Roskilde at https://www.wetteronline.de/wetter/oldenburg

- Forecasts up to 90 minutes
- Forecasts for today and tomorrow (heute/morgen)
- Forecasts for the more thatn 2 days ahead: morning

Temporal scales of forecasts

Temporal scales: Forecast horizon, Temporal resolution of forecasts,Update Frequency

Spaital sclaes: Spatial resolution, spatial coverage

How ist forecast horizon and spatio/temporal resolution related?

Check for Roskilde at https://www.wetteronline.de/wetter/oldenburg

- Forecasts up to 90 minutes: 15 minutes
- Forecasts for today and tomorrow (heute/morgen): hourly
- Forecasts for the more thatn 2 days ahead: morning, afternoon, evening, night

Thank you for your attention!

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