Smart4RES

Towards the next generation forecasting tools of renewable energy production

George Kariniotakis, Simon Camal | ARMINES, MINES ParisTech, Center PERSEE
in behalf of the Smart4RES team (see abstract for list of names).
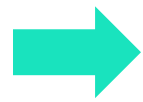
Introduction

Context

- Renewable Energy Sources (RES) forecasting is a mature technology with operational tools and services used by different actors

- However, there are gaps and bottlenecks in the value/model chain...

- Significant research worldwide

Number of publications with "solar" or " photovoltaic" and " forecast " in Scopus Database
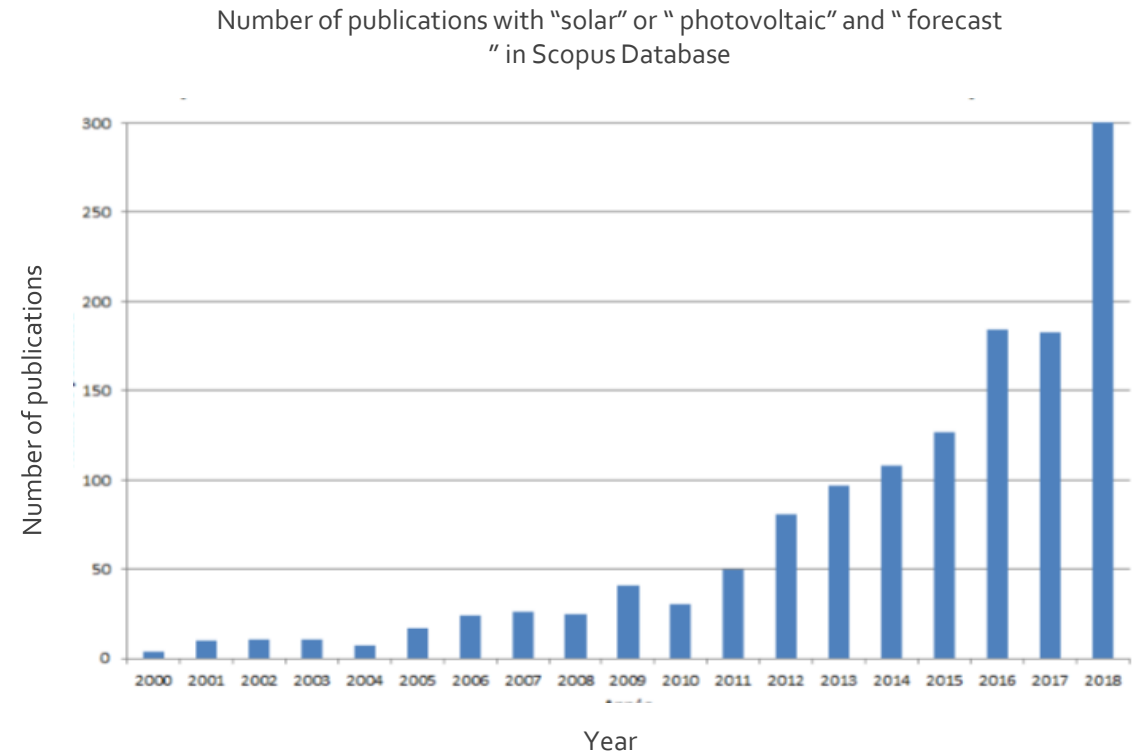
The RES forecasting model & value chain
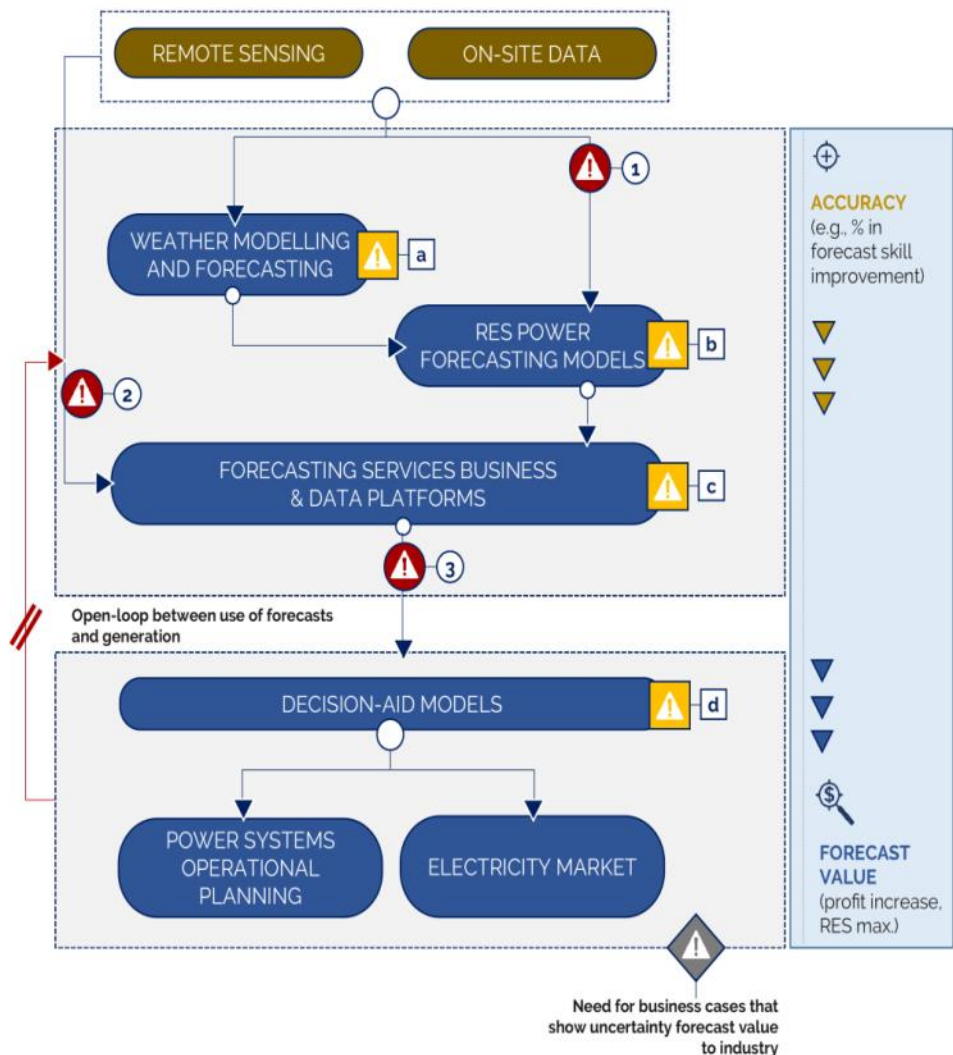
Power, weather variables measurements, satellite images, sky cameras, radars, lidars....

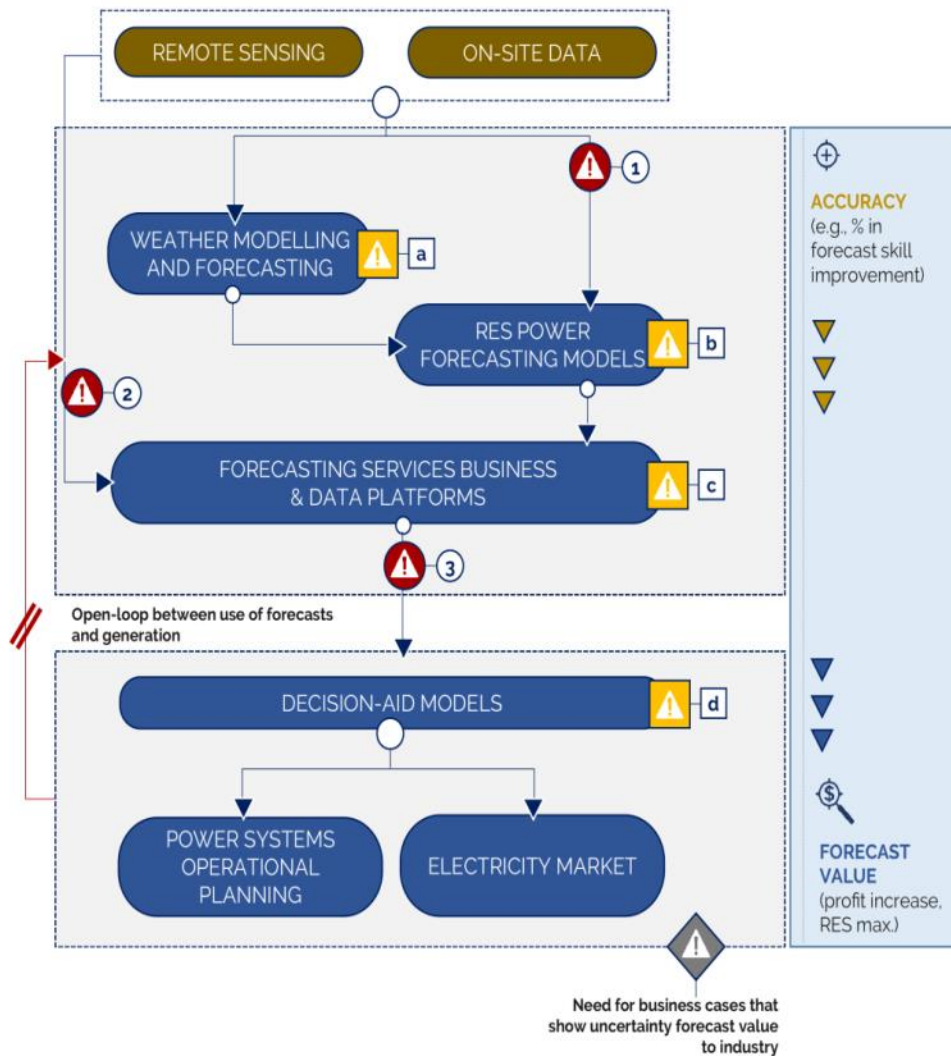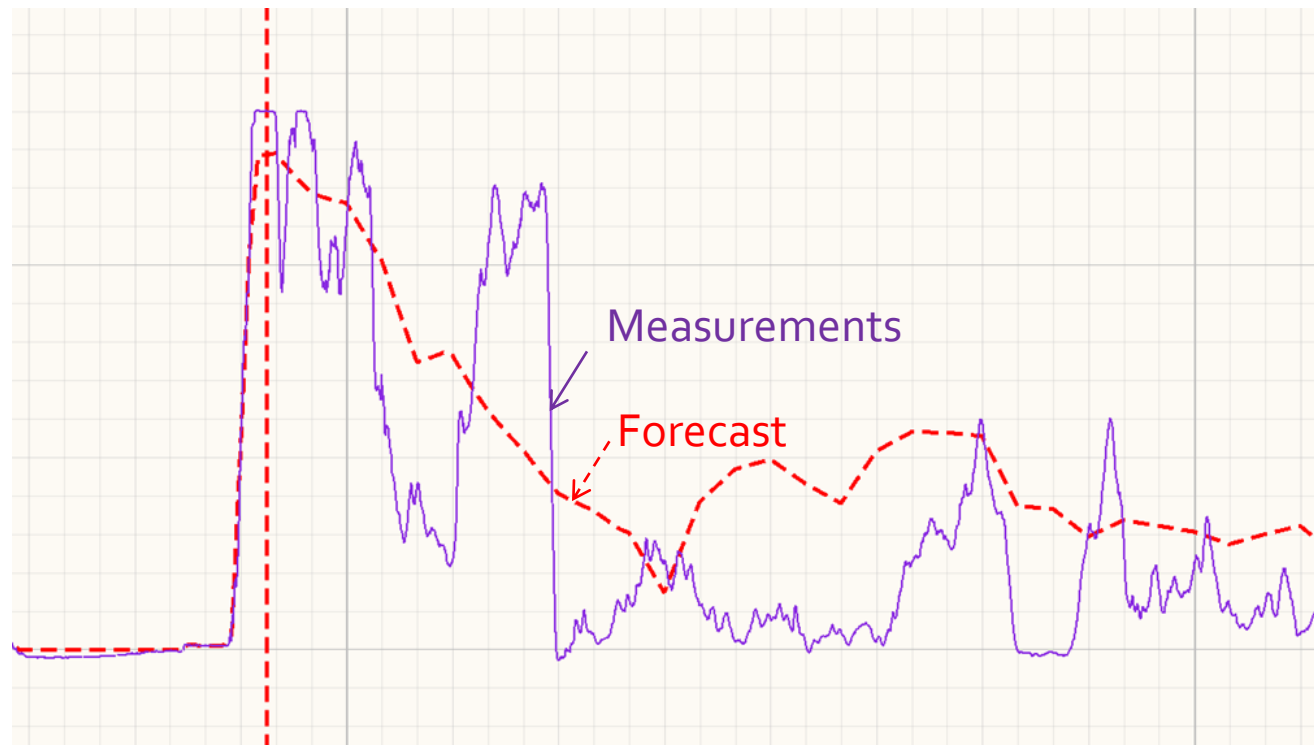Forecasts of RES production for the next minutes up to the next days

A "mature technology", but...

REMOTE SENSING   **ON-SITE DATA**

⚠ ①

WEATHER MODELLING AND FORECASTING ⚠ a

RES POWER FORECASTING MODELS ⚠ b

⚠ ②

FORECASTING SERVICES BUSINESS & DATA PLATFORMS ⚠ c

⚠ ③

Open-loop between use of forecasts and generation

DECISION-AID MODELS ⚠ d

POWER SYSTEMS OPERATIONAL PLANNING   **ELECTRICITY MARKET**

⊕ **ACCURACY** (e.g., % in forecast skill improvement)

▼
▼
▼

▼
▼
▼

💲 **FORECAST VALUE** (profit increase, RES max.)

⚠ Need for business cases that show uncertainty forecast value to industry

...Forecasting accuracy remains low

Measurements

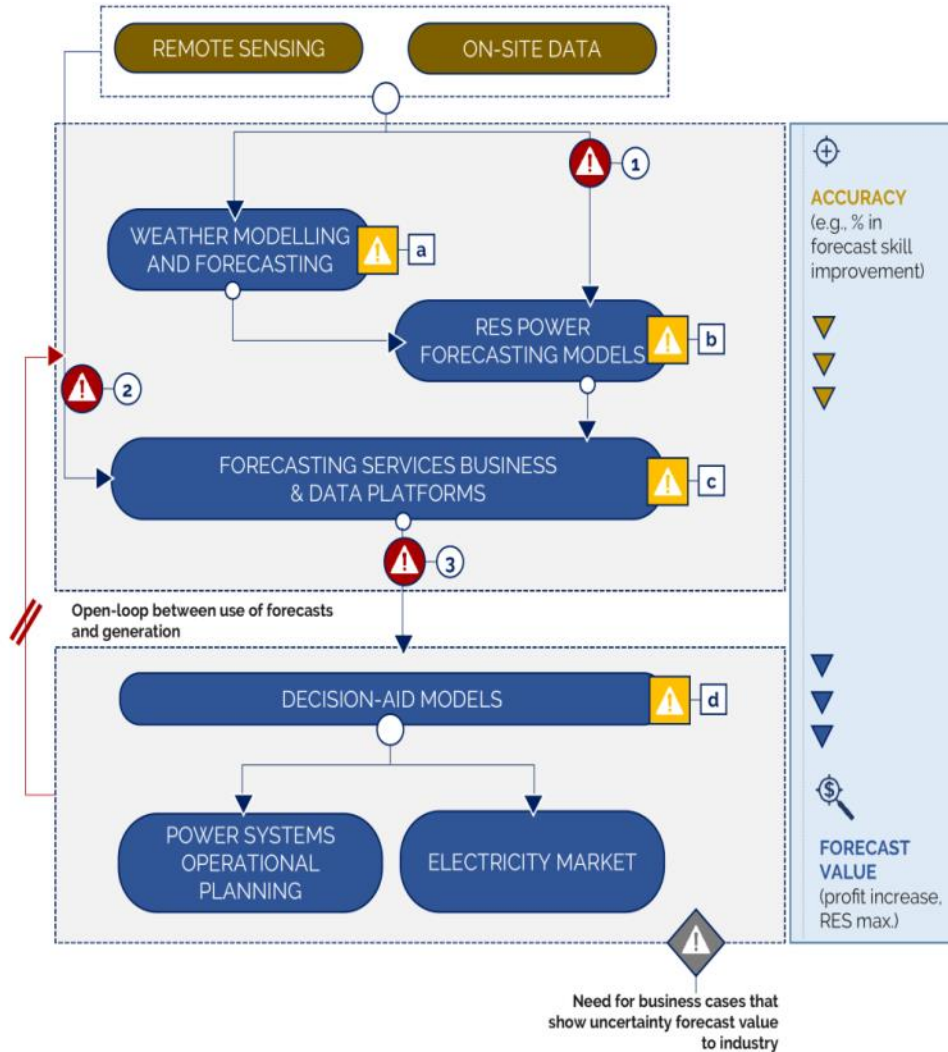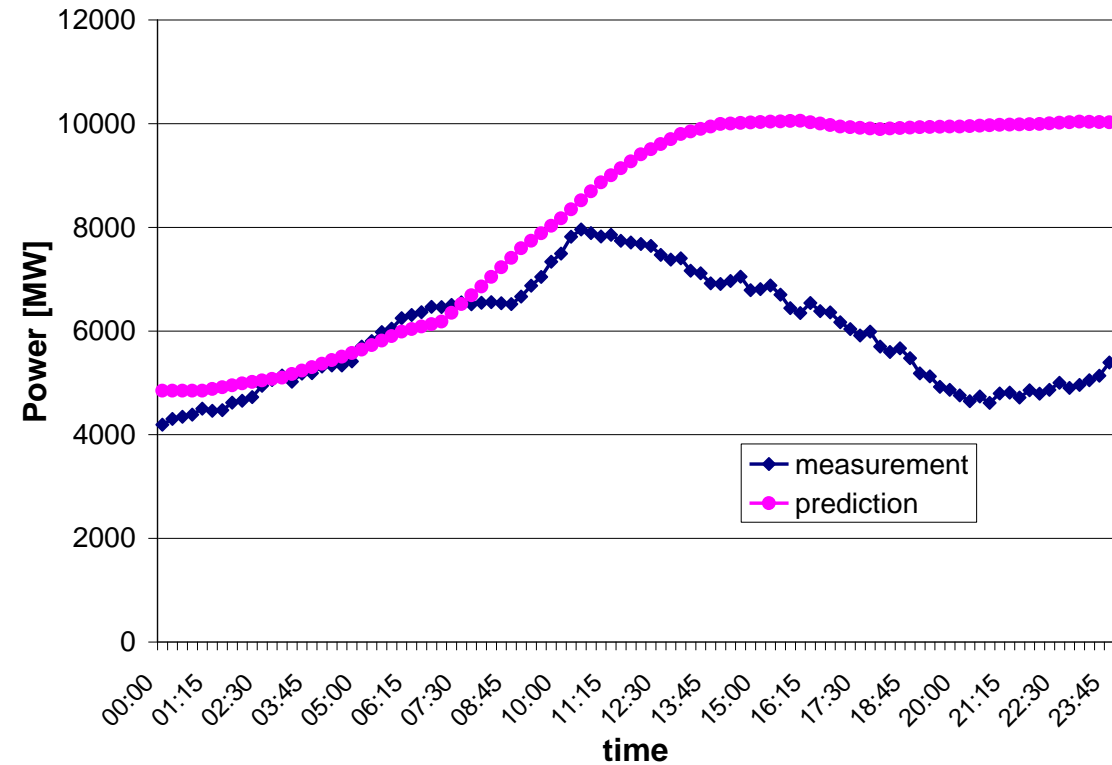Forecast

Power output of a wind farm on a day
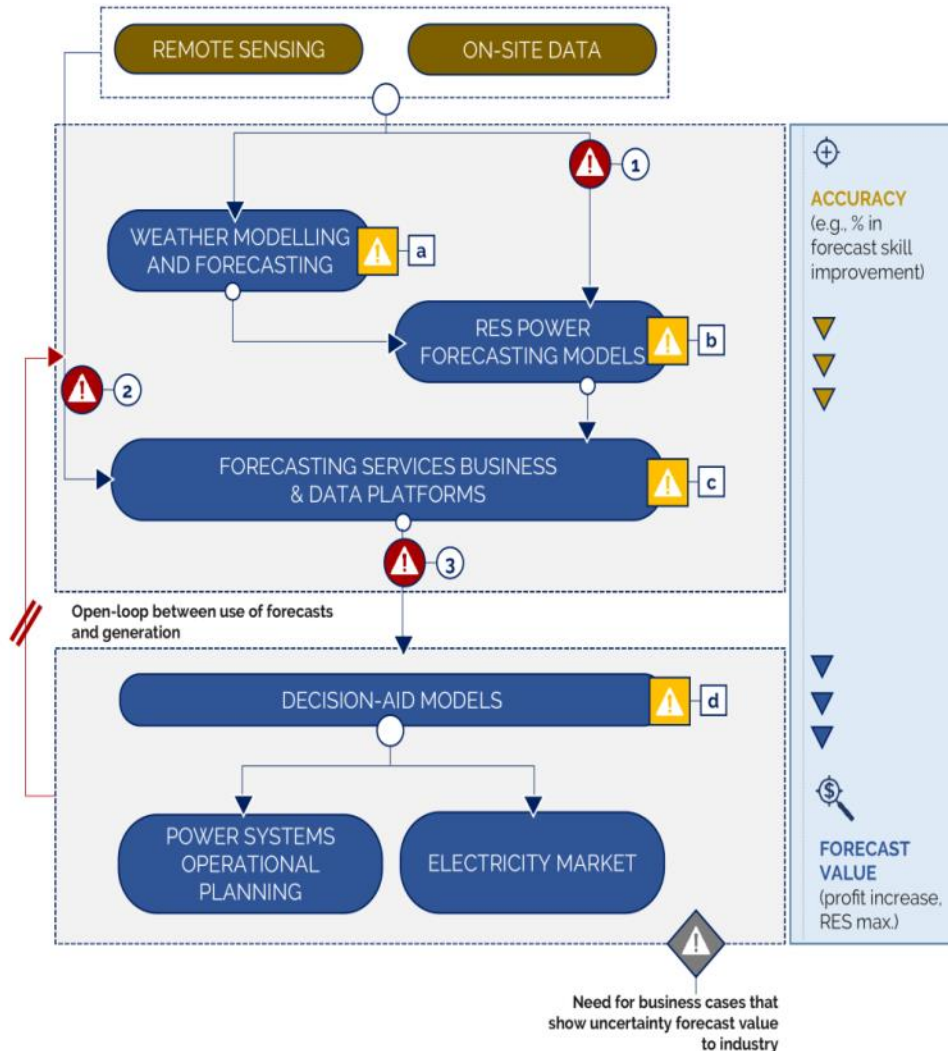
A "mature technology", but...

...Forecasting accuracy remains low

Example of aggregated production in Germany:
Path of low-pressure system was different than predicted,
Max. error: 5500 MW...

A "mature technology", but...

## ...Forecasting accuracy remains low

Impacts

- Imbalance costs for traders
- Increased need for costly remedies (reserves, storage, demand response...)
- Limited capacity to support the grid with reliably ancillary services (AS)
- Lower RES acceptability by operators
- RES curtailment
- Higher maintenance costs for RES plants
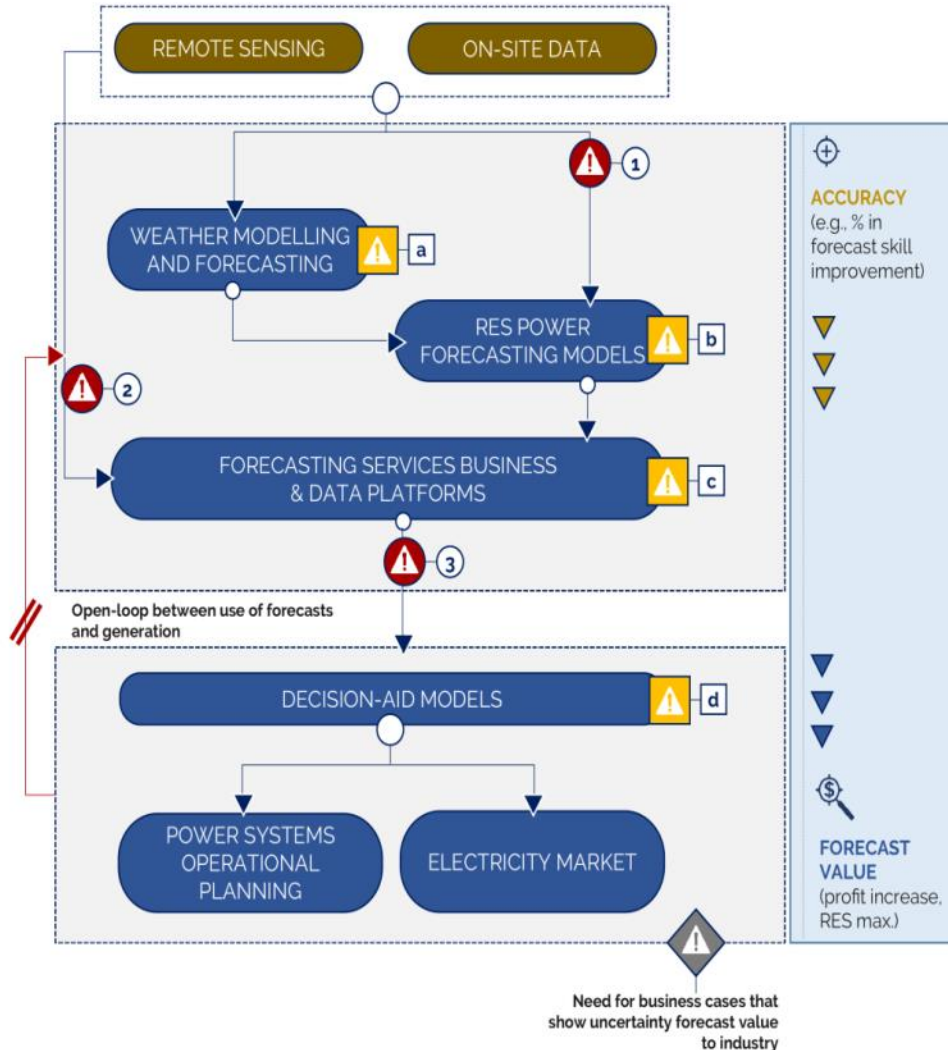- .....

A "mature technology", but…
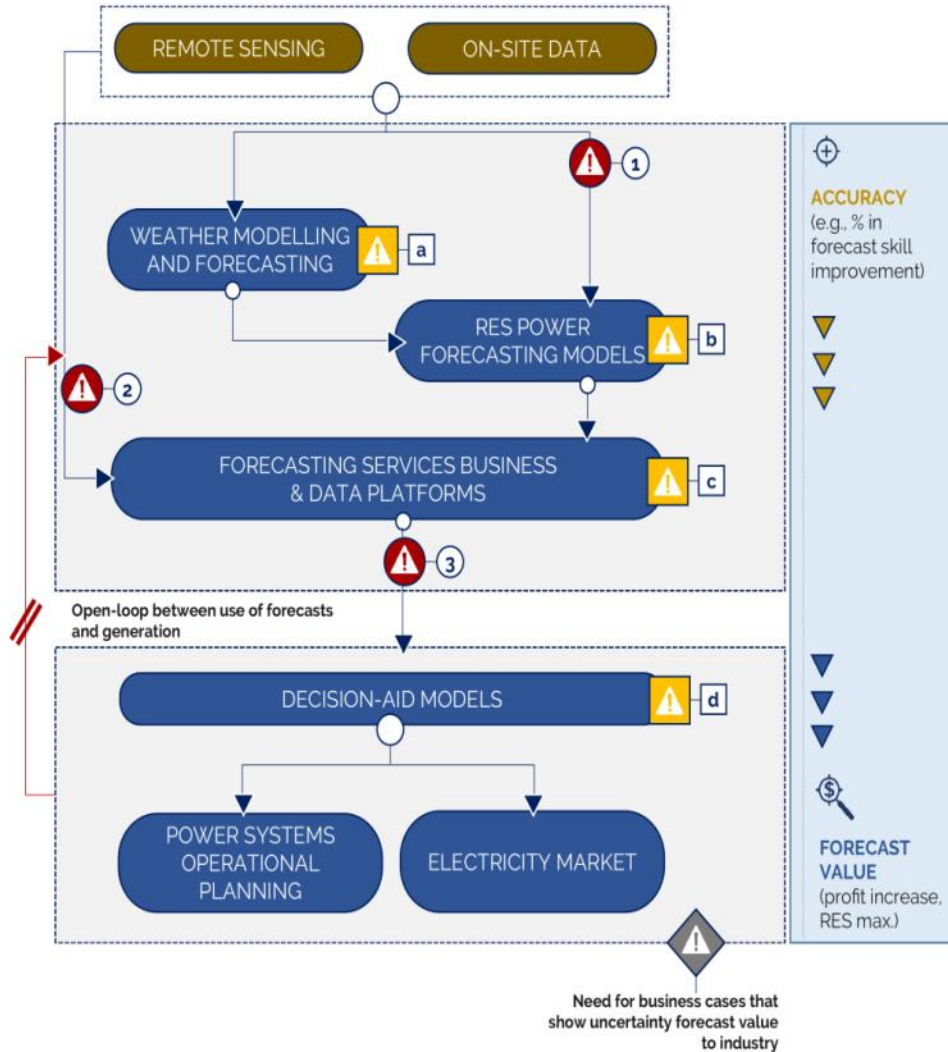
… **New forecasting needs emerge for applications like provision of ancillary services by VPPs**
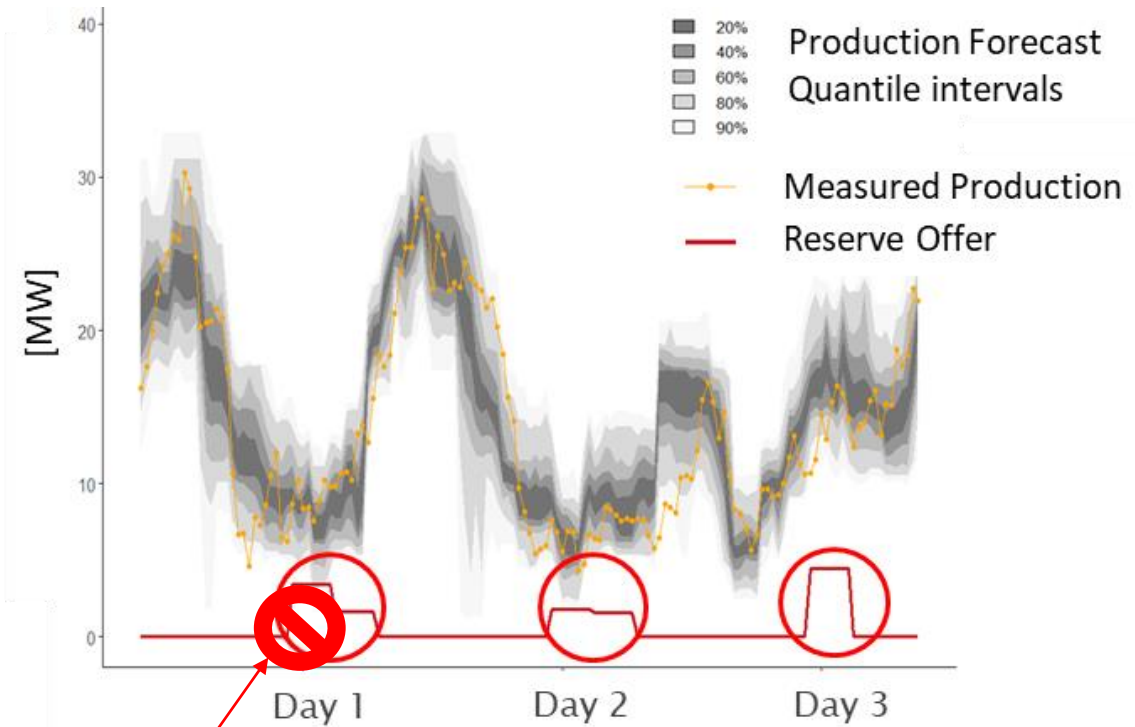
If service can not be fulfilled, TSO may charge high penalties

BOTTLENECKS IN THE CONNECTION:

① Lack of open data (privacy issues)

② Lack of price-based incentives to share data

③ Accuracy remains low & lack of standardization

BOTTLENECKS IN THE MODELS:

a — Need for NWP products adapted to RES use cases

b — Limitation of models to exploit large and heterogeneous data

c — Decaying commercial value of forecast products

d — Need for models adequate in high RES integration scenarios and digitalization of the energy sector

The consortium

6 countries, 12 partners

- Budget: 4 Mio€
- Duration: 3.5 years, 11/2019 - 04/2023

End-users / Industry / Research / Universities / Meteorologists

The project

Our Vision: Achieve **outstanding improvement** in RES predictability through **a holistic approach**, that covers the **whole model and value chain** related to RES forecasting (from weather prediction up to end-use applications).

Objectives

Overarching objective: Propose and test a number of forecasting and decision-aid tools to cover gaps and/or prepare the energy system of 2030 and beyond

1/ Requirements for forecasting technologies to enable near 100% RES penetration.

2/ RES-dedicated weather forecasting with **10-15% improvement** using various sources of data and very high-resolution approaches.

3/ New generation of **RES production forecasting tools** enabling **15% improvement** in performance

4/ Streamline the process of getting optimal value through new forecasting products, datamarket places, and novel business models.

5/ New data-driven optimisation and decision-aid tools for RES and storage.
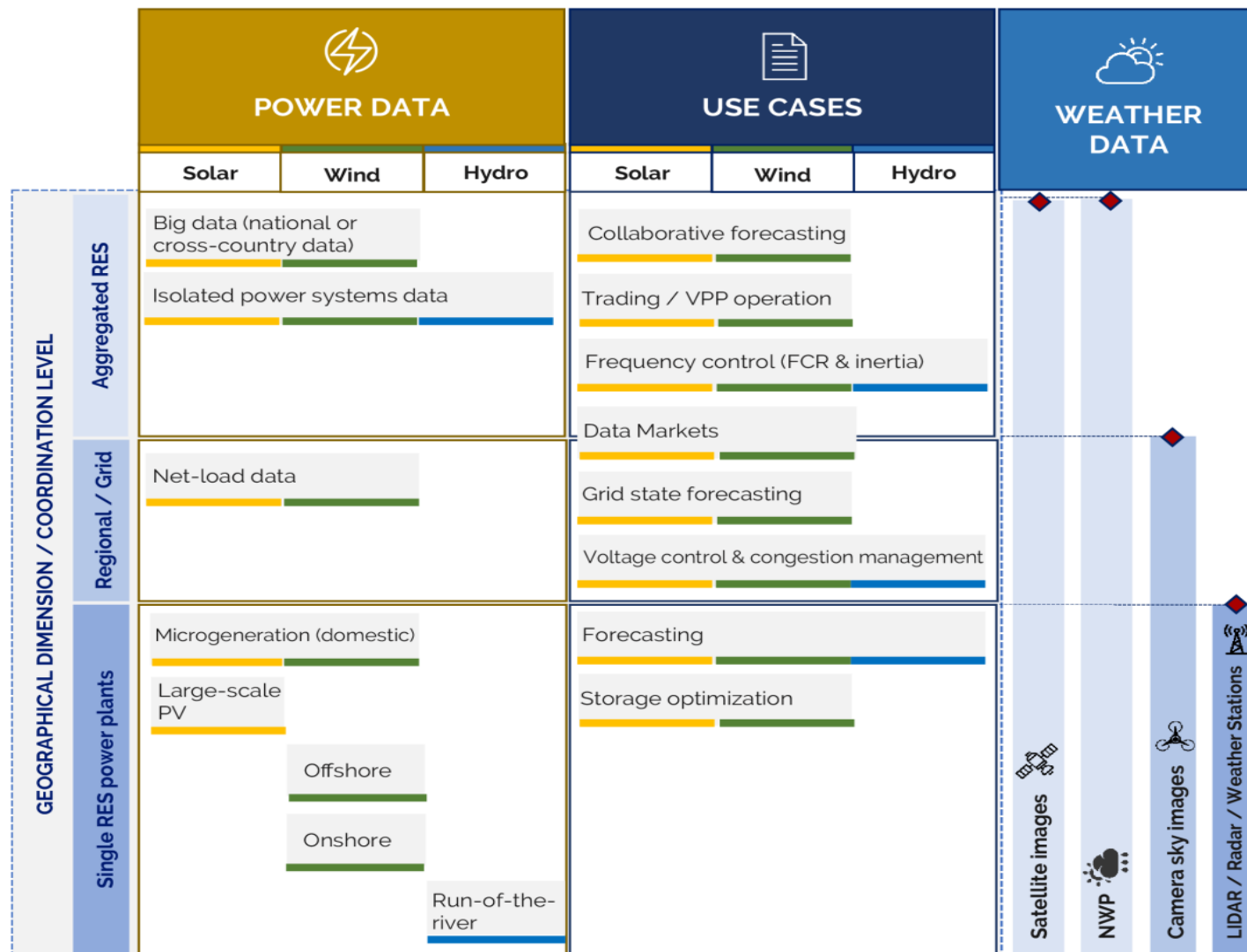
6/ Validation of new models in living labs and assesment of forecasting values vs remedies.
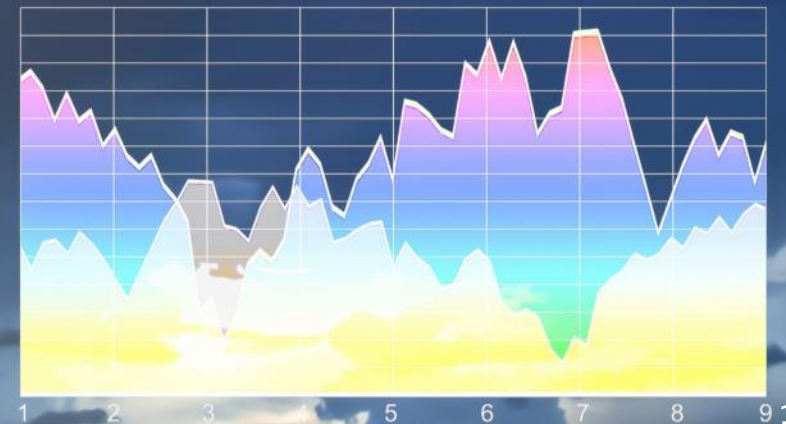
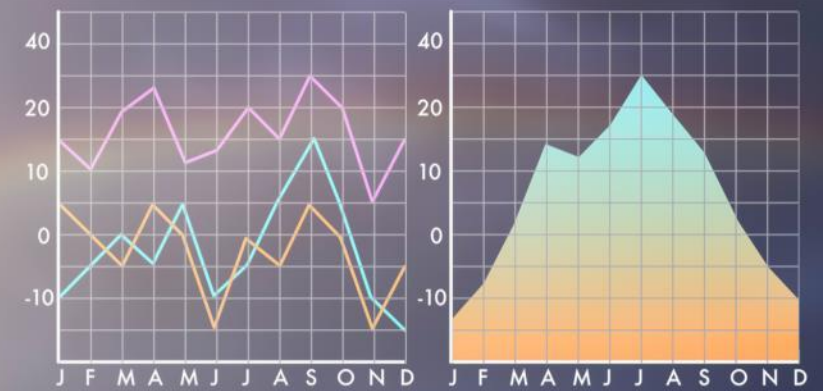Weather   RES prediction   Applications

Concept & methodology

Focus on NWP improvements

- Very/Ultra high resolution NWPs
- Regional solar irradiance nowcasting

Focus – NWP improvements

- Refined cloud radiative impact for solar irradiance forecast

- Advanced tools to take advantage of ensemble simulations for wind and solar forecasts

- Seamless forecast from very short to medium ranges
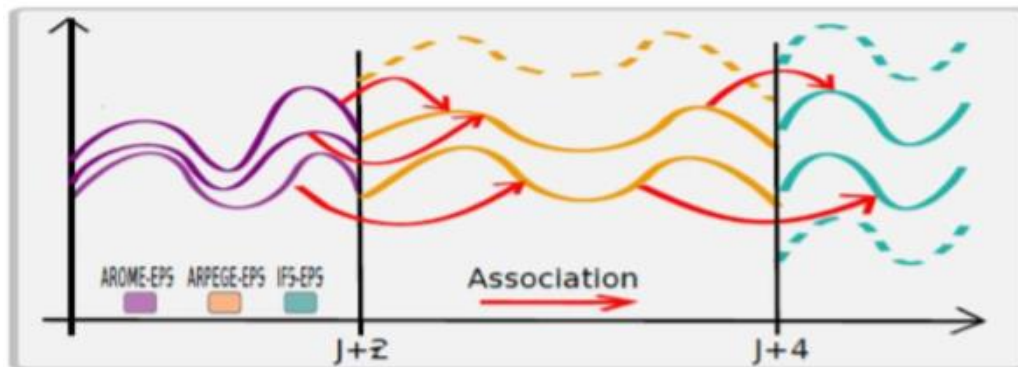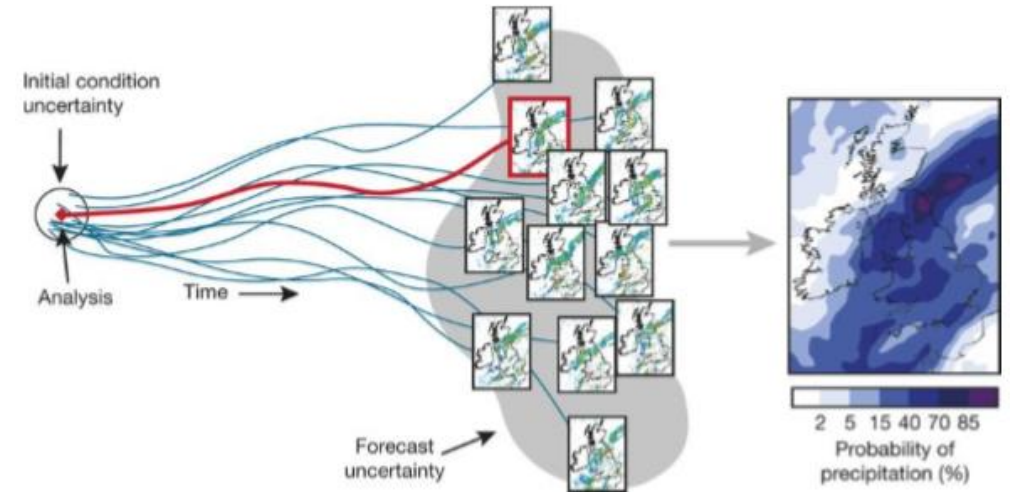
Focus – NWP improvements

- Very high resolution NWPs
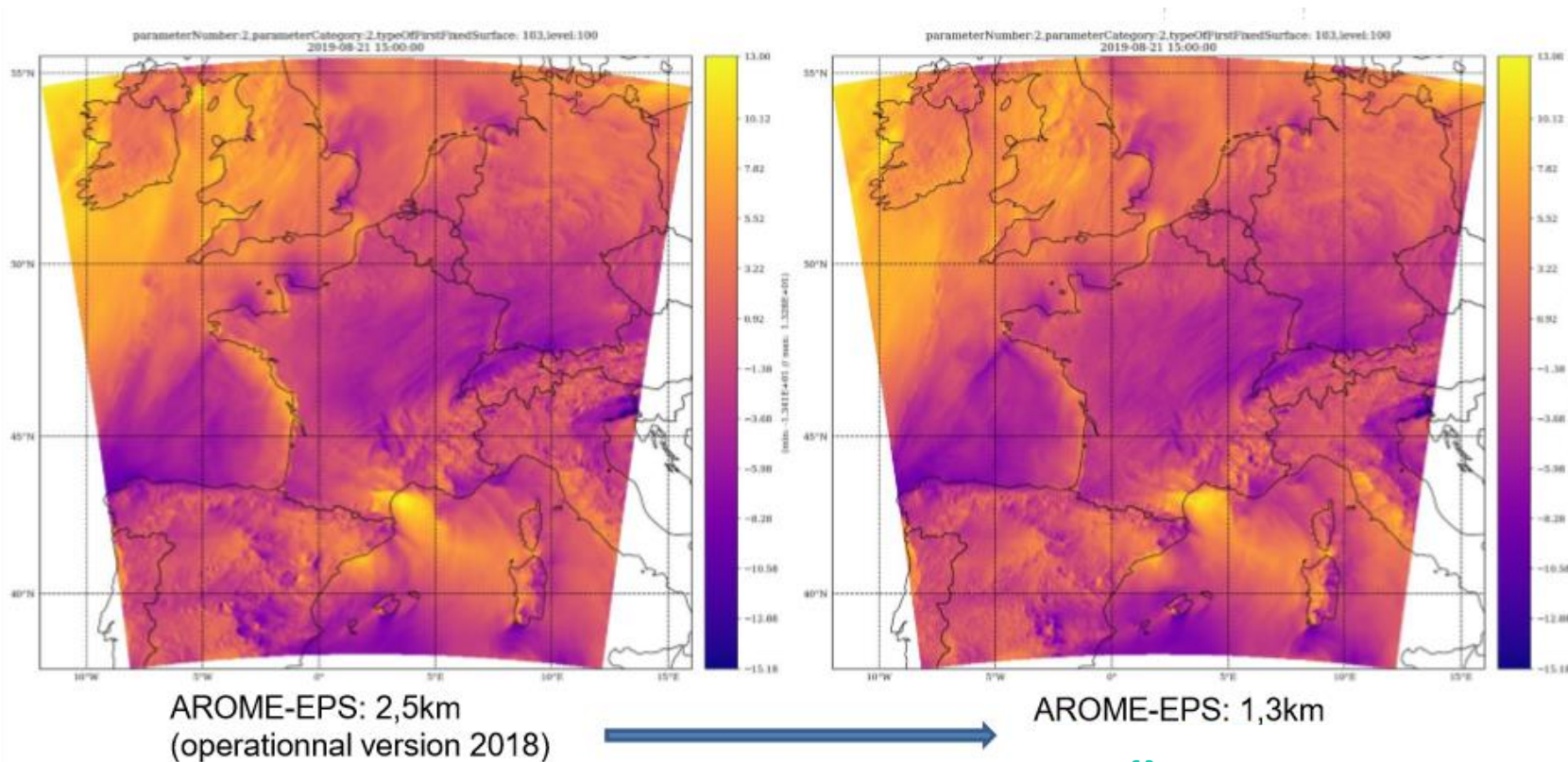
AROME-EPS: 2,5km
(operationnal version 2018)

AROME-EPS: 1,3km

ARPEGE-EPS
- global 5km

AROME-EPS
- Limited area 1,3km

WHIFFLE-LES
- fews meters

Focus – NWP improvements

- Very high resolution LES (large-eddy simulations) and advanced data assimilation (https://vimeo.com/335806229)

LES: very high resolution simulation

https://vimeo.com/whiffle/mv2

ARPEGE-EPS
- global 5km

AROME-EPS
- Limited area 1,3km

WHIFFLE-LES
- fews meters

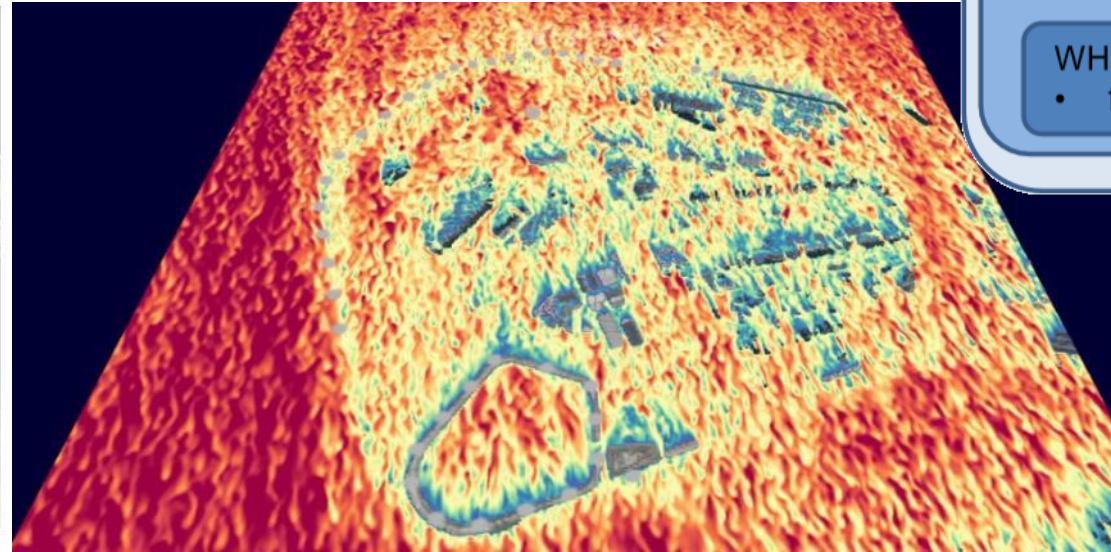# Focus – NWP improvements

- Advanced analysis of camera images for cloud characterization

- Eye2Sky network of 35 sky cameras (Northern Germany)
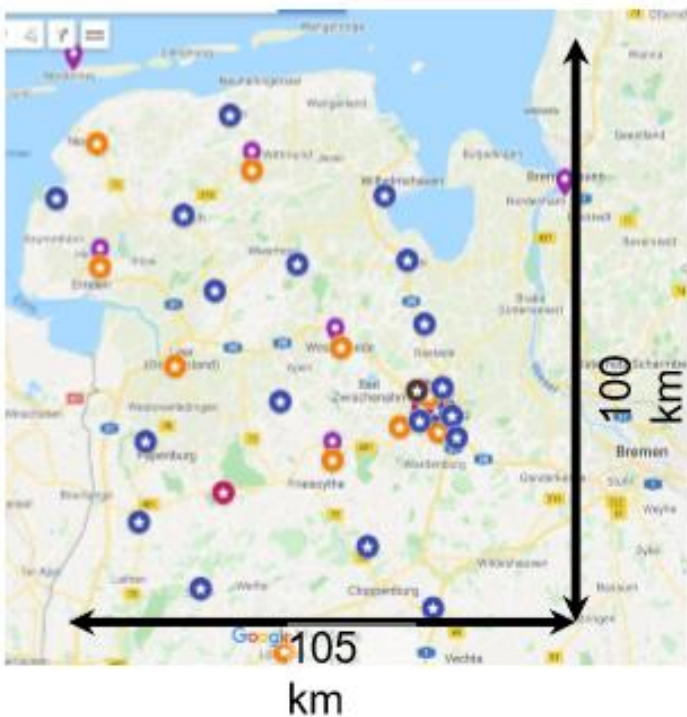
Camera (10 in operation & 10 planned/negotiation)

Camera + irradiance (6 in operation & 6 planned/negotiation)

Camera + reference meteo station (2 in operation)

Camera + PV monitoring station (Solarpark Ammerland)

Ceilometer (6 ☐ 2 Eye2Sky & 4 DWD)

17
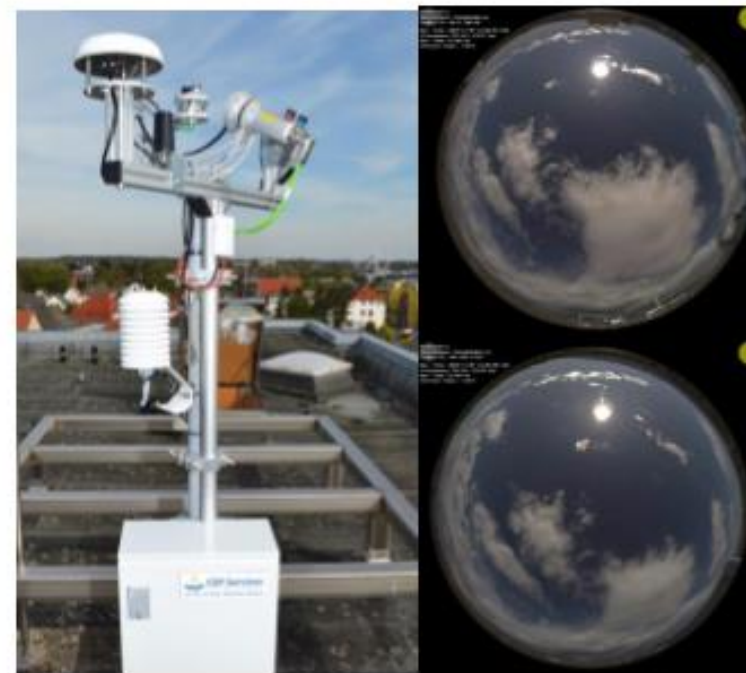
Focus on methods to improve RES production forecasts

How can we improve accuracy without increasing complexity of the overall model chain?

Smart4RES

Very short-term RES forecasting

- Improve very short-term PV and wind forecasting (cameras, lidar.. / machine learning)

Towards generic RES forecasting

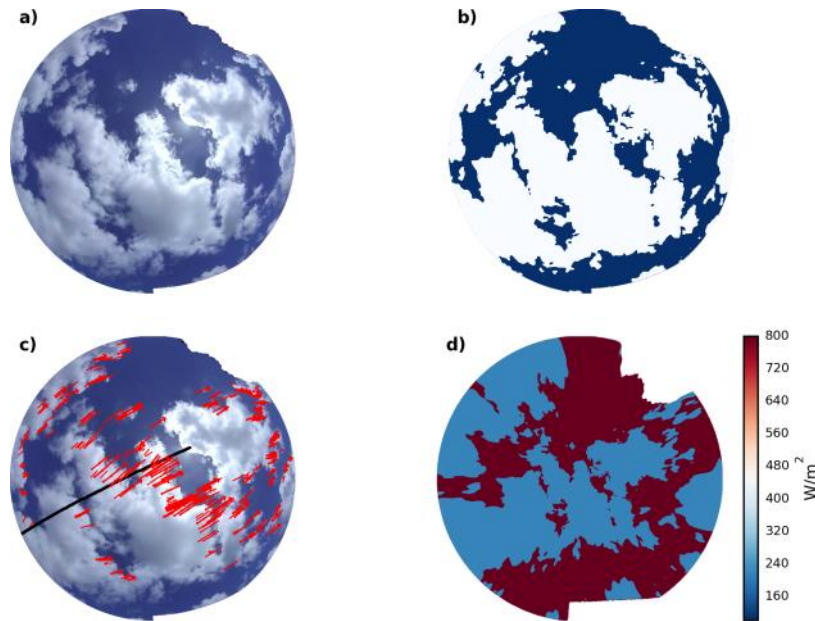- Towards models fed with **multi-source data inputs**
  - Increase quantity/quality of inputs
  - Methodologies to tackle challenges from multiple sources of input (dimensionality, heterogeneous correlations between data sources and production…)

- Towards better **seamless forecasting**
  - Looking for generic models: assess validity for various renewable energy sources, cover multiple time frames
  - Best candidates to reproduce temporal correlations / exploit temporal information? (e.g. recurrent models, adversarial networks…)
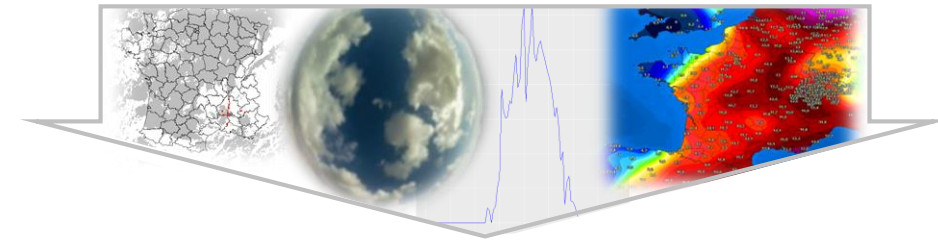
Multi-source input PV forecasting

Weights on sources at runtime 12.00
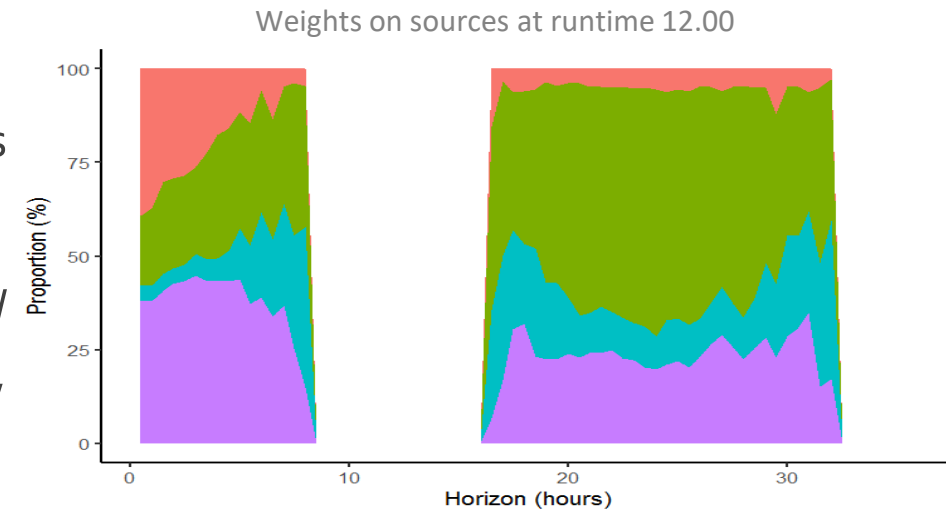
Focus

Collaborative RES forecasting

- The traditional approach to forecast for a single location:
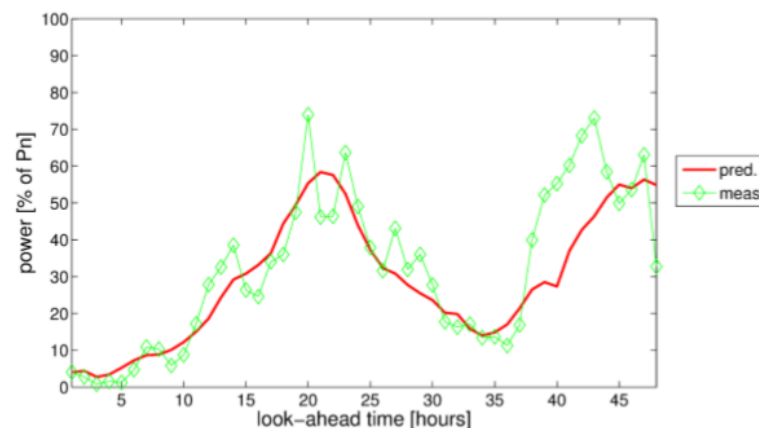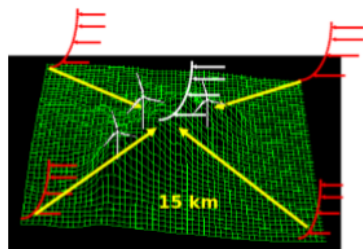
- Many works have shown the benefits from integrating spatially distributed information (neighbor wind farms or PV plants as sensors)

- In Smart4RES we develop a framework for **data sharing preserving privacy and confidentiality constraints**

- And **a data market concept** to valorise data sharing
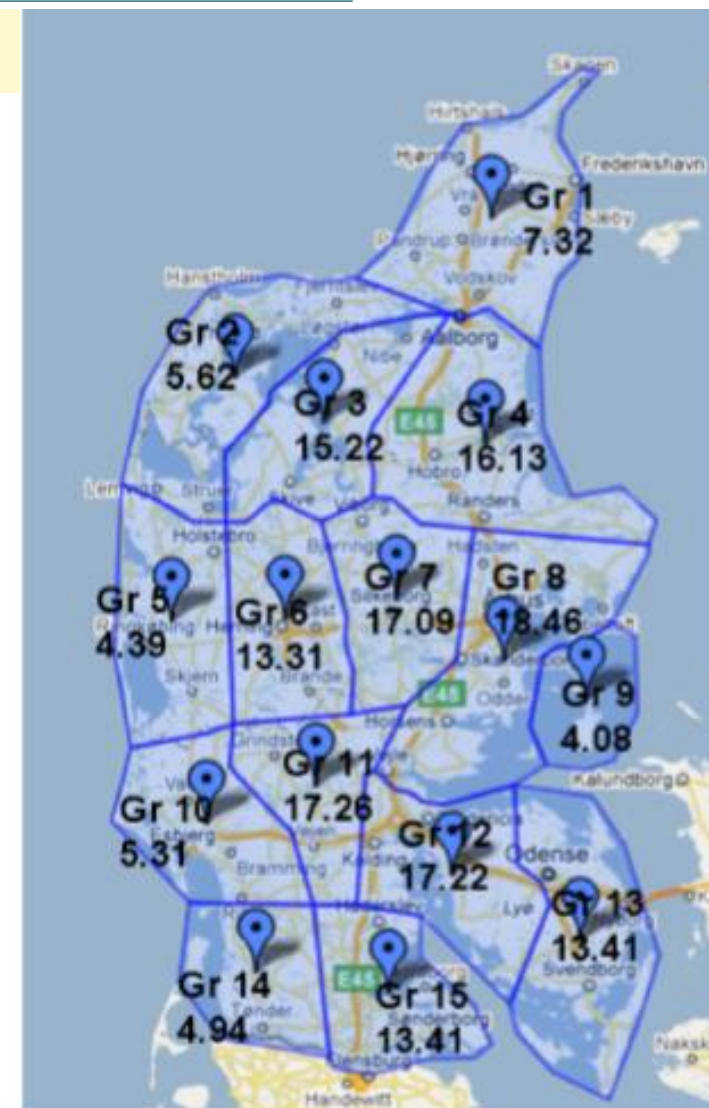
improvement of 1-hour ahead forecast RMSE

Focus on a selection of innovative Use Cases

How to maximise the value of RES forecasts in Electrical Grids, Electricity Markets and Storage Operation?

Application: bidding strategy for RES + storage (1/2)

Challenge   **How to optimize the operation and trading performance in electricity markets of a combined vRES and Storage system?**

Markets:
- Energy (day ahead, intra-day)
- Ancillary services,
- Local flexibility…

Auxiliary Services

Feeder #1 (5 WTGs)   Feeder #2 (4 WTGs)   Feeder #3 (4 WTGs)

13 WTGs Vestas V90
Total 26 MW
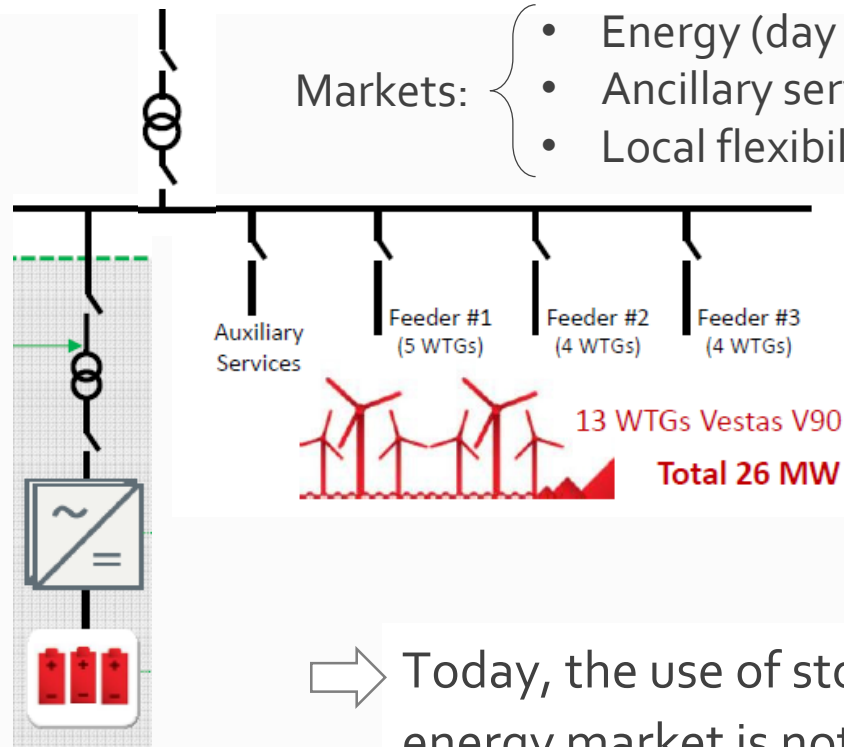
⇨ Today, the use of storage systems only to compensate RES imbalances on the energy market is not sufficient to pay back the investment in storage.

Application: bidding strategy RES + storage (2/2)

Approach — **Data-driven bidding strategy for any vRES + storage on multiple electricity markets**

Data on RES, storage, markets

Forecast RES production (DA + ID)

Forecast energy market quantities (DA, ID, RT)

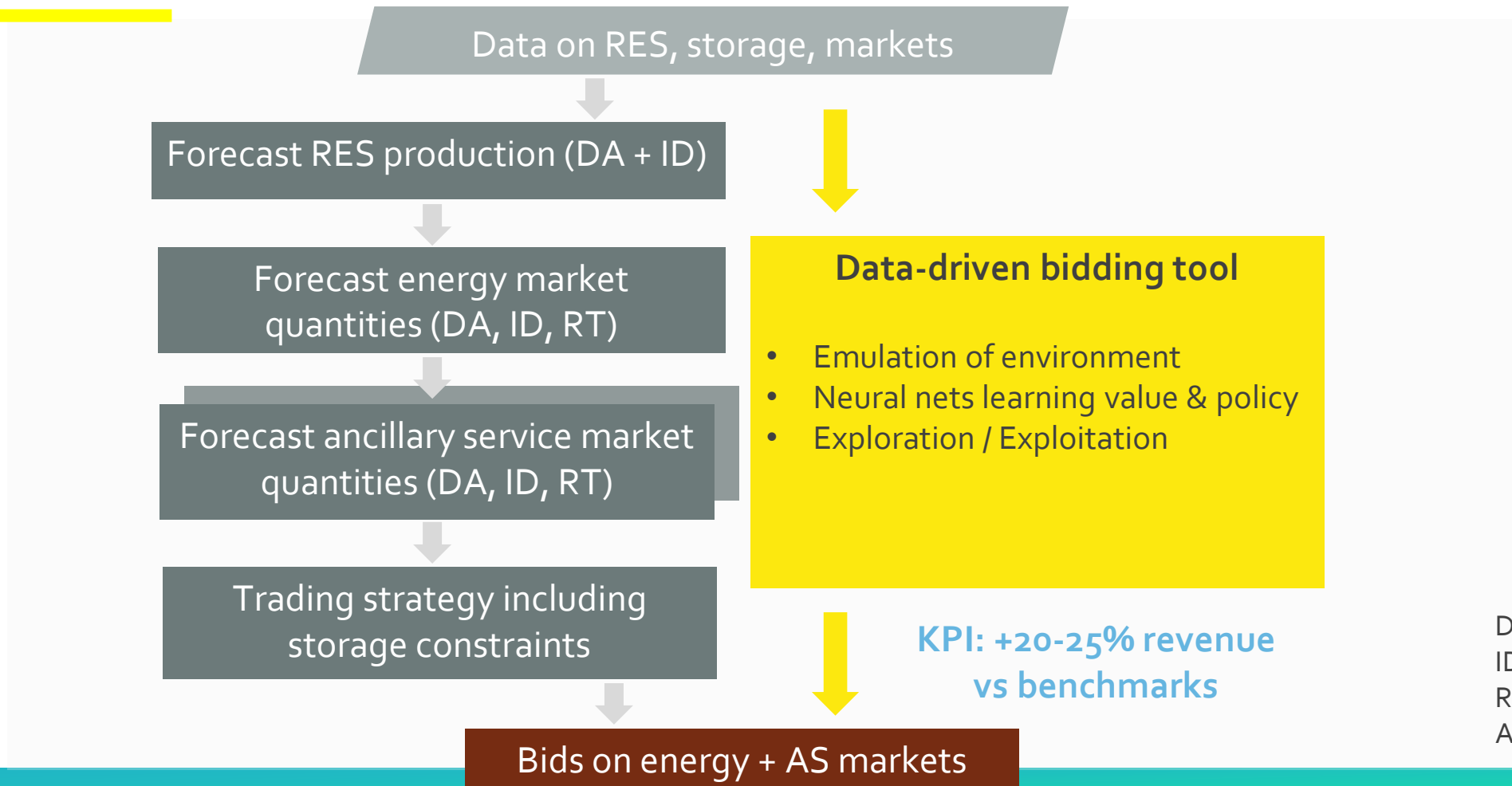Forecast ancillary service market quantities (DA, ID, RT)

Trading strategy including storage constraints

Data-driven bidding tool

- Emulation of environment
- Neural nets learning value & policy
- Exploration / Exploitation

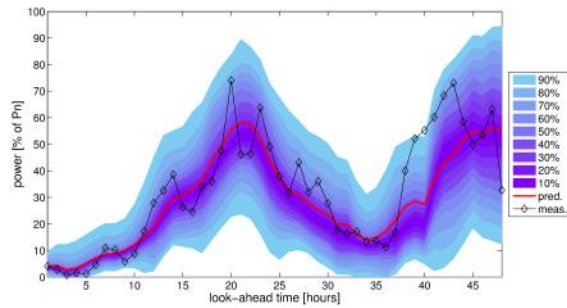**KPI: +20-25% revenue vs benchmarks**

Bids on energy + AS markets

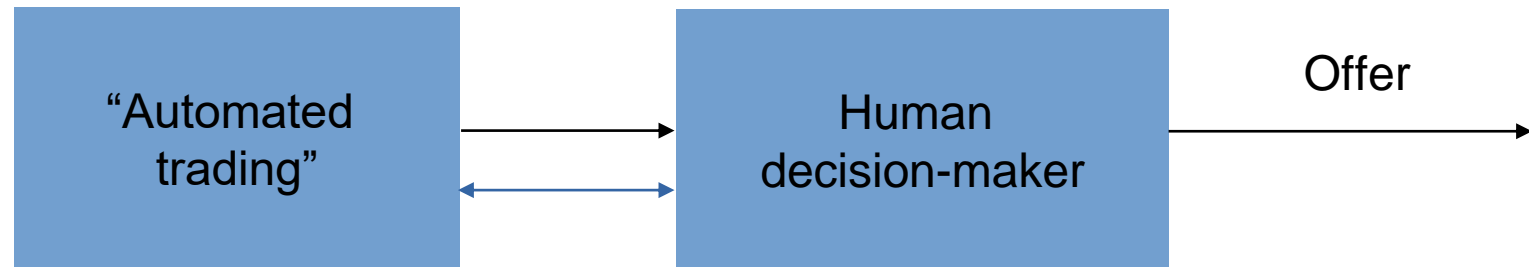DA: Day ahead
ID: Intra-day
RT: Real time
AS: Ancillary Services.

Application: Include the human in trading

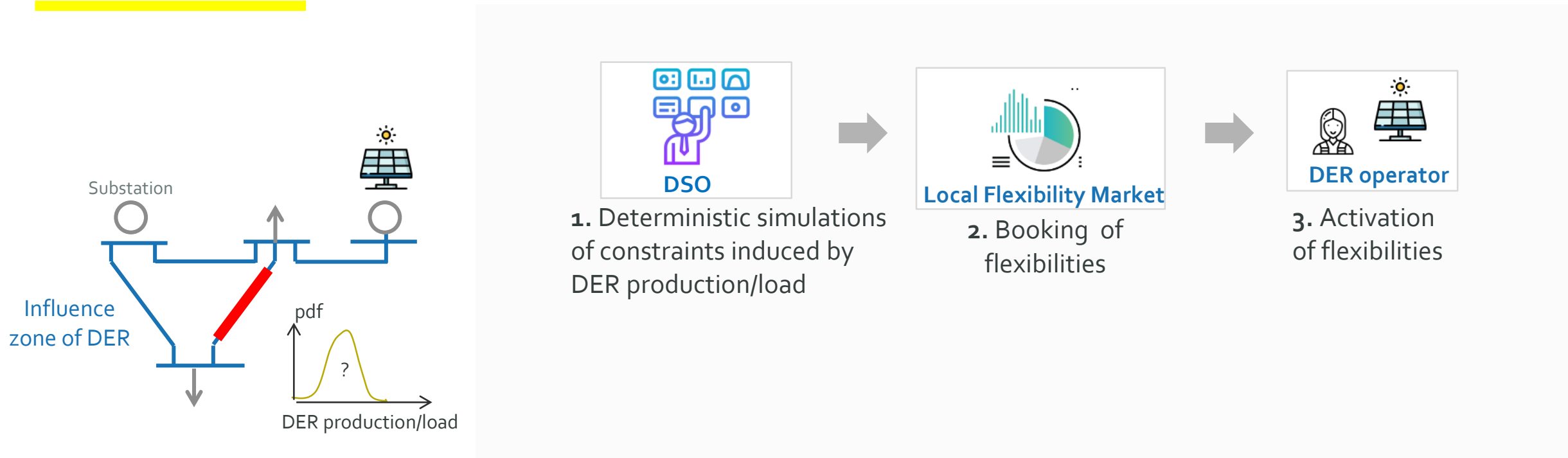- Extend the state-of-the-art approach for RES trading to include the human behaviour of the traders.

Application: Predictive management of grids (1/2)

Challenge — **How can a DSO optimize the predictive management of local flexibilities?**

Substation

Influence zone of DER

pdf

?

DER production/load

DSO
1. Deterministic simulations of constraints induced by DER production/load

Local Flexibility Market
2. Booking of flexibilities
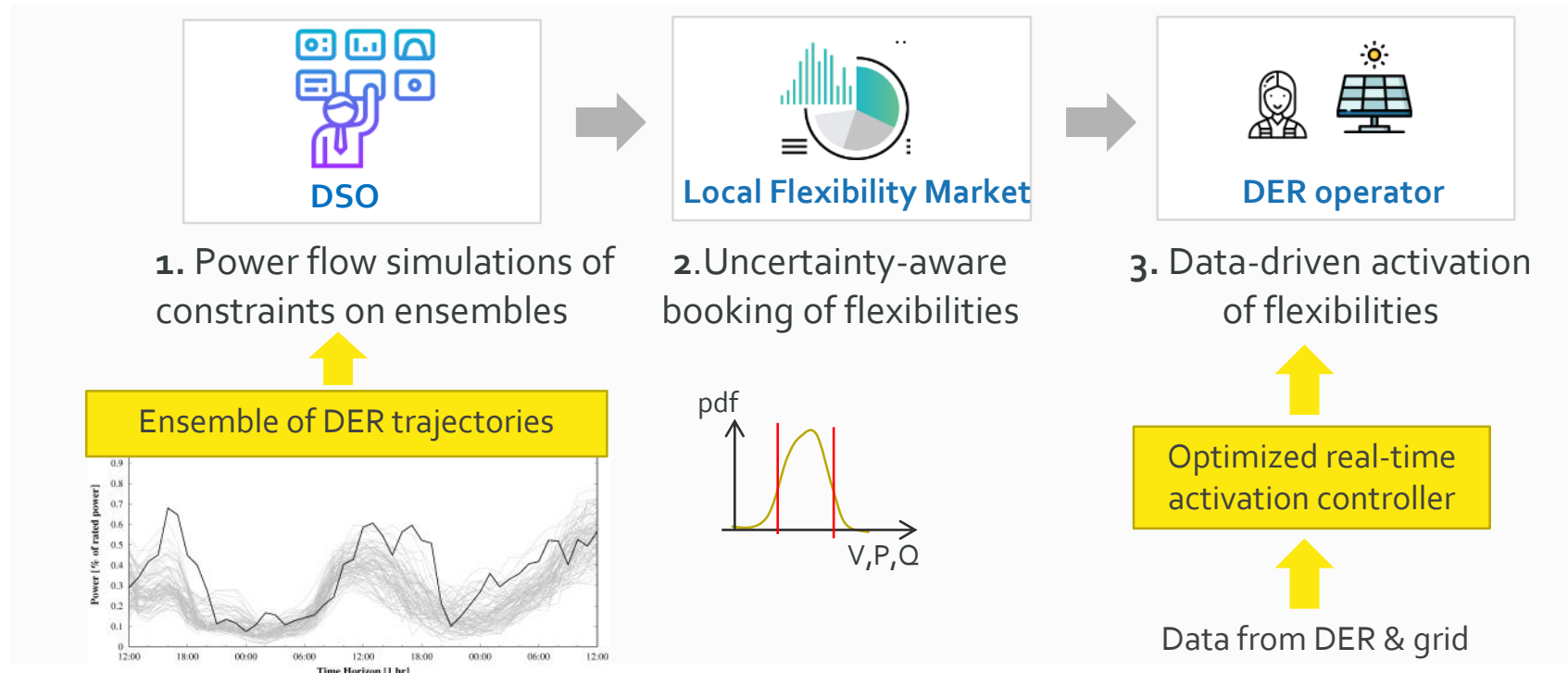
DER operator
3. Activation of flexibilities

⇨ Today, DSO do not fully consider uncertainties from Distributed Sources (DER) operation and their local impact on booking and activation of flexibilities.
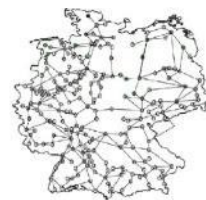
Application: Predictive management of grids (2/2)

Approach Uncertainty-aware booking of flexibilities + data-driven local activation controller

DSO

Local Flexibility Market

DER operator

1. Power flow simulations of constraints on ensembles

2. Uncertainty-aware booking of flexibilities

3. Data-driven activation of flexibilities

Ensemble of DER trajectories

pdf

V,P,Q

Optimized real-time activation controller

Data from DER & grid

Evaluated on distribution grids in Europe

KPI: +50% increased DER hosting capacity

www.smart4res.eu

Contact: info -at- smart4RES.eu

INCOMING ACTIVITIES

- **Webinar, June 5th 14:00 CEST**, G.Kariniotakis and P.Pinson (hosted by ISGAN)
  - The Role of RES forecasting in future power system applications: innovative use cases (ARMINES)
  - Research for innovative weather and RES production forecasting products (DTU)

- **Questionnaires to stakeholders** on their experience and expectations regarding RES forecasting and applications