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Research directions and results in the Smart4RES project for improving renewable energy forecasting

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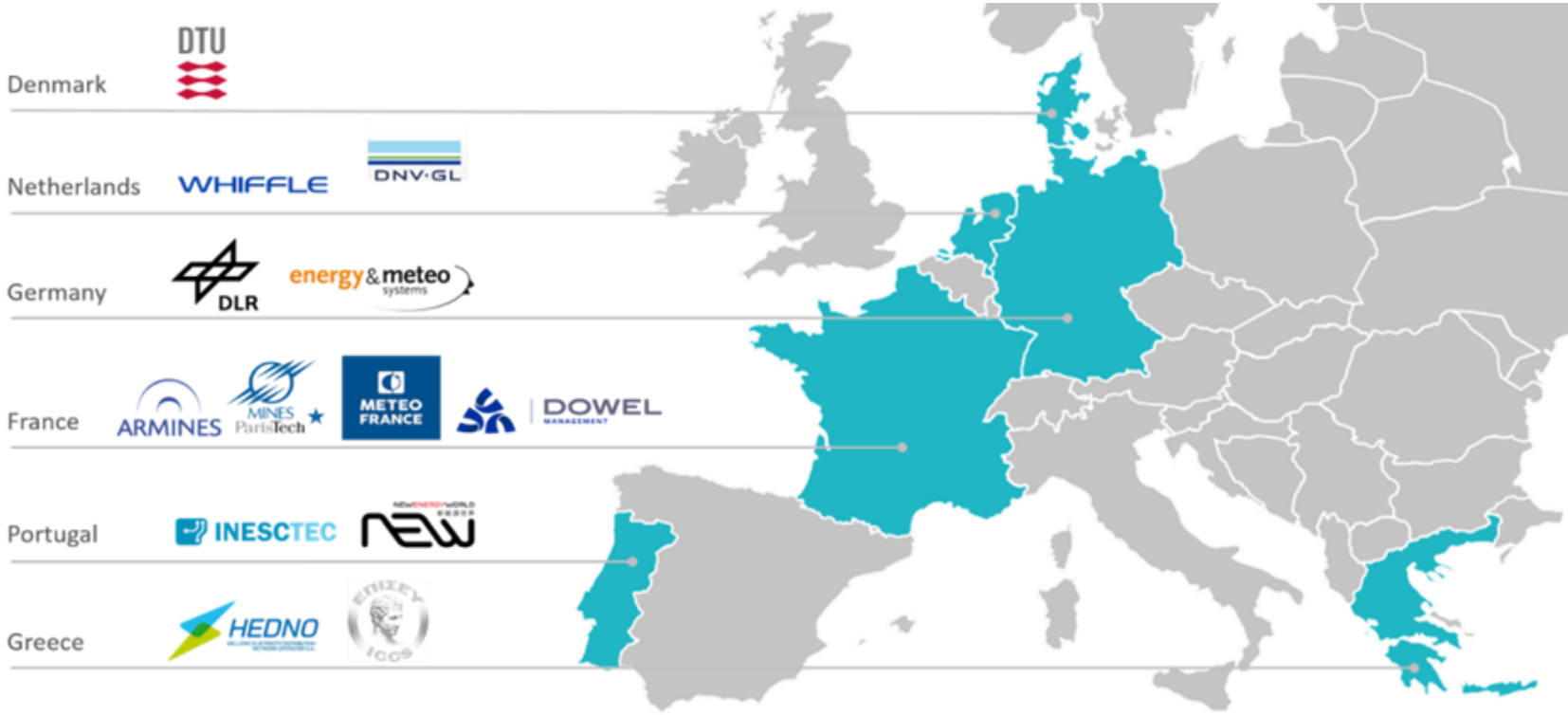
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864337

What is Smart4RES?

A collaborative research project aiming to give a new boost to the RES forecasting technology through some disruptive ideas.

- 6 countries, 12 partners
- Budget: 4 M€
- Duration: 11/2019 - 04/2023
- End-users / Industry / Research / Universities / Meteorologists
- TRLs: 1-5

HORIZON 2020
LE PROGRAMME DE RECHERCHE ET D'INNOVATION DE L'UNION EUROPÉENNE

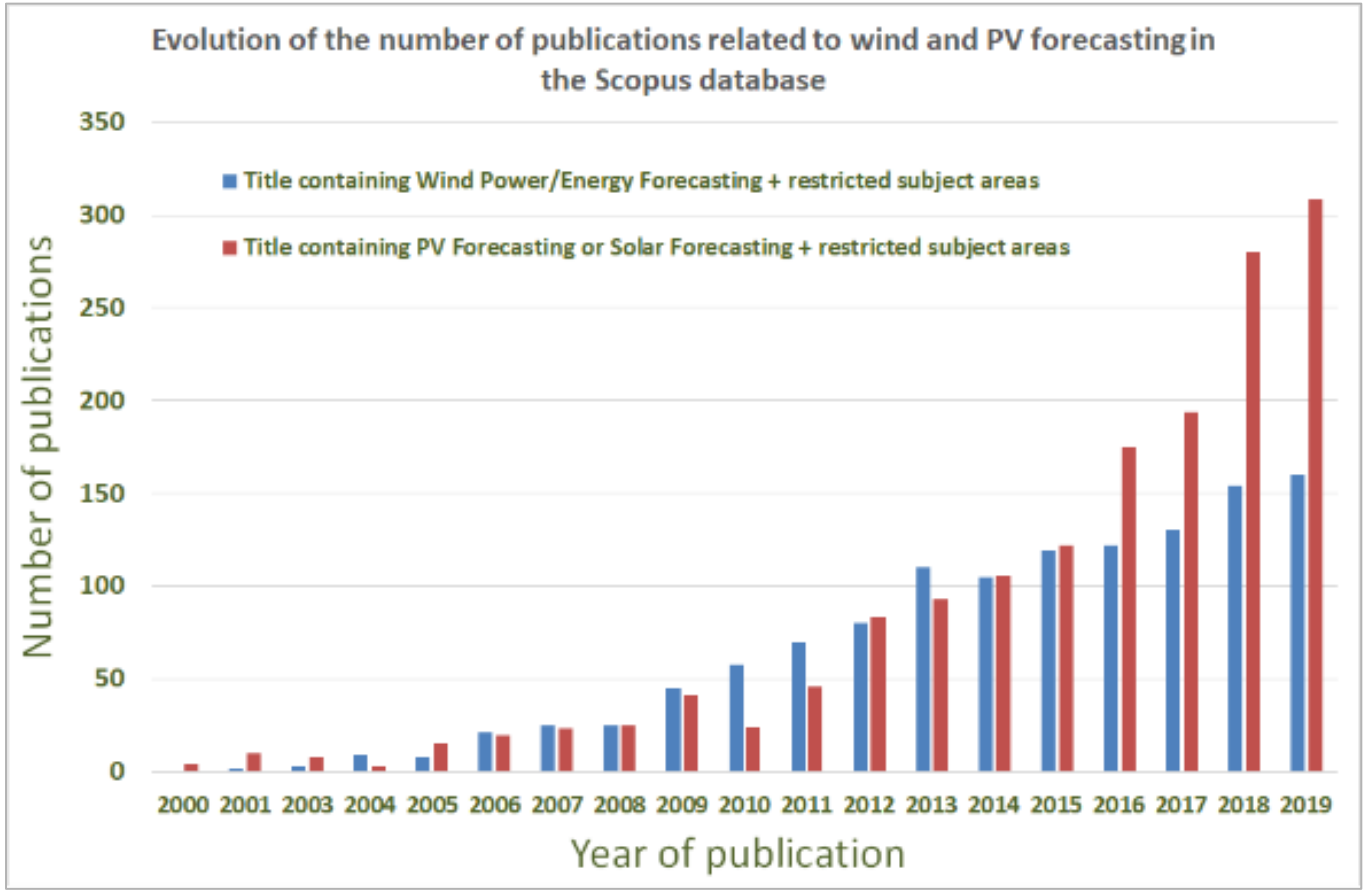


http://www.smart4RES.eu

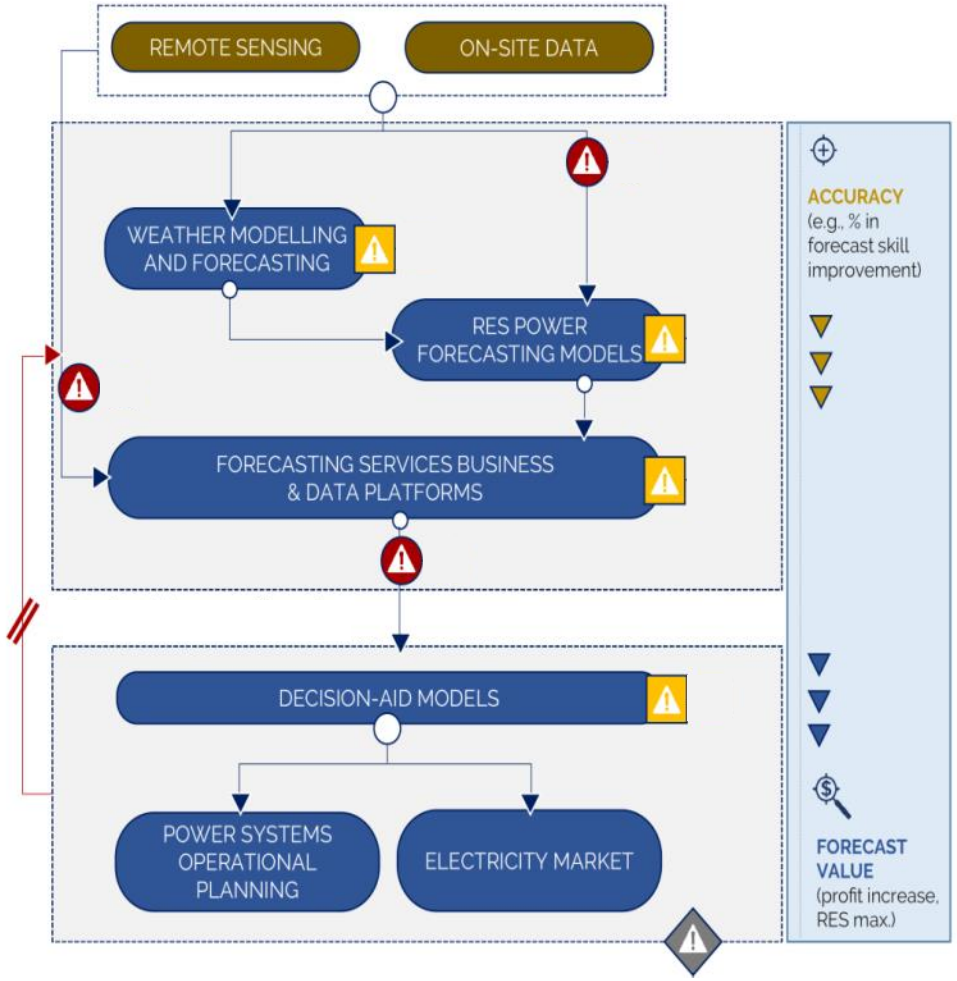
Context

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

- However, there are several gaps and bottlenecks in the **model & value chain** stimulating significant research worldwide



The RES forecasting model & value chain

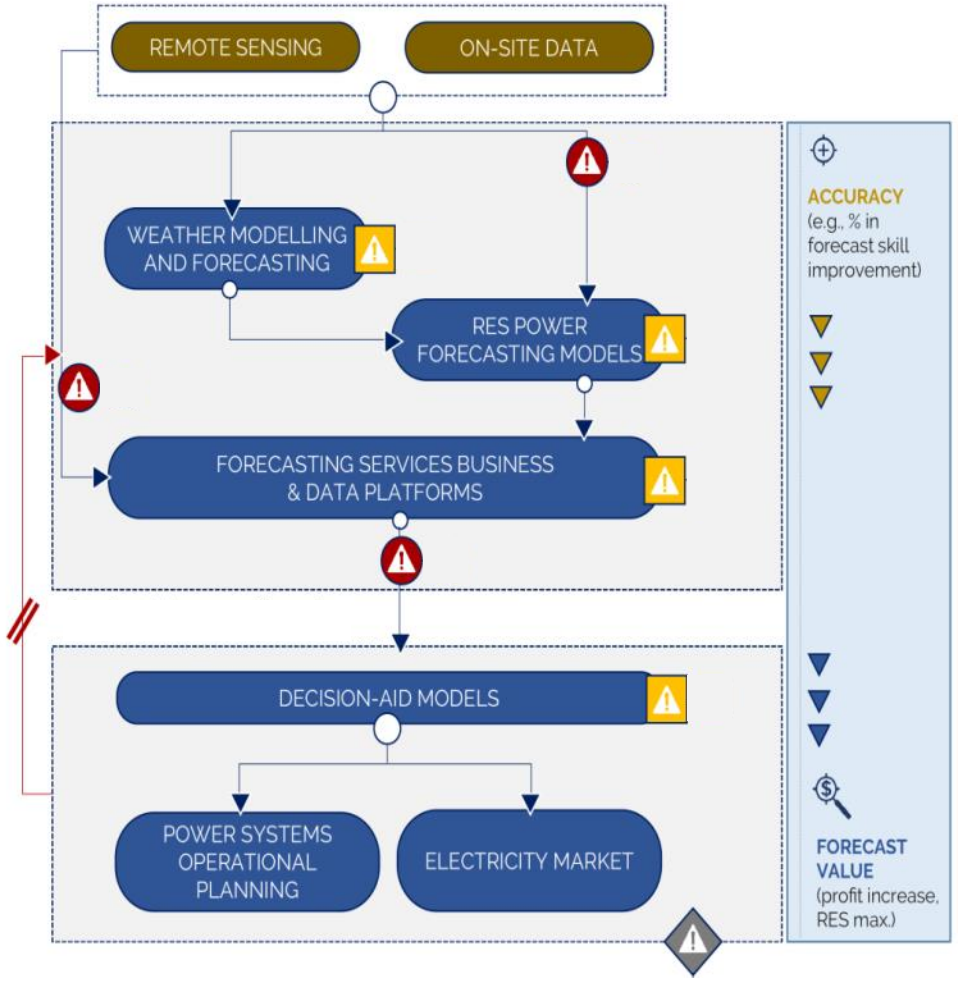


Power, weather variables measurements, satellite images, sky cameras, radars, lidars….

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

storage management
reserve allocation
predictive maintenance
trading
economic dispatch
scheduling
congestion management

The RES forecasting model & value chain

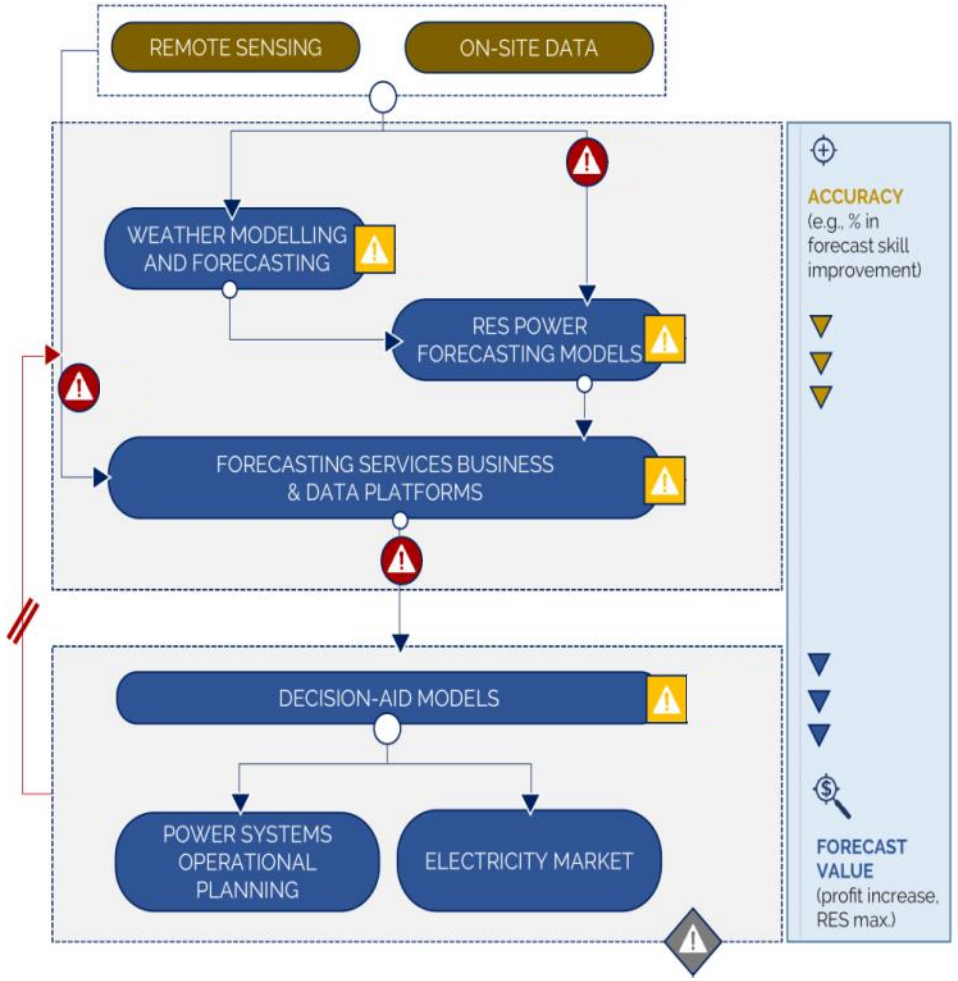


….."mature technology", but forecasting accuracy remains low

Impacts

- Financial losses in electricity markets
- Increased need for costly remedies (reserves, storage, demand response…)
- Limited capacity of RES plants to deliver reliable ancillary services (AS)
- Lower RES acceptability by operators
- RES curtailment
- Higher maintenance costs for RES plants
- …

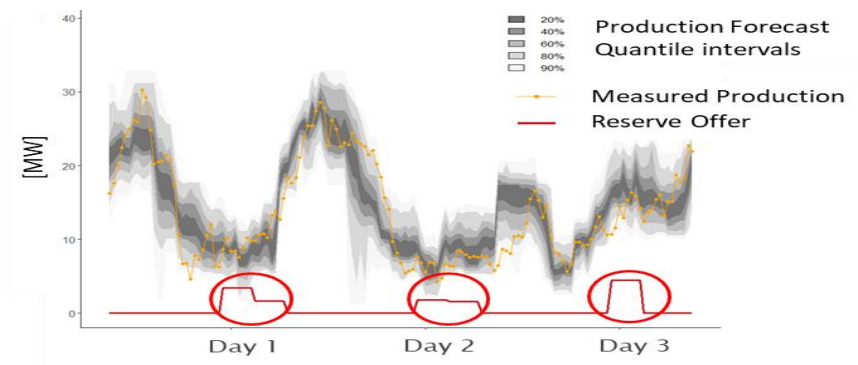
The RES forecasting model & value chain



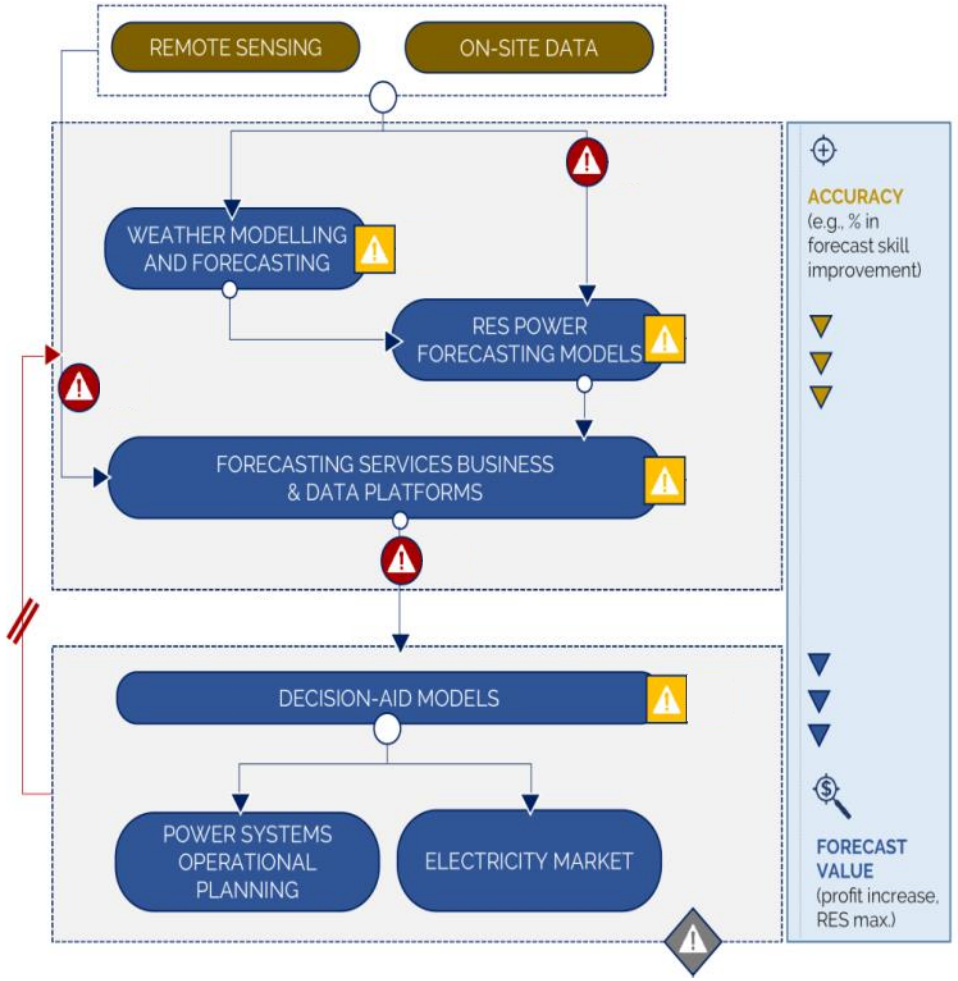
....”mature technology”, but forecasting accuracy remains low and new needs are emerging

new needs

- Forecasts for aggregated RES plants
- Forecasts for net load at different points of the grid
- Dedicated forecasts for ancillary service provision
- …



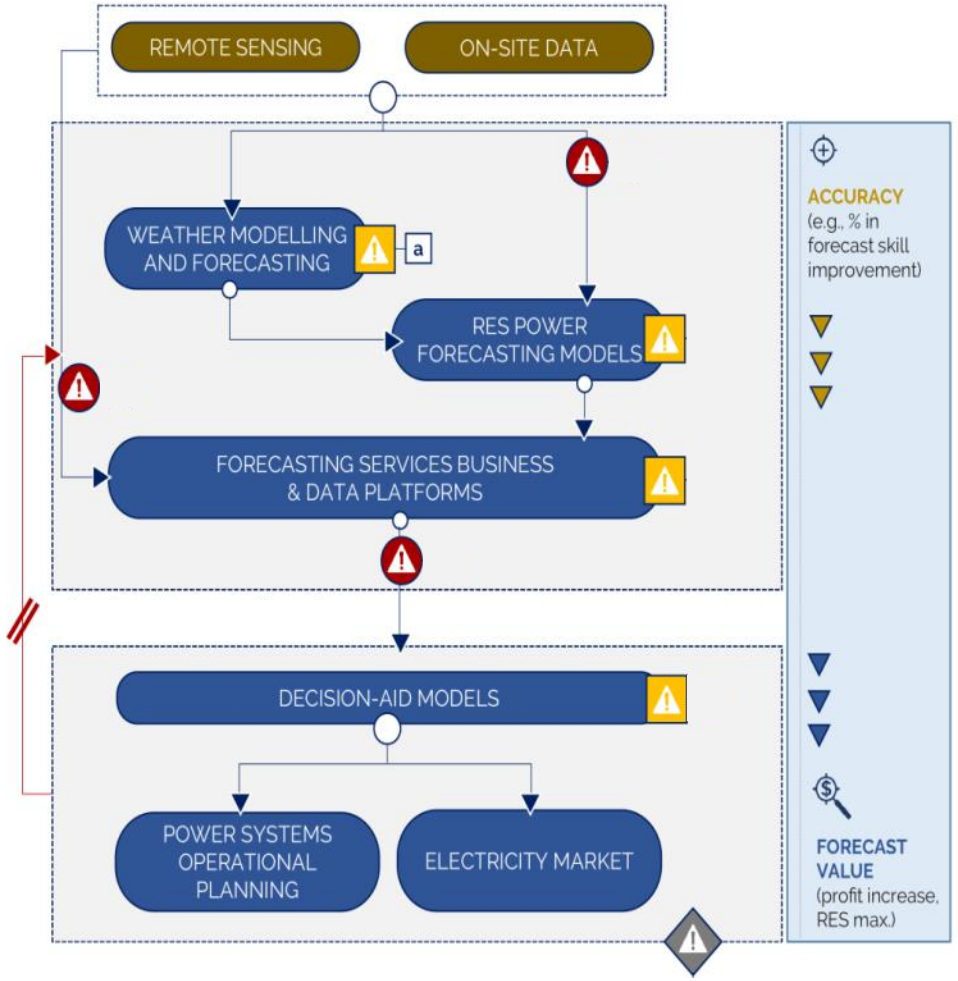
The Smart4RES vision & objectives



Achieve outstanding improvement in RES predictability through a holistic approach, that covers the whole model and value chain related to RES forecasting

1. Requirements for forecasting solutions to enable 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, data market places, and novel business models
5. New data-driven optimisation and decision aid tools for power system management and market participation
6. Validation of new models in living labs and assessment of forecasting value vs remedies.

Research directions (weather variables)

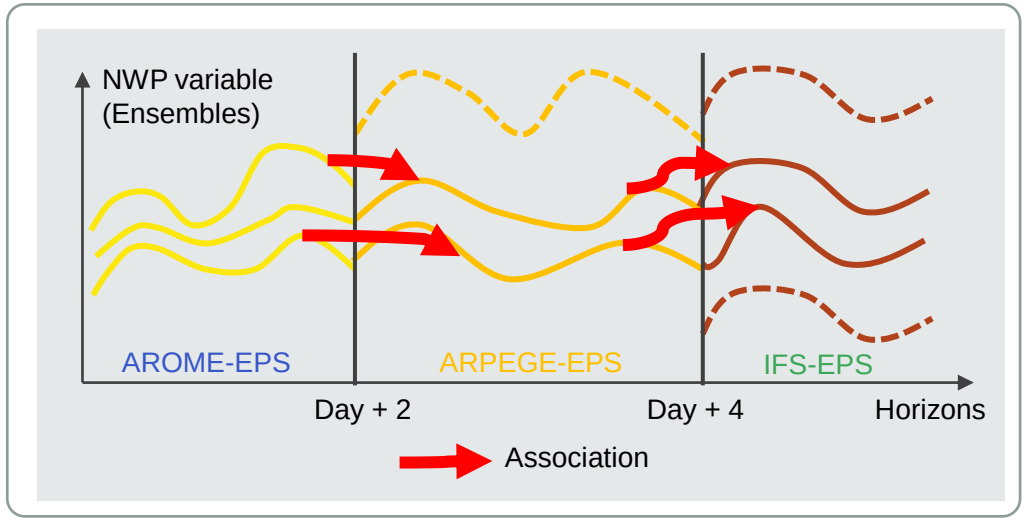


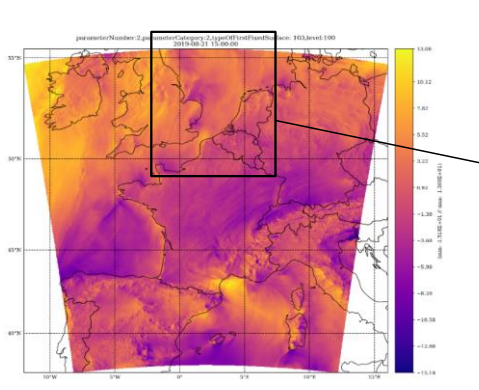
Challenges in the models and the connections:

Need for Numerical Weather Prediction (NWP) products adapted to RES use-cases.

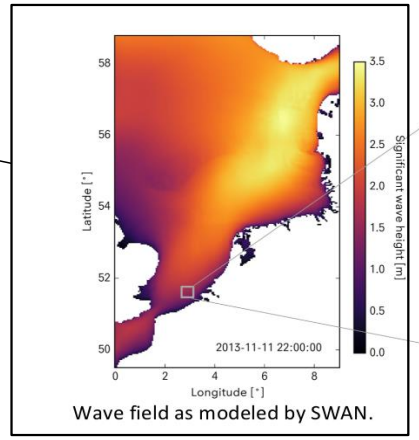
Research directions (weather variables)

- NWP models dedicated to RES applications
  - Higher temporal resolution outputs and frequent updates
  - Additional relevant variables for RES (i.e. cloud optical thickness, spectral distribution of radiation)
  - Evaluation & calibration of NWP models accounting for RES scores Improved RES-oriented modelling of NWP variables.
- Development of seamless NWPs
- Ultra-high resolution NWPs through Large Eddy Simulation (LES)

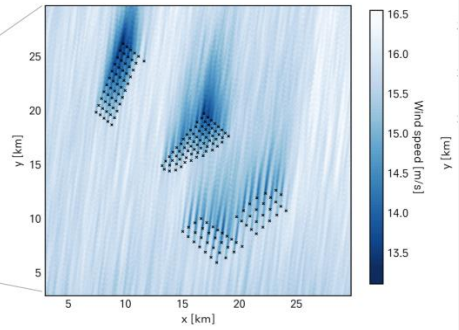




AROME operational domain



Wave field as modeled by SWAN.

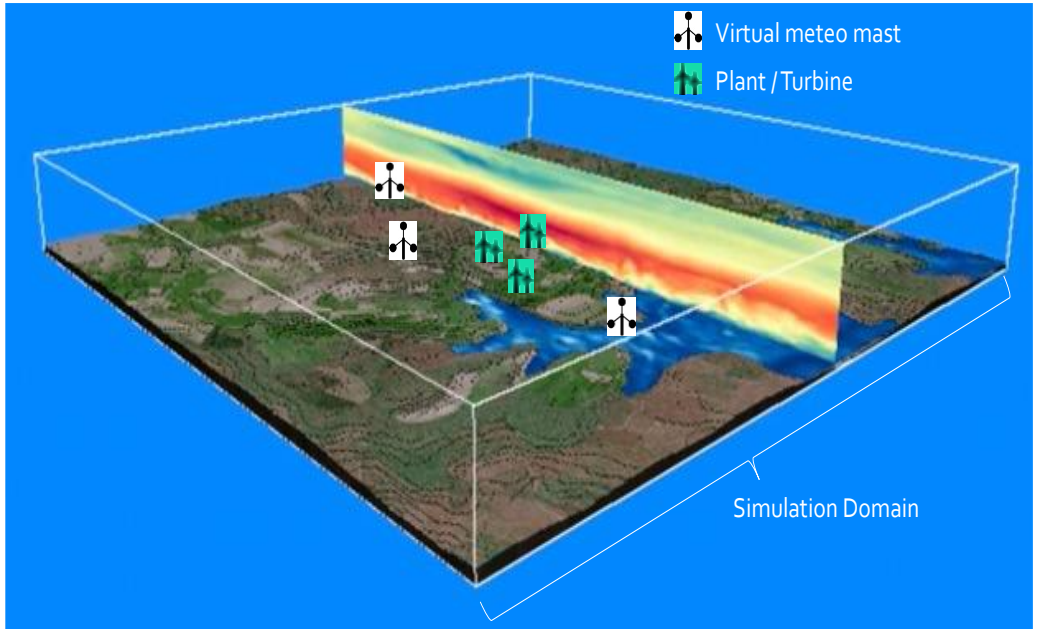


Wind field modeled by GRASP
(for the Belgian Offshore Wind zone)

WHIFFLE-LES application

Research directions (weather variables)

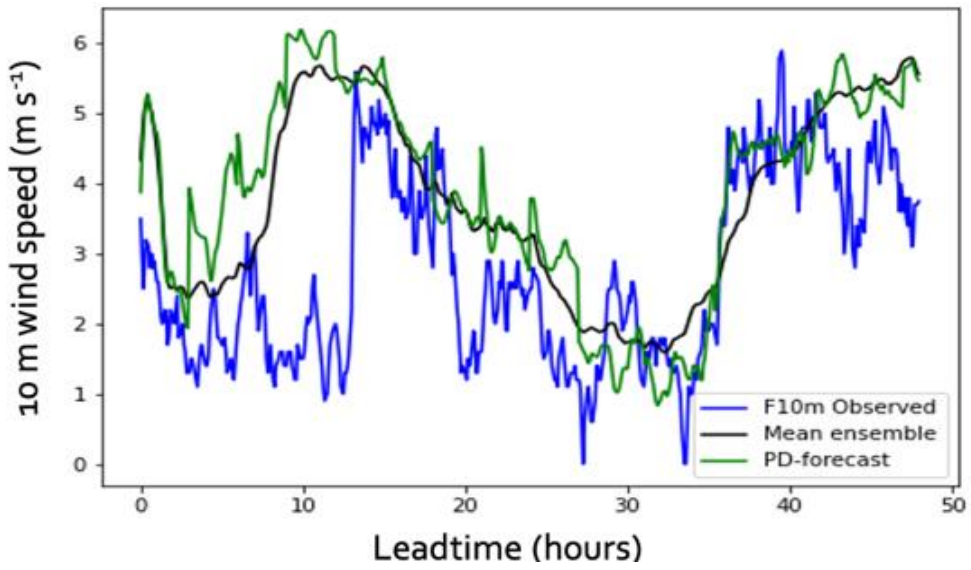
- Examples of Large Eddy Simulation (LES) at Engie's open data wind farm Haute Borne (left) and for the whole Rhodes island in Greece (right)

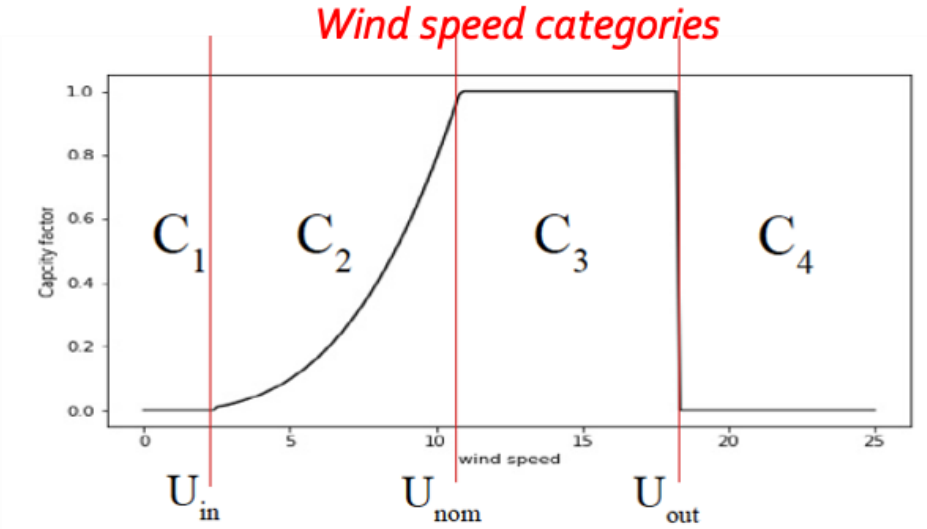


(source: WHIFFLE)

Research directions (weather variables)

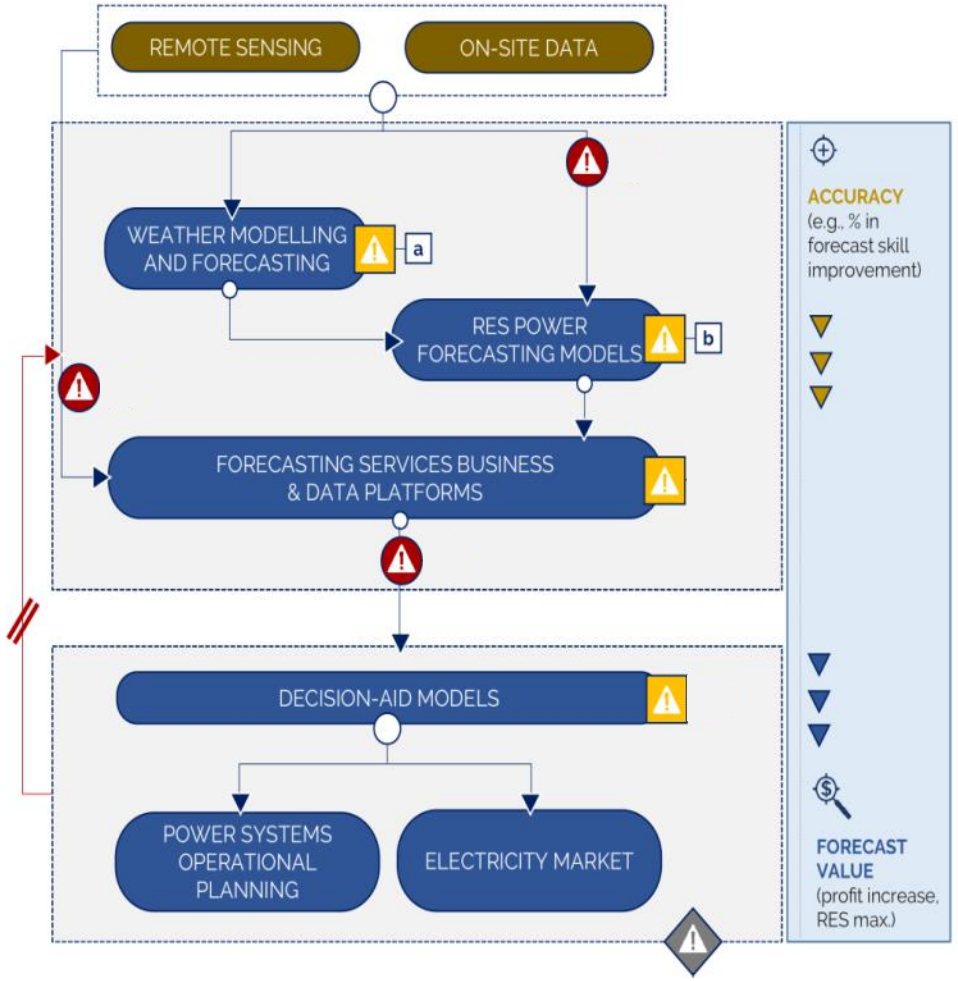
- Examples of pseudo-deterministic (PD) wind speed forecast.
  - This forecast selects a single member of the ensemble NWP (AROME) for each predefined time period, selected among the most represented wind speed categories.
  - These categories are derived from the wind power curve and can be refined.
  - The obtained forecast shows more realistic high frequency variability than the ensemble mean (e.g. ramp at lead-times 35-40 on the left figure), which is important for wind power trading or grid integration.





(source: Météo France)

Research directions (RES prediction)



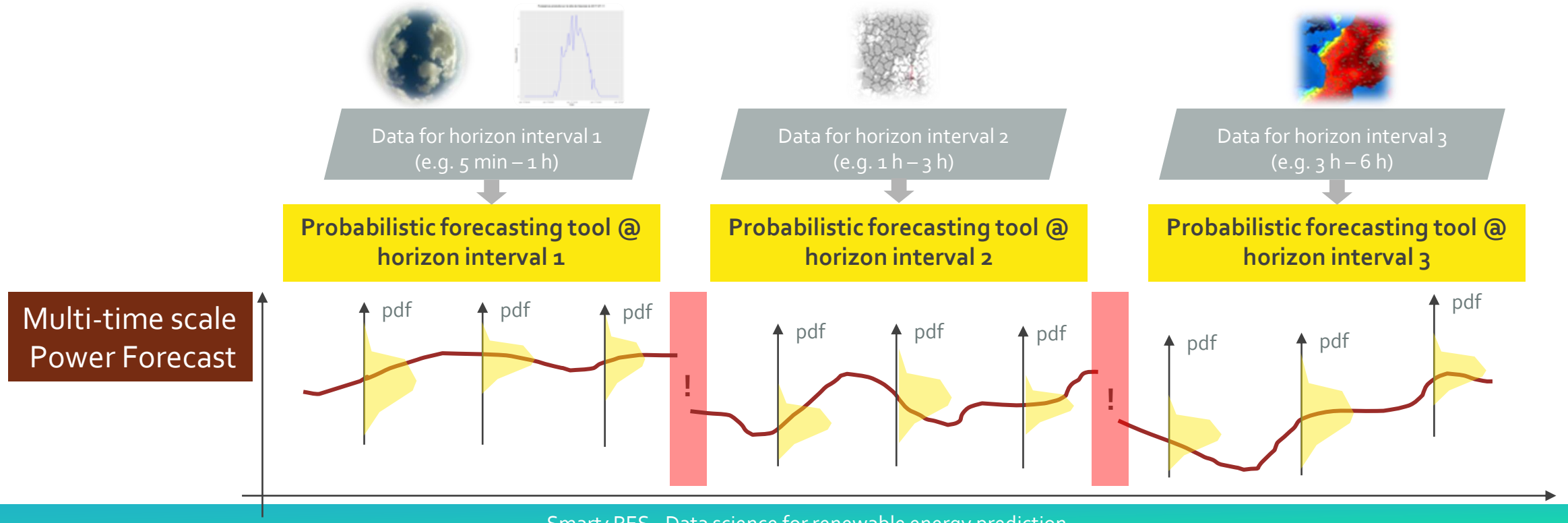
Challenges in the models and the connections:

a — Need for NWP products adapted to RES use-cases.

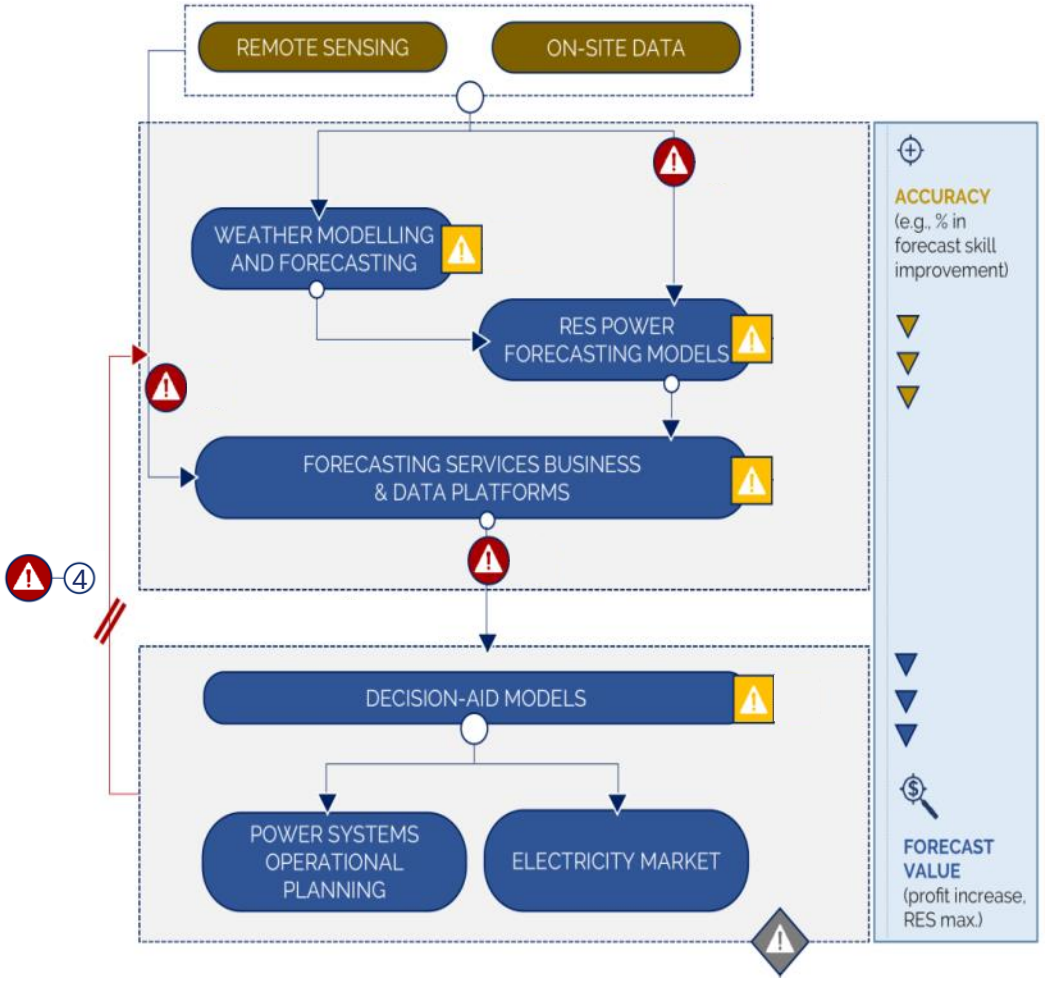
b — Limitations of RES prediction models to exploit large amounts of heterogenous data

Research directions (RES prediction)

- State of the art consists in separate models for different time frames (e.g. 5 min to 1 h, 1h to 6h, 6h to 48h ahead…), each exploiting different data sources as input.
- Development of a **seamless** and **generic** forecasting approach based on analog ensembles, able to consider simultaneously **i)** heterogenous data, **ii)** multiple RES, **iii)** multiple time frames => Towards a convergence of forecasting solutions



Research directions (optimal use of forecasts)



Challenges in the models and the connections:

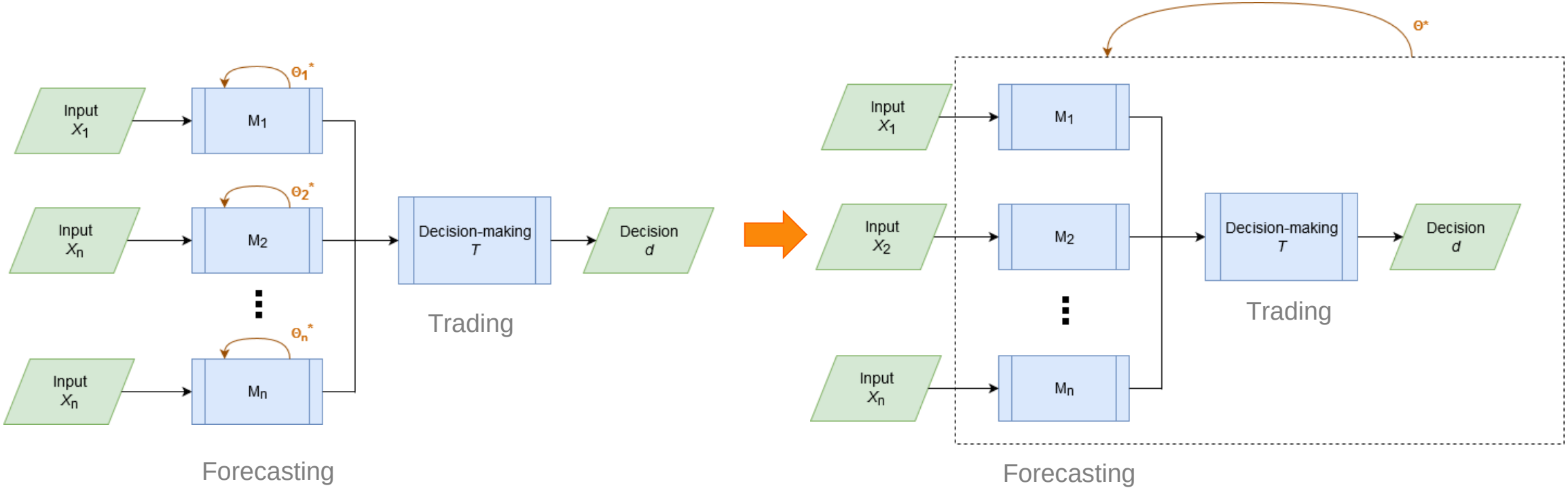
a — Need for NWP products adapted to RES use-cases.

b — Limitations of RES prediction models to exploit large amounts of heterogenous data

4 — Open loop between forecasts generation and their use in apps

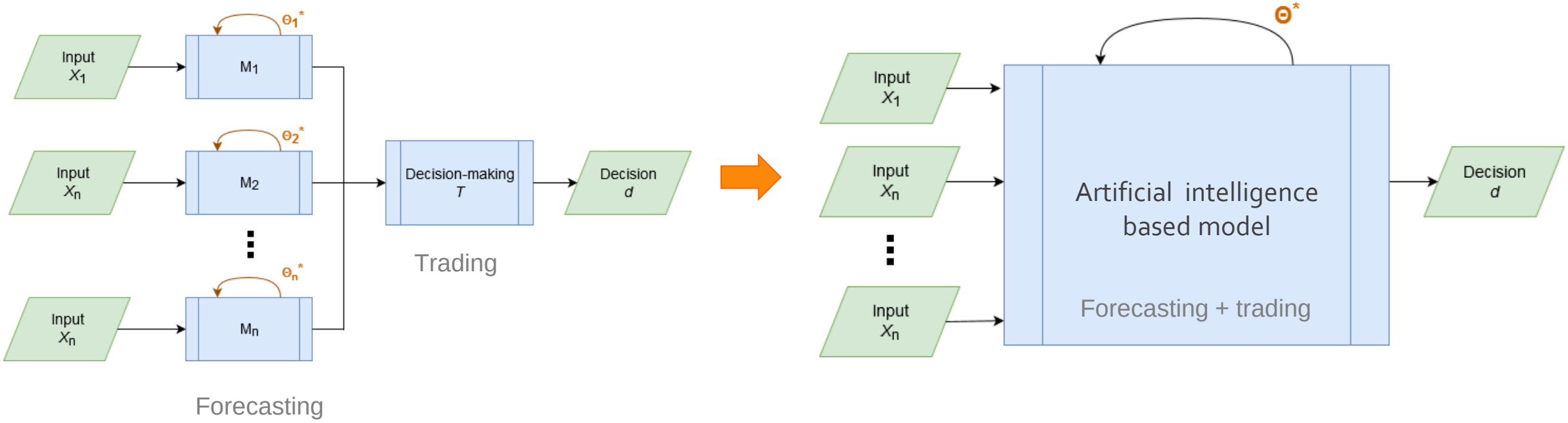
Research directions (optimal use of forecasts)

- RES forecasting models are tuned today upon their **accuracy.**
- An alternative could be to “tune” them considering, not only accuracy, but also the “**value**” they bring when used in a specific application (i.e. revenue €s in trading).

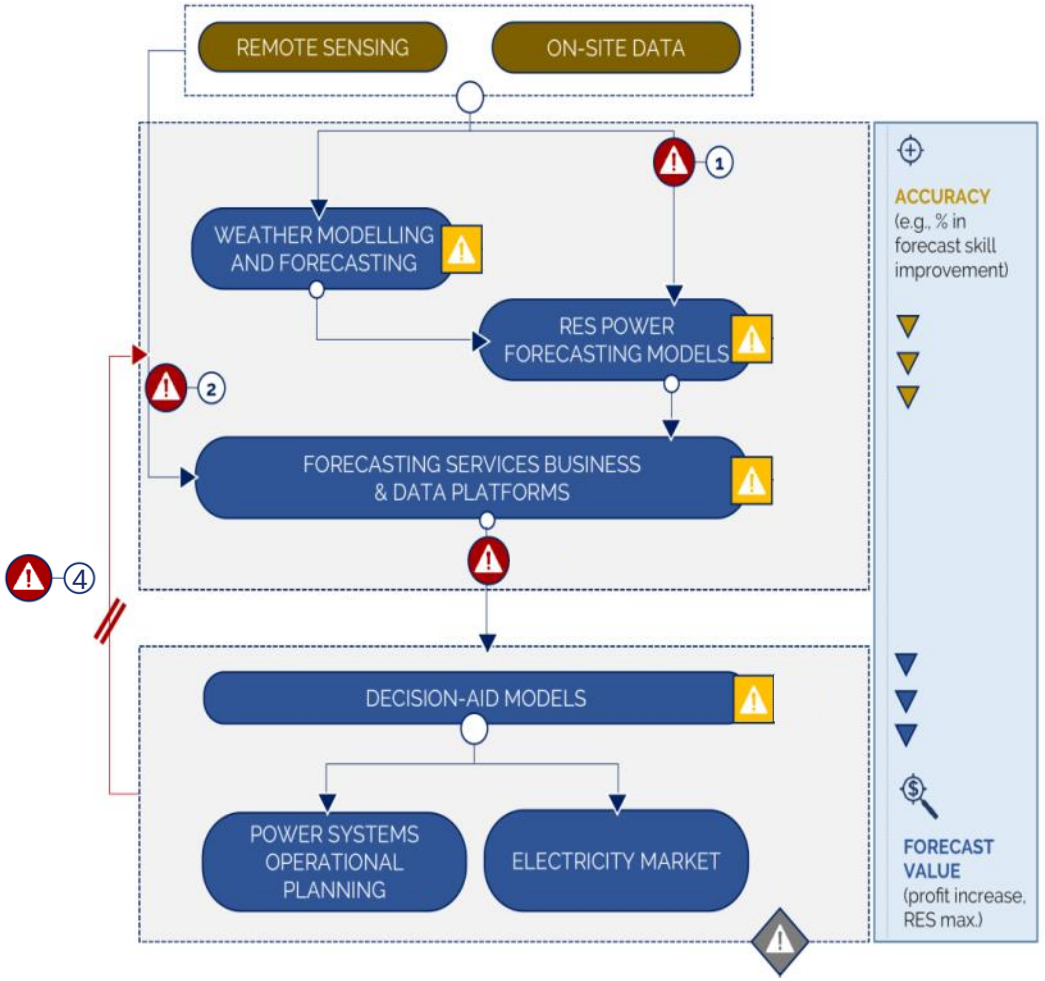


Research directions (optimal use of forecasts)

- RES forecasting models are tuned today upon their **accuracy.**
- An alternative could be to “tune” them considering, not only accuracy, but also the “**value**” they bring when used in a specific application (i.e. revenue €s in trading).
- Development of AI-based prescriptiove analytics **to simplify** the whole model chain



Research directions (data sharing)

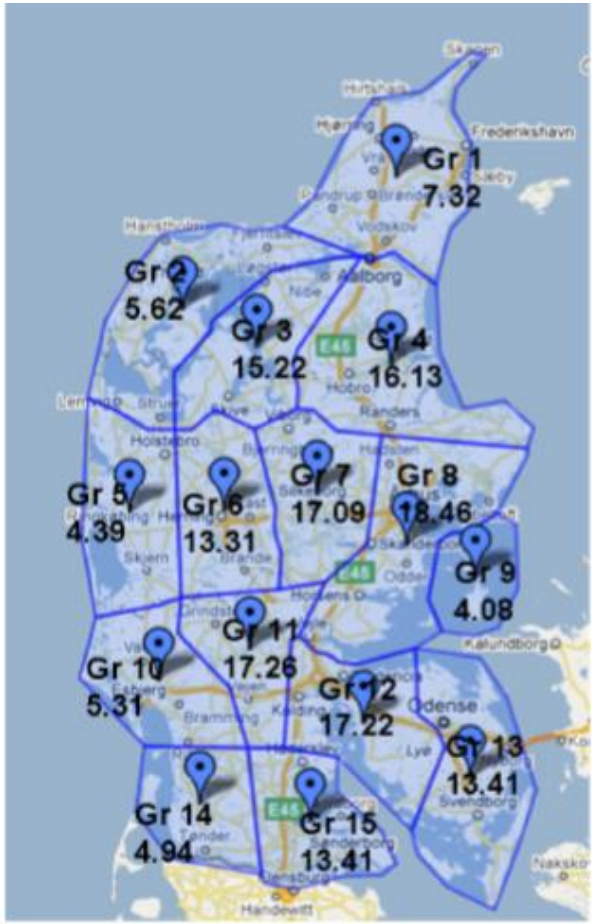


Challenges in the models and the connections:

- a — Need for NWP products adapted to RES use-cases.
- b — Limitations of RES prediction models to exploit large amounts of heterogenous data
- 4 — Open loop between forecasts generation and their use in apps.
- 1 — Lack of meaningful open data (privacy issues)
- 2 — Lack of price incentives to share data

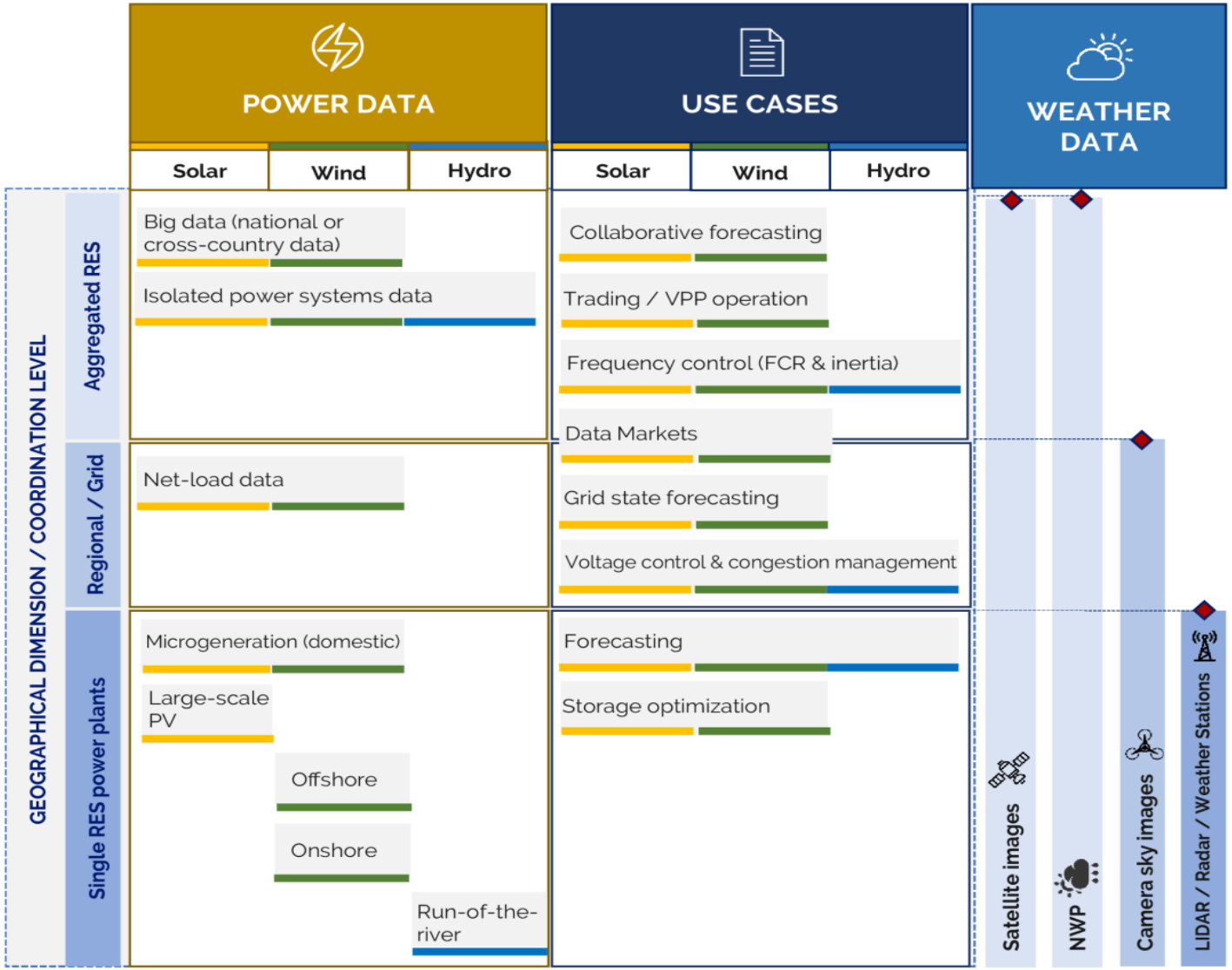
Research directions (data sharing)

- Many works have shown the benefits of integrating spatially distributed information (neighbor PV/wind farms as sensors).
- With Smart4RES we will exploit data science techniques, like **federated learning**, to develop a framework for **collaborative forecasting** through **data sharing** that respects **privacy and confidentiality constraints**
- And a **data market concept** to foster data sharing



improvement of 1-hour ahead forecast RMSE

Use cases


POWER DATA
USE CASES
WEATHER DATA
Solar
Wind
Hydro
Solar
Wind
Hydro
GEOGRAPHICAL DIMENSION / COORDINATION LEVEL
Aggregated RES
Regional / Grid
Single RES power plants
Big data (national or cross-country data)
Isolated power systems data
Net-load data
Microgeneration (domestic)
Large-scale PV
Offshore
Onshore
Run-of-the-river
Collaborative forecasting
Trading / VPP operation
Frequency control (FCR & inertia)
Data Markets
Grid state forecasting
Voltage control & congestion management
Forecasting
Storage optimization
Satellite images
NWP
Camera sky images
LIDAR / Radar / Weather Stations

Take away messages

- RES-oriented research for **improving weather forecasting**
- Seamless approaches to permit **convergence of the technology**
- Data science approaches for **alternative forecasting and decision-making paradigms.**
- Data sharing and data markets to extract the **value out of data**!

Smart4RES webinar series (hosted by IEA –ISGAN)

#1 June 2020	#2 Dec 2020	#3 March & April 2021	#4 9 June 2021	#5 September 2021	#6 October 2021
Replay on Youtube	Replay on Youtube	Replay on Youtube			
Introduction to Smart4RES - Data science for renewable energy prediction	Extracting value from data sharing for RES forecasting	Advanced weather forecasting for RES applications 3.1 NWP & High-resolution models 3.2 Data observations & assimilation	Optimising participation of RES generation in electricity markets: new opportunities and the role of forecasting	Optimizing the value of storage in power systems and electricity markets	Modelling tools for integrating RES forecasting in electrical grids
ARMINES DTU	INESCTEC DTU	energy&meteo systems WHIFFLE DTU DLR METEO FRANCE	energy&meteo systems DTU ARMINES	ARMINES NEW ENERGY WORLD	INESCTEC ARMINES

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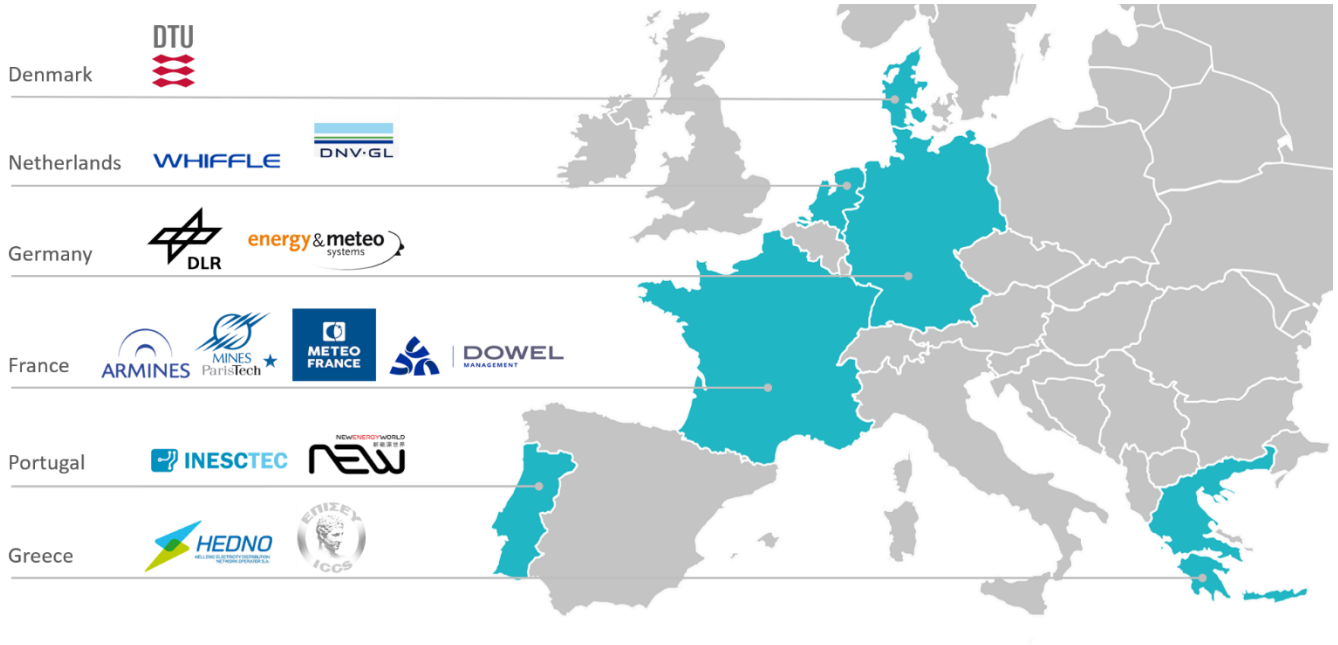
Smart4RES

THANK YOU !



Smart4RES

APPENDIX

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864337

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