



A Holistic Approach to Improve the Model & Value Chain of Renewable Energy Forecasting – The Smart4RES Project

Simon Camal, George Kariniotakis, ARMINES - MINES ParisTech PSL University, Centre PERSEE
Wind Europe Technology Workshop 2021
8 September 2021

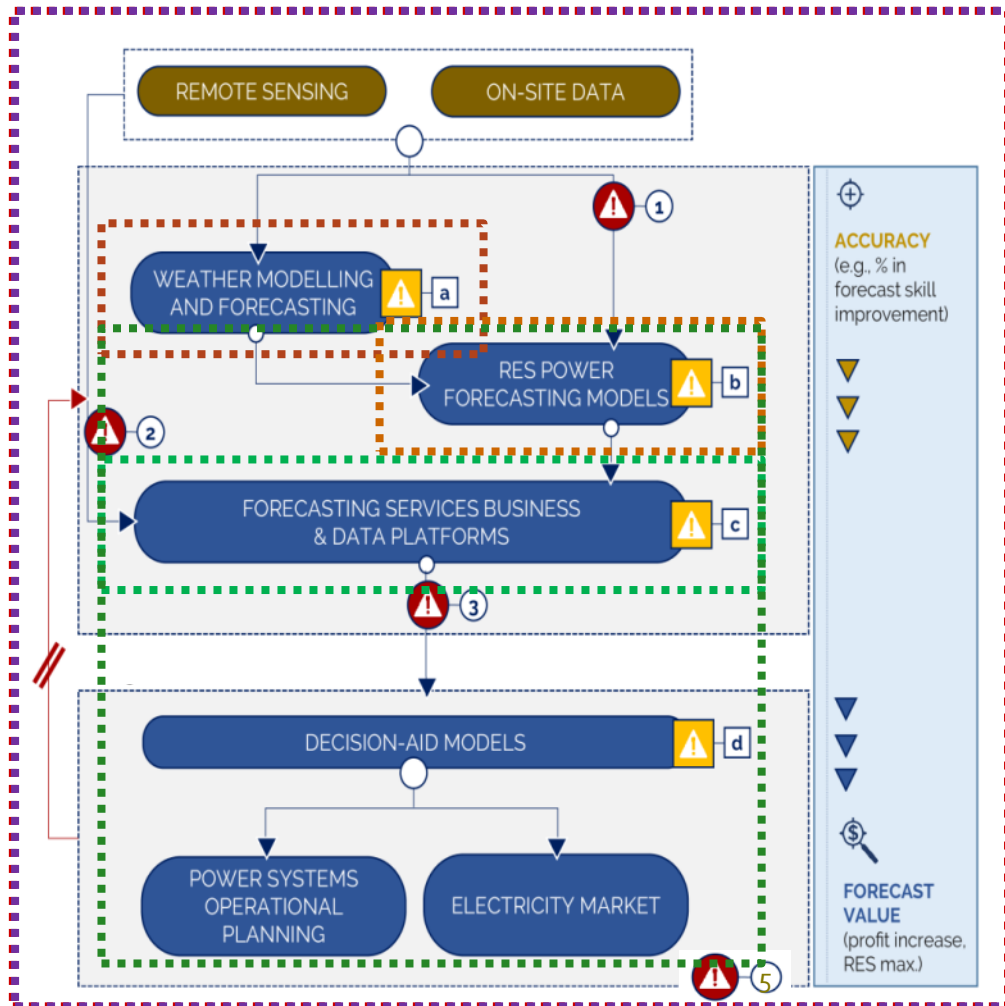


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864337

1. The Smart4RES project
2. Solutions for the modelling and value chain of renewable energy forecasting
3. Advanced renewable forecasting over multiple timeframes
4. Trading under renewable uncertainty, with AI/data science methods
5. Conclusion

1. The Smart4RES project

- Objectives: prepare the next generation of solutions for RES forecasting and applications



- 1 Requirements for forecasting technologies 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.

1. The Smart4RES project

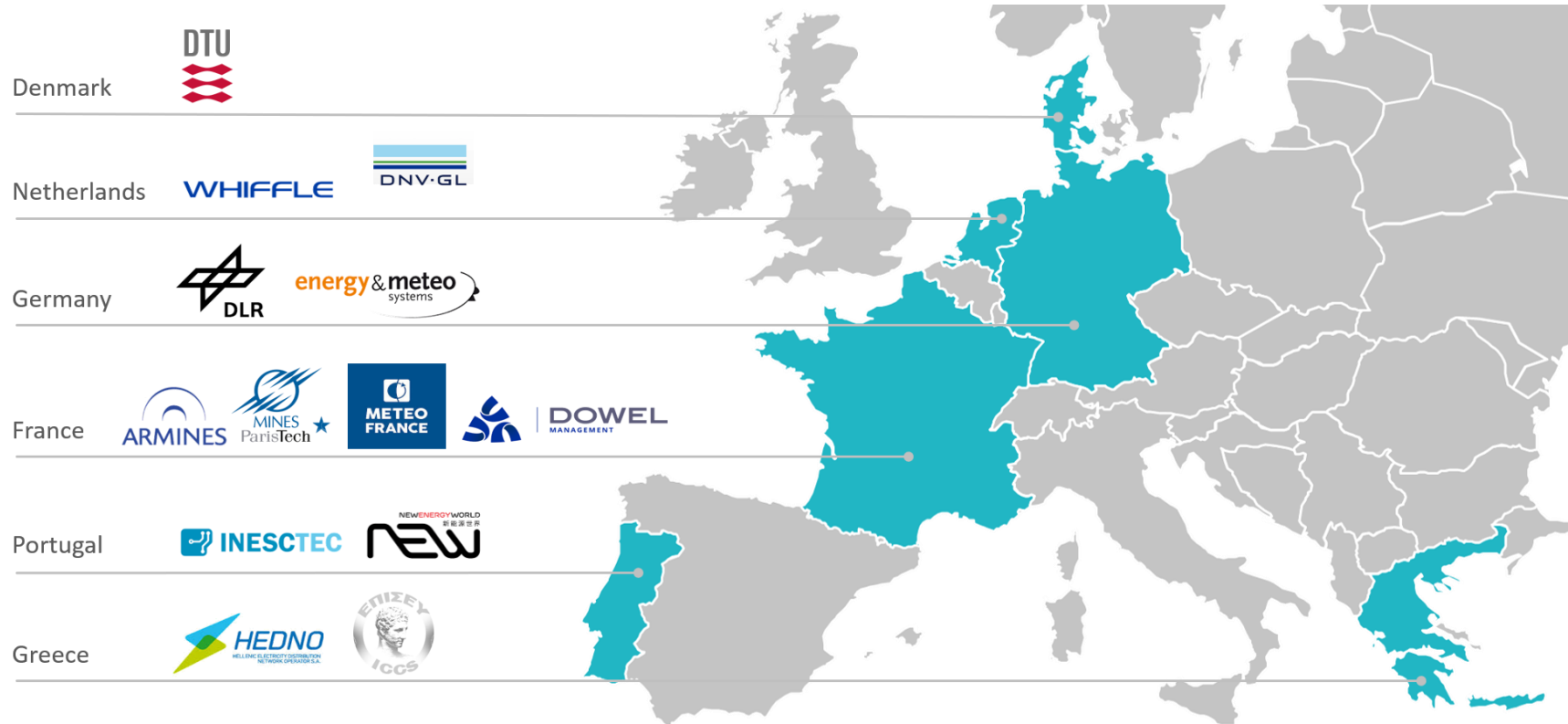
- A multi-disciplinary consortium

6 countries
12 partners

End-users
Industry
Research
Universities
Meteorologists

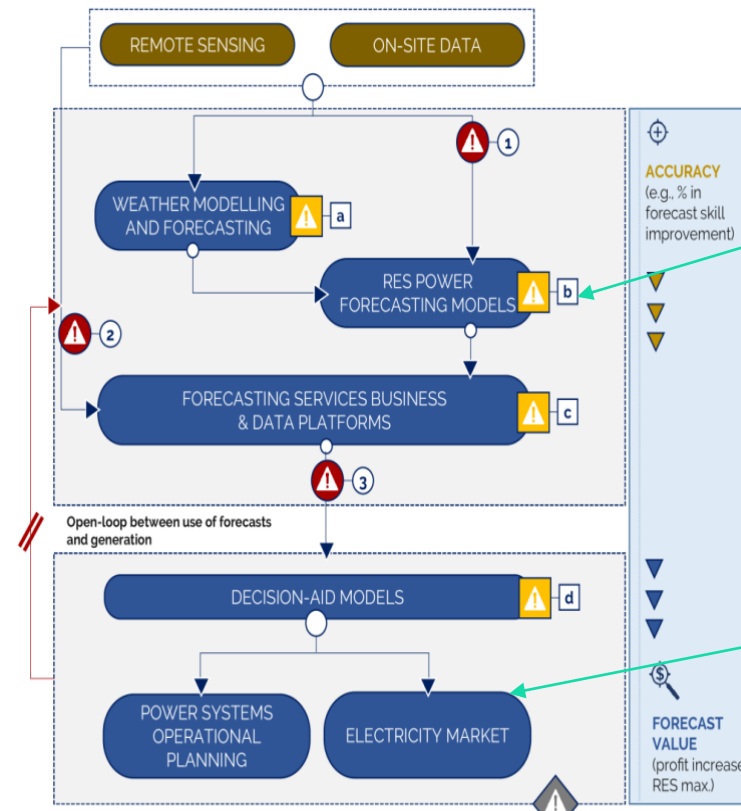
Funds: H2020
programme
Budget: 4 Mio€
Duration: 3.5 years

11/2019-4/2023



2. Solutions for the modelling and value chain of RES forecasting

- From data to decision
- Focus of this presentation: highlight AI/data science solutions for wind power



Advanced RES forecasting over multiple timeframes:

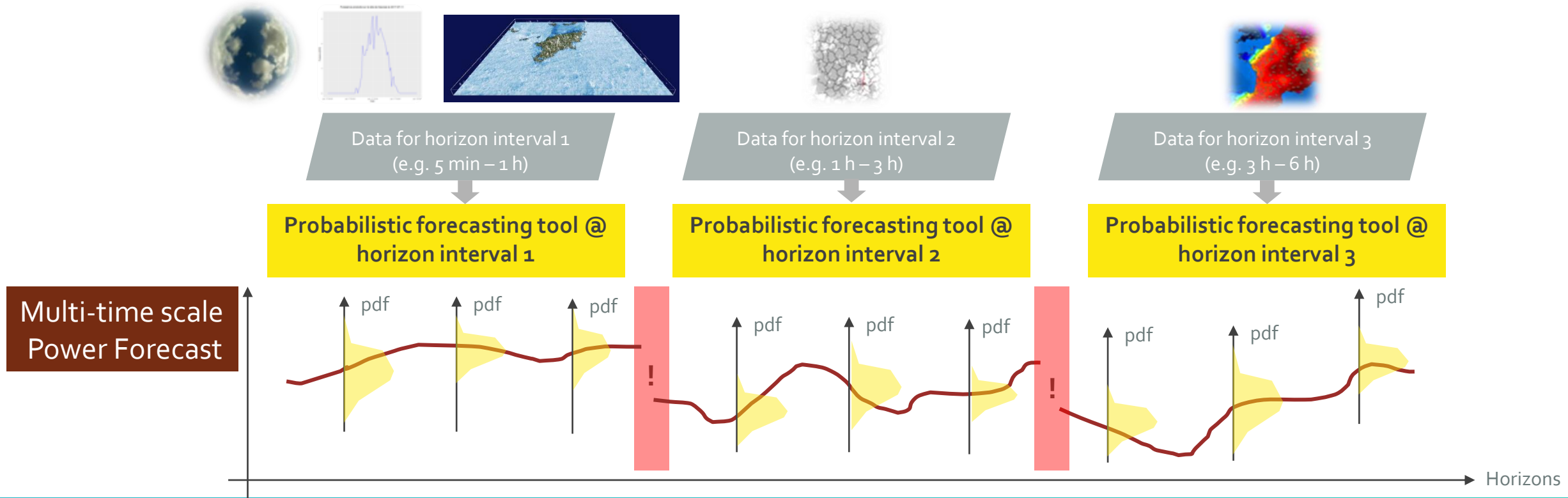
- Multiple data sources
- The role of data science tools

AI/Data science approaches to optimize trading decisions for RES (& storage):

- Probabilistic forecasting and optimization
- Integrated Machine Learning + Optimization

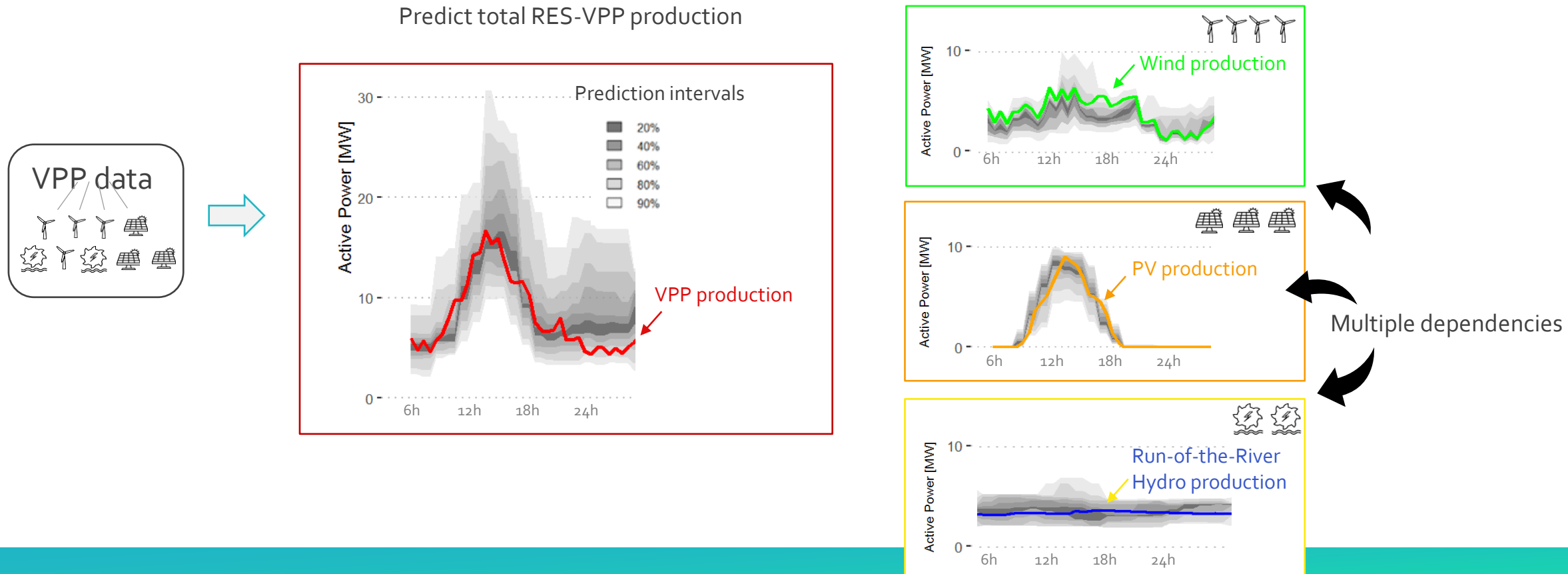
3. Advanced renewable forecasting over multiple timeframes

- State of the art RES forecasting 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.
- Need for **seamless** and **generic** (for wind, PV, aggregations...) forecasting approaches, able to consider simultaneously **heterogenous data**. =>Possible a convergence of forecasting solutions?



3. Advanced renewable forecasting over multiple timeframes

- Build a **scalable regression** model accounting for the dynamic contributions of diverse data sources
- Example: Forecast of RES Virtual Power Plant (VPP) production

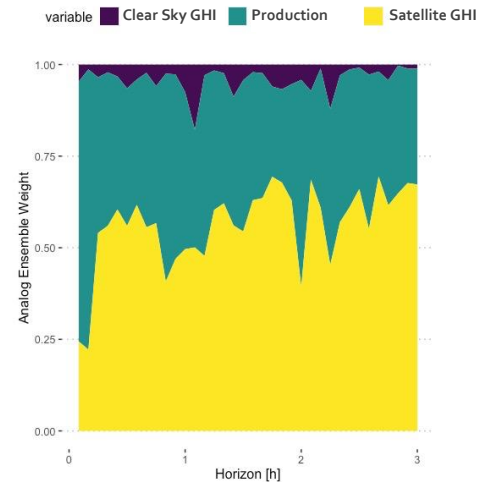


3. Advanced renewable forecasting over multiple timeframes

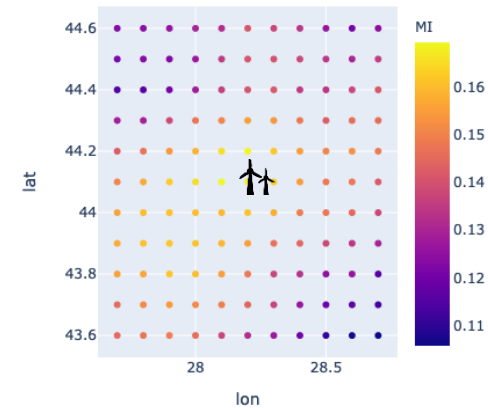
- **Statistical models** adapted to large dimension
- Example: Analog Ensembles, weighted distance between historical features \mathbf{x} and features for instant to predict $\hat{\mathbf{x}}$

$$\operatorname{argmin}_{\mathbf{w}_h} \sum_{i \in \mathcal{D}} w_{ih} \|\mathbf{x}_{t+h}^i - \hat{\mathbf{x}}_{t+h}^i\|_2, \hat{\mathbf{y}}_{t+h} = \text{KDE}(\mathbf{w}_h, \hat{\mathbf{x}}_{t+h})$$

- Advantages: adaptive and continuous prediction over horizon range, good interpretability



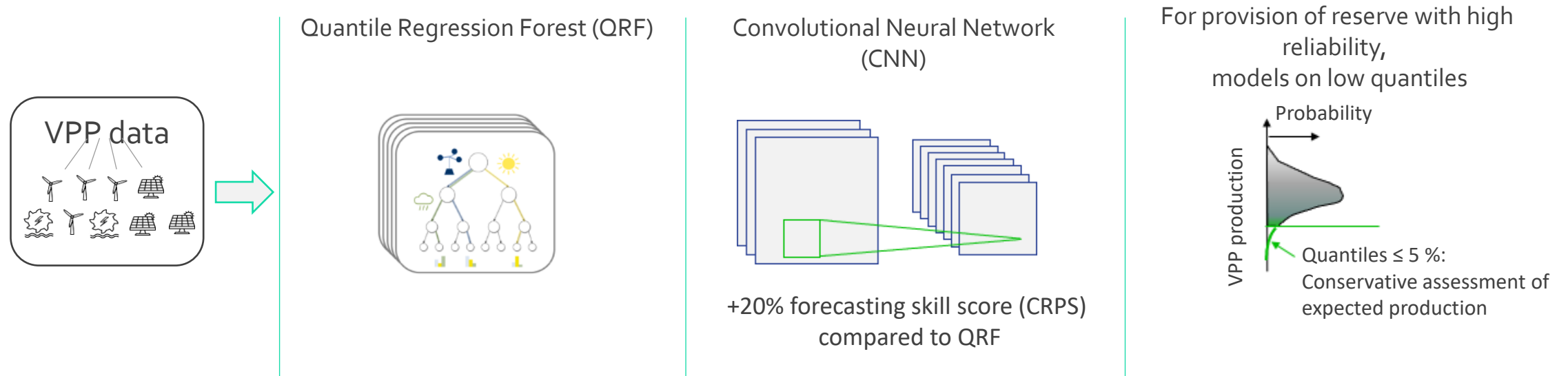
Weights for PV



Weights for wind speed predictions at grid points surrounding a Wind Farm

3. Advanced renewable forecasting over multiple timeframes

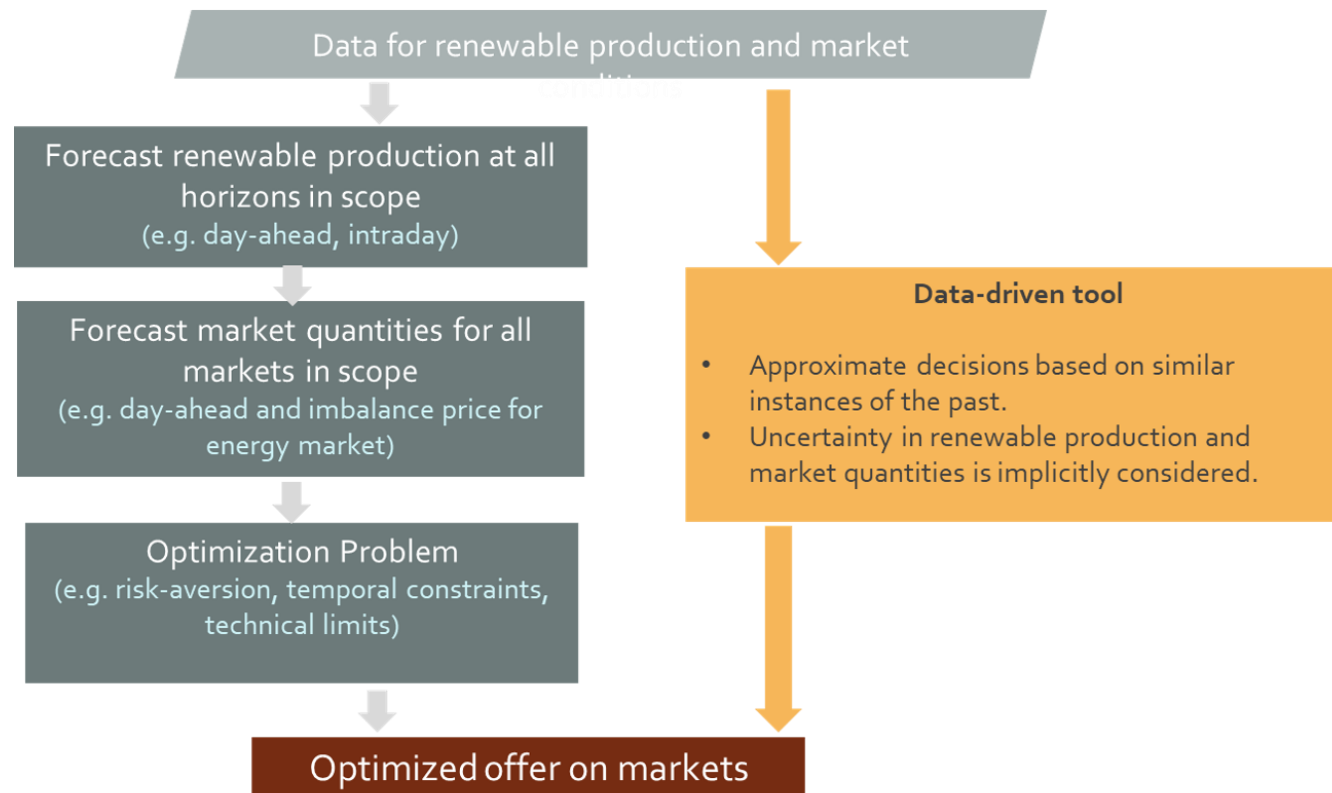
- Machine Learning models are good candidates to predict RES production from large and heterogenous data



4. Trading under RES uncertainty, data science approaches

▪ Forecast then Optimize vs Data-driven approach

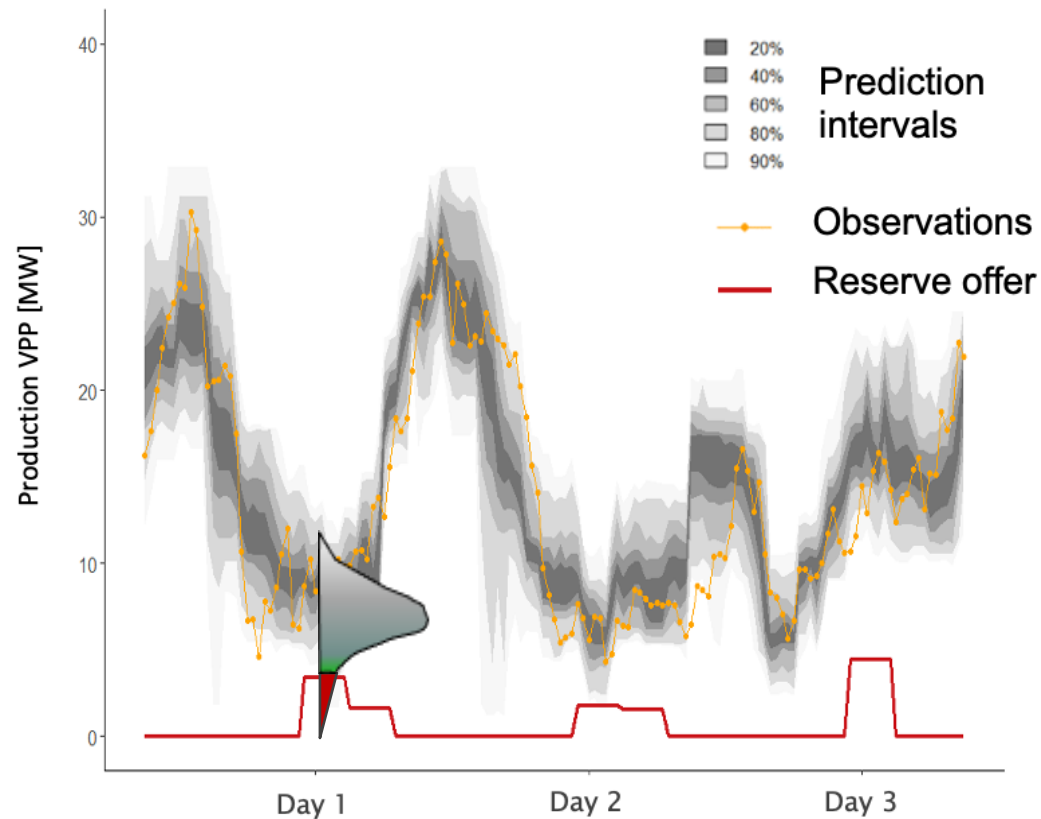
- Case study: RES-VPP offering on short-term electricity markets (energy and/or reserve)



4. Trading under RES uncertainty, data science approaches

Forecast then Optimize

Probabilistic forecasting of RES-VPP production (here QRF) +
 Deterministic forecasting of market quantities (here statistical / Machine Learning models)



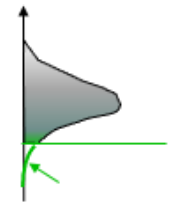
$$\text{Optimal reserve offer} = F^{-1}(\tau_R(\boldsymbol{\pi}_R, \boldsymbol{\pi}_E))$$

F : probabilistic forecast of VPP production

τ_R : optimal quantile for reserve

$\boldsymbol{\pi}_R$: prices of reserve market

$\boldsymbol{\pi}_E$: prices of energy market

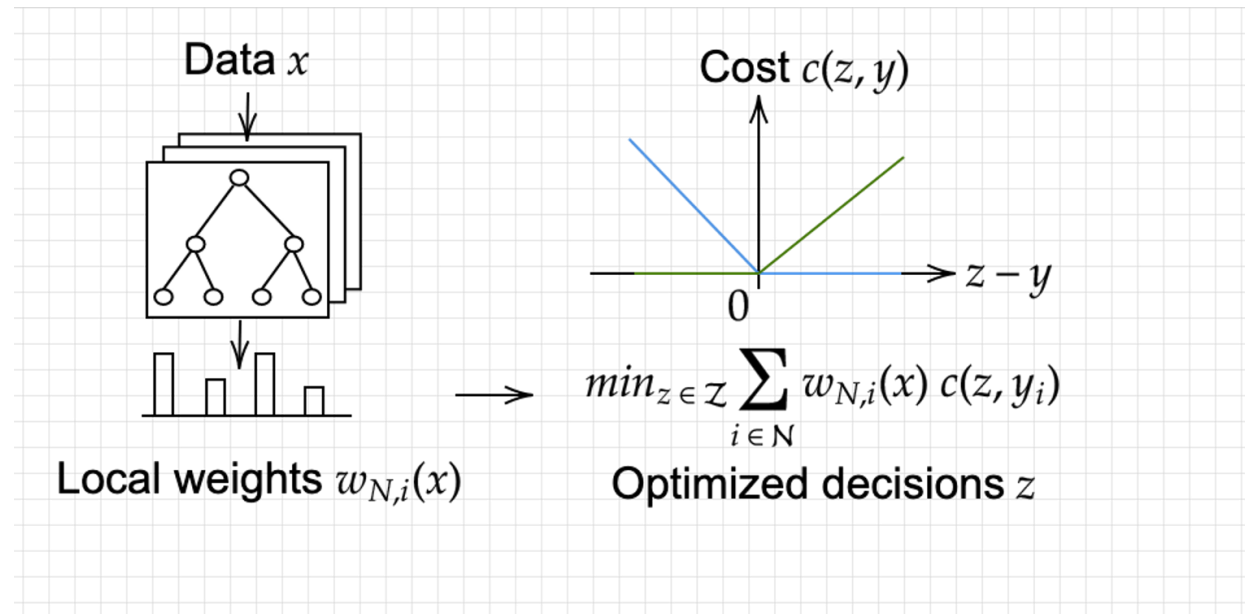


Identified periods when reserve is profitable.

	Forecasts VPP & Market	Reserve = 0.5%-quantile VPP Forecast
Increased revenue vs energy only	+5%	+4%
Frequency of underfulfilled reserve	0.1%	0%

4. Trading under RES uncertainty, data science approaches

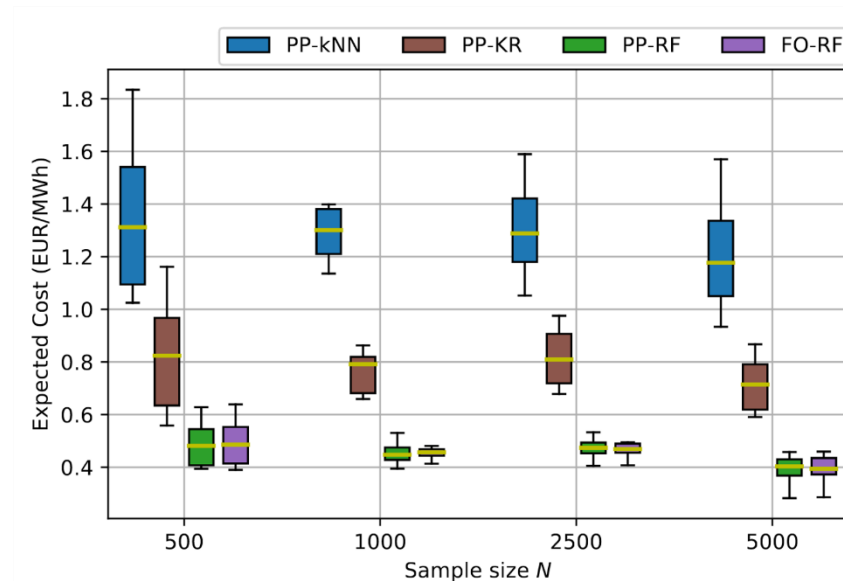
- **Data-driven Approach: Integrated Machine Learning and Optimization**
 - Instead of multiple forecasting models, deploy a single decision-aid model
 - Convergence guarantees
 - Applicable to constrained problems
 - Based on **Predictive Prescriptions (PP)**:



4. Trading under RES uncertainty, data science approaches

▪ Integrated Machine Learning and Optimization – Case study

- RES-VPP offering on the energy market, comparison of PP with standard Forecast-Optimize Method (FO-RF)
- The choice of the local weighting algorithm matters: best results obtained with **Random Forest** (RF) compared to k-Nearest Neighbors (kNN), Kernel Regression (KR)
- **Take-away**: Similar performance than state-of-the-art FO with less complexity, robust to test size



Trading results of PP with different local weighting algorithms and sample size (ARMINES / MINES ParisTech, A. Stratigakos)

5. Conclusion

- Smart4RES: a multi-disciplinary approach to provide solutions for forecasting and decisions under renewable uncertainty
- Improved data science tools are needed to leverage the value of multiple data sources for renewable forecasting
- Machine learning models optimize the forecasting and trading performance of Virtual Power Plants offering energy and ancillary services
- Advanced AI / data science methods simplify the trading modelling chain compared to the standard 'forecast-then-optimize' approach
- To know more, visit www.smart4res.eu: use cases, deliverables, webinars.



THANK YOU !



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

