



# Smart4RES: Next generation solutions for renewable energy forecasting and its applications with focus on wind power forecasting

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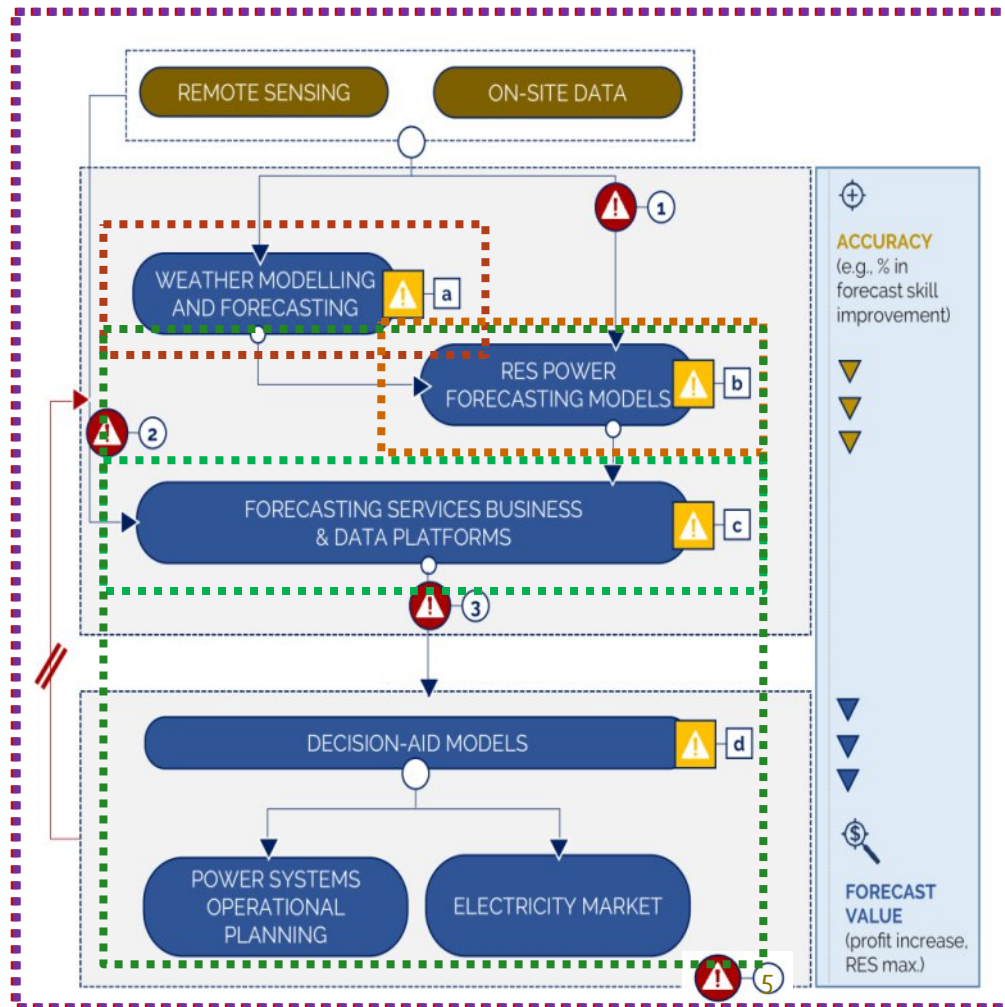


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1. The Smart4RES project
  2. High-resolution weather forecasting for wind power applications
  3. Wind power forecasting over multiple time scales
  4. Collaborative analytics and monetized value of wind data
  5. Conclusion
- } Some highlight results

# 1. The Smart4RES project

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



- Requirements** for forecasting technologies to enable 100% RES penetration
- RES-dedicated weather forecasting with 10-15% improvement using various sources of data and very high resolution approaches.
- New generation of **RES production forecasting tools** enabling 15% improvement in performance.
- Streamline the process of getting optimal value** through new forecasting products, data market places, and novel business models
- New **data-driven** optimisation and decision aid tools for power system management and market participation
- 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

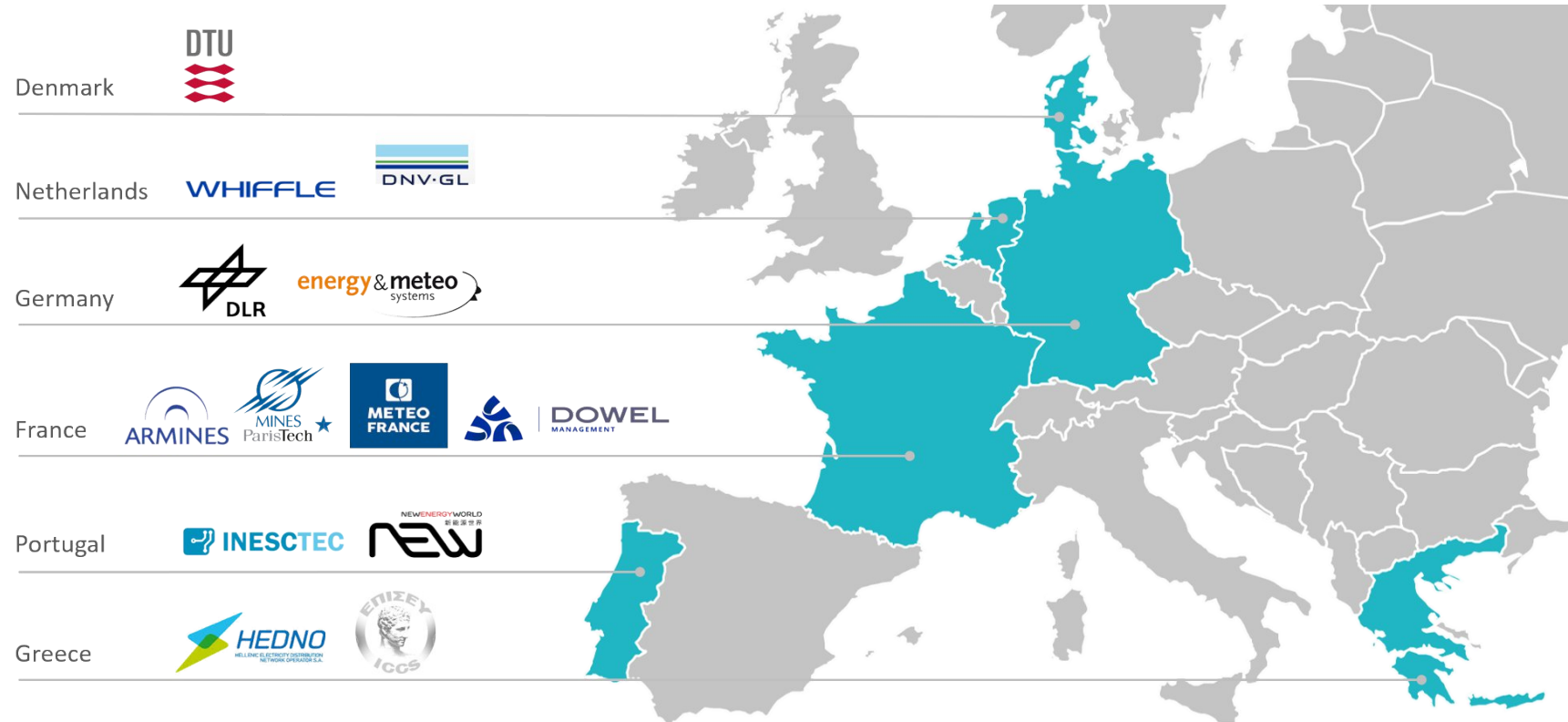
Funds: H2020

programme

Budget: 4 Mio€

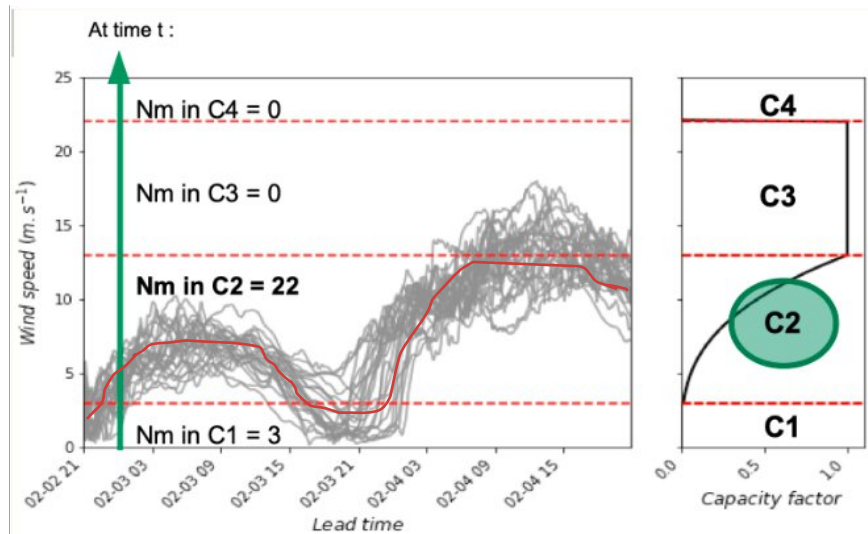
Duration: 3.5 years

**11/2019-4/2023**

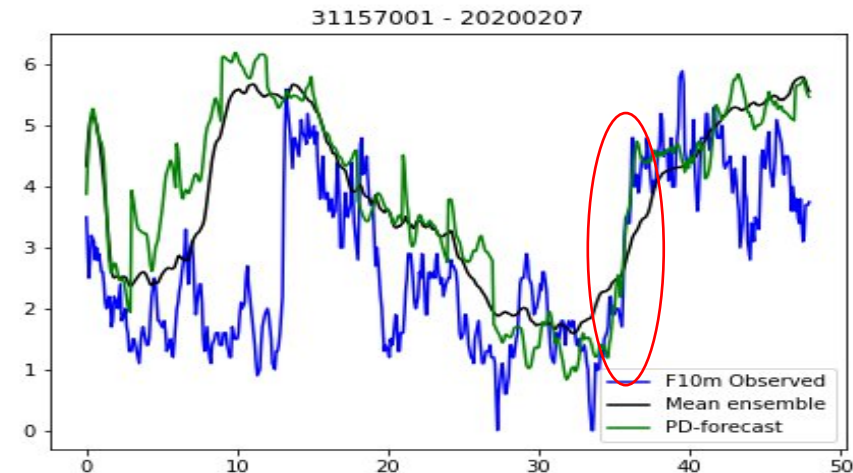


## 2. High-resolution weather forecasting for wind power

- Pseudo-deterministic Numerical Weather Predictions at high-resolution (1km-5min, MeteoFrance)



Strategy to build pseudo-deterministic wind speed simulations based on clustering and most represented category



Comparison of time series of observed and simulated wind speed

Optimizing the information from ensembles

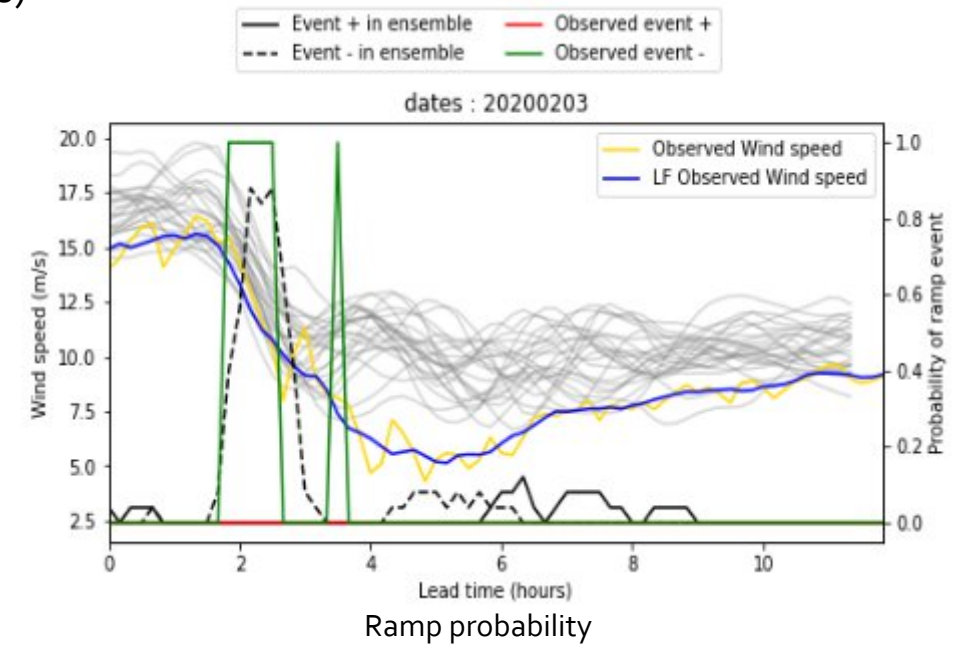
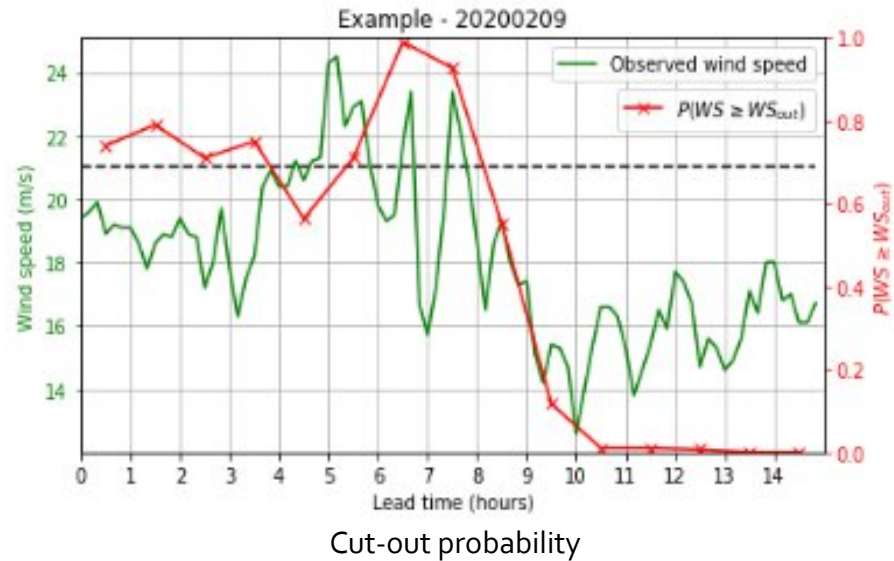


## 2. High-resolution weather forecasting for wind power

- Pseudo-deterministic Numerical Weather Predictions at high-resolution (1km - 5min, MeteoFrance)

Building the best 5 min timeseries from an ensemble:

- applied to wind speed and direction at hub height (121 wind farms)
- optimal percentile of the ensemble (minimizing RMSE)

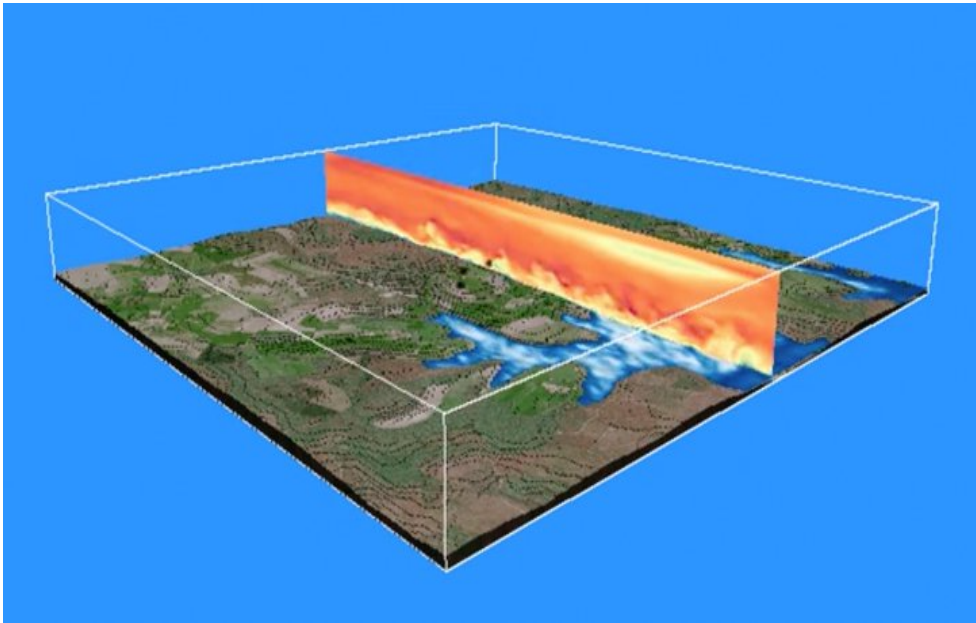


- 15% improvement of RMSE compared to standard NWP model
- Ability to provide specific forecasting products

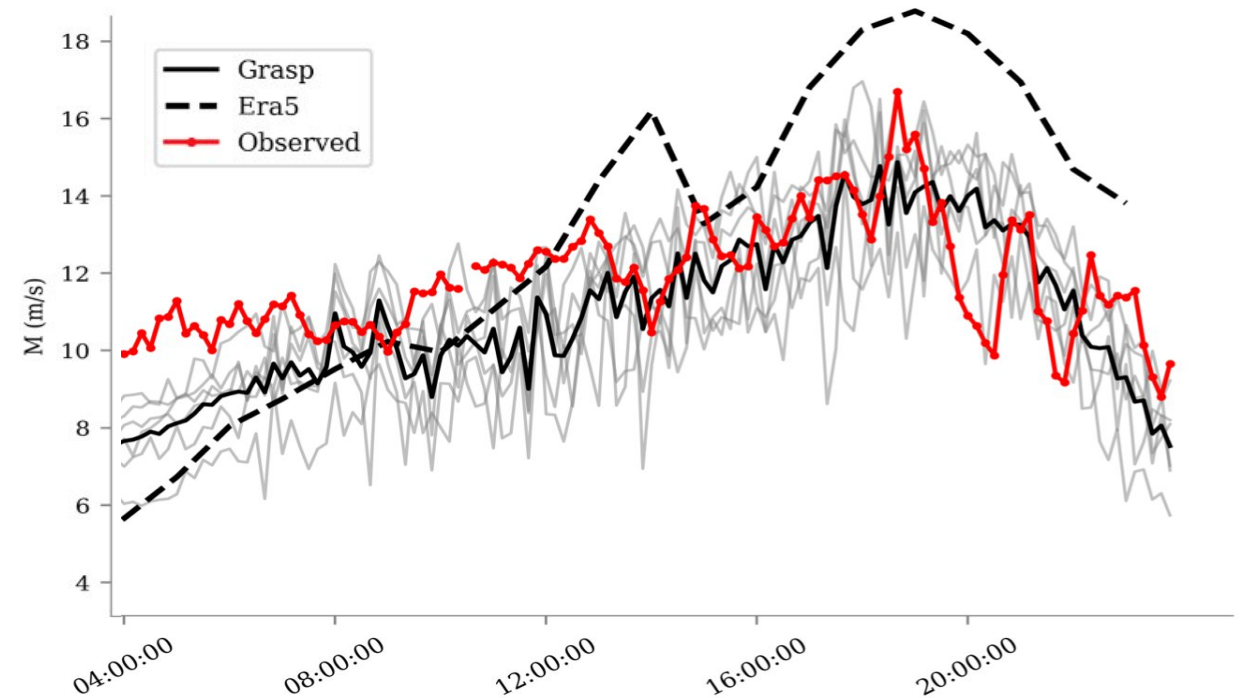
## 2. High-resolution weather forecasting for wind power

- Large Eddy Simulation provide local forecasts of wind speed and power (Whiffle)

Resolves turbulence, clouds/fog and effect of surface on **local weather conditions**, by numerical simulation over a much finer grid than conventional NWP (50m - 30sec resolution)



More realistic variability than conventional NWP



## 2. High-resolution weather forecasting for wind power

- It is possible to scale up LES using multi-GPU systems

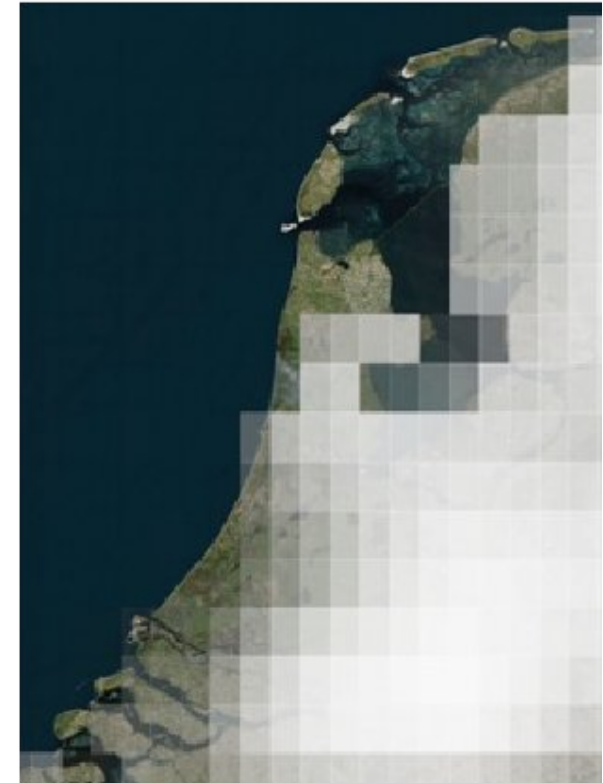
LES forecast



Satellite image



Traditional weather forecast

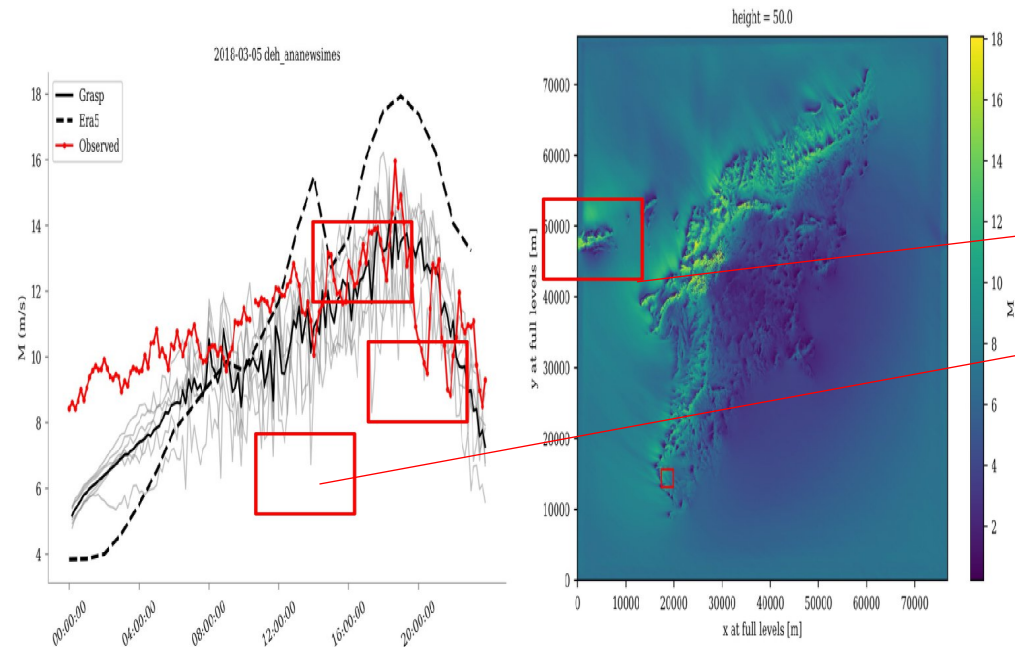




## 2. High-resolution weather forecasting for wind power

- Complex terrain is challenging

Aim: accurate, spatio-temporal forecast on sites distributed over a small island



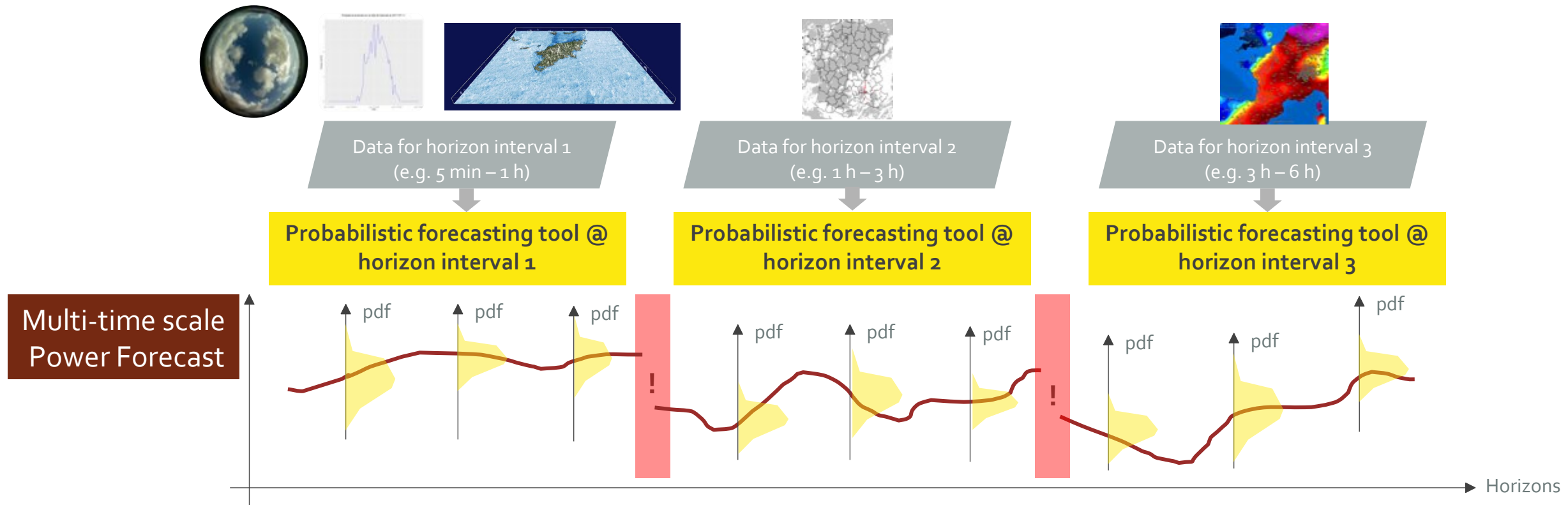
### Approach: nested LES

- Outer domain captures Rhodes ~ 200m resolution
- 4 inner domains on wind farms: ~ 40m resolution
- LES output at turbine locations

- LES is an additional data source for wind power forecasting
- New forecasting products for grid management and flexibility provision

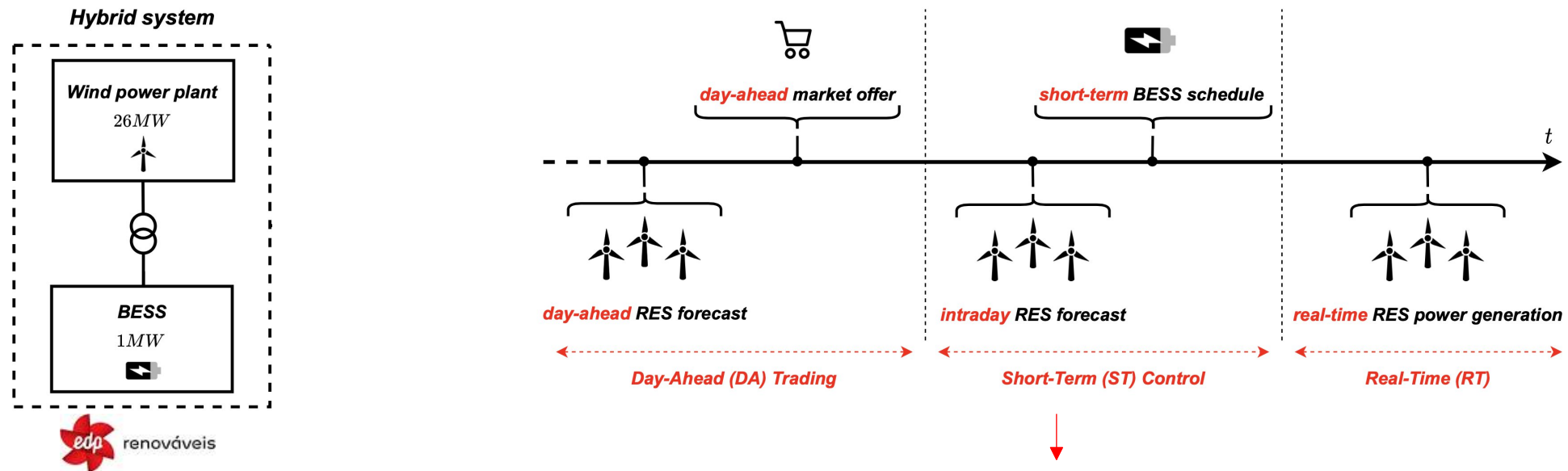
### 3. Towards seamless wind power forecasting over multiple time scales

- 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. Towards seamless wind power forecasting over multiple time scales

- Predictive control of hybrid Wind+storage system providing energy and ancillary services



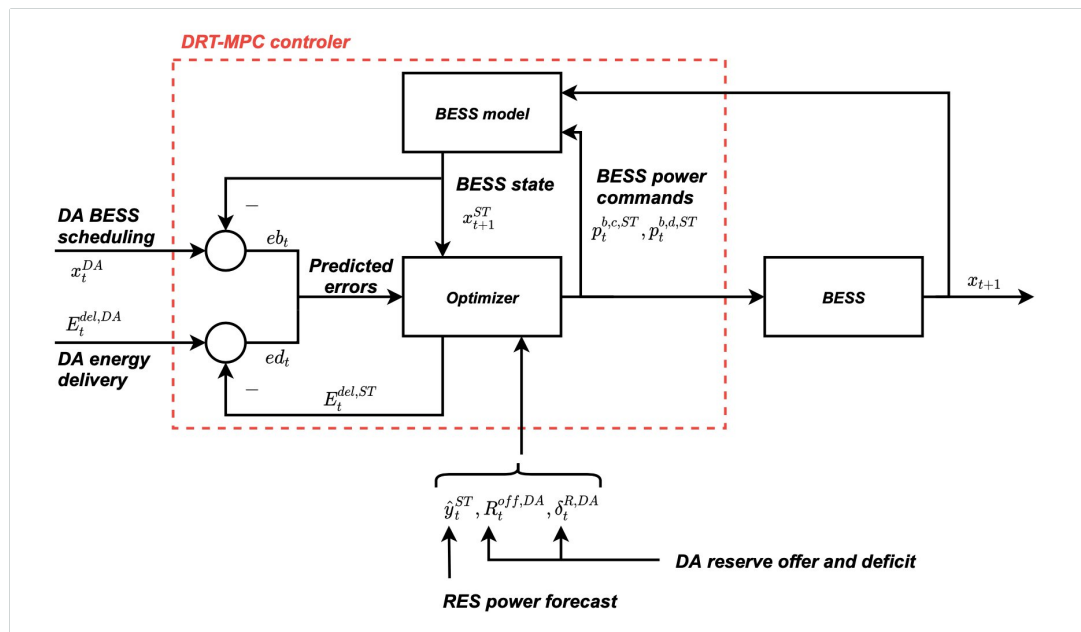
$$\sum_{\omega \in \Omega} \sum_{k \in N} w_M \cdot \underbrace{\left( \pi^{E,up} \cdot E_{t+k,\omega|t}^{up,ST} - \pi^{E,down} \cdot E_{t+k,\omega|t}^{down,ST} \right)}_{\text{market revenue}} + w_B \cdot \underbrace{\mathbb{E}_N(x_{t+k,\omega|t}^{ST})}_{\text{BESS degradation}}$$

Multi-objective optimization integrating revenue and storage degradation

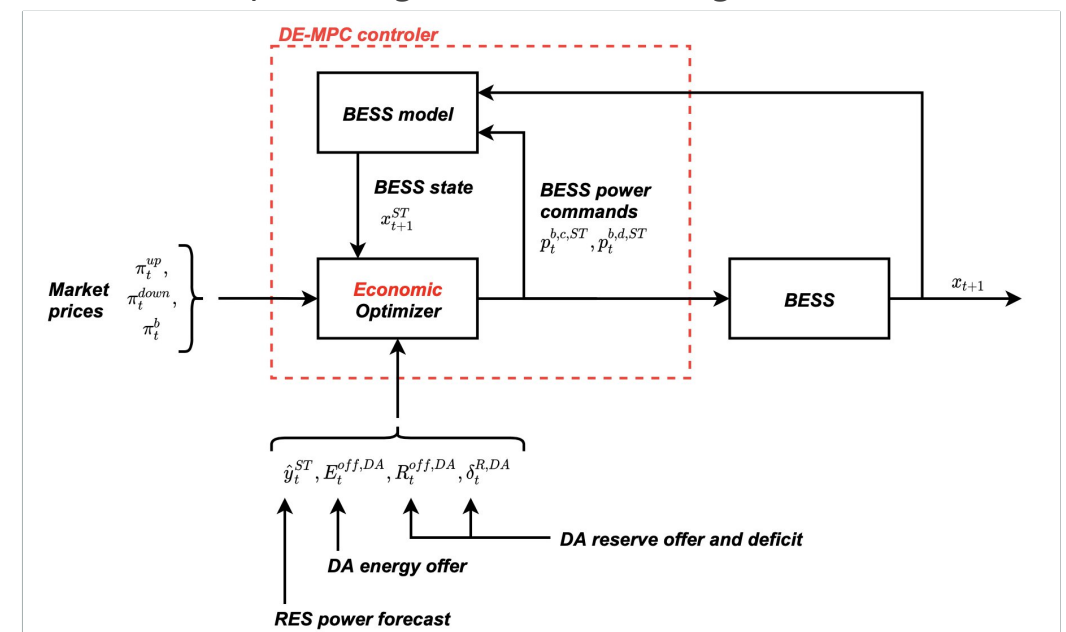
### 3. Towards seamless wind power forecasting over multiple time scales

- Predictive control of hybrid Wind+storage system providing energy and ancillary services

Control tracking reference trajectories



Control optimizing revenues and degradation cost



L. Santosuosso, A complete framework for the problem of trading in electricity market and control applied to renewable energy and storage system, Msc Thesis, Sapienza University of Rome, 2021

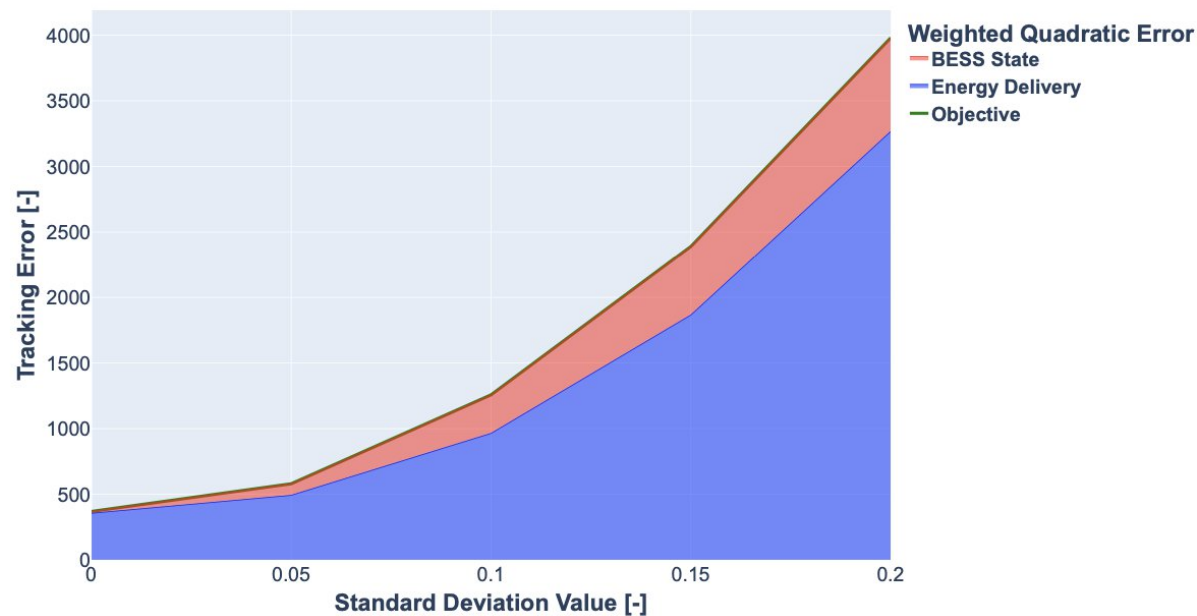
A control framework tailored to technical and economic objectives



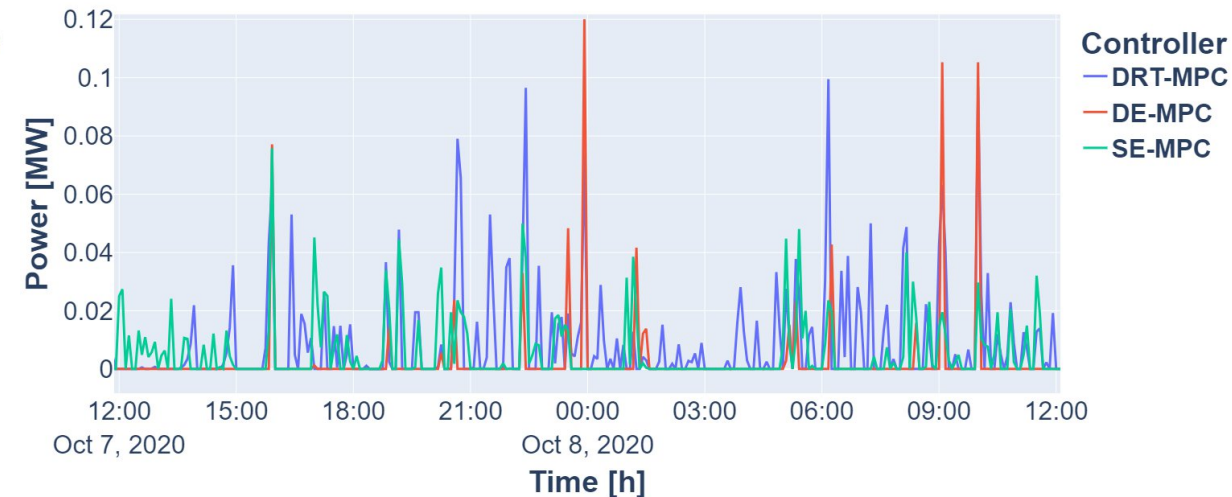
### 3. Towards seamless wind power forecasting over multiple time scales

- Predictive control of hybrid Wind+storage system providing energy and ancillary services

Evolution of control error with forecast perturbation



Storage charge profile with different control methods

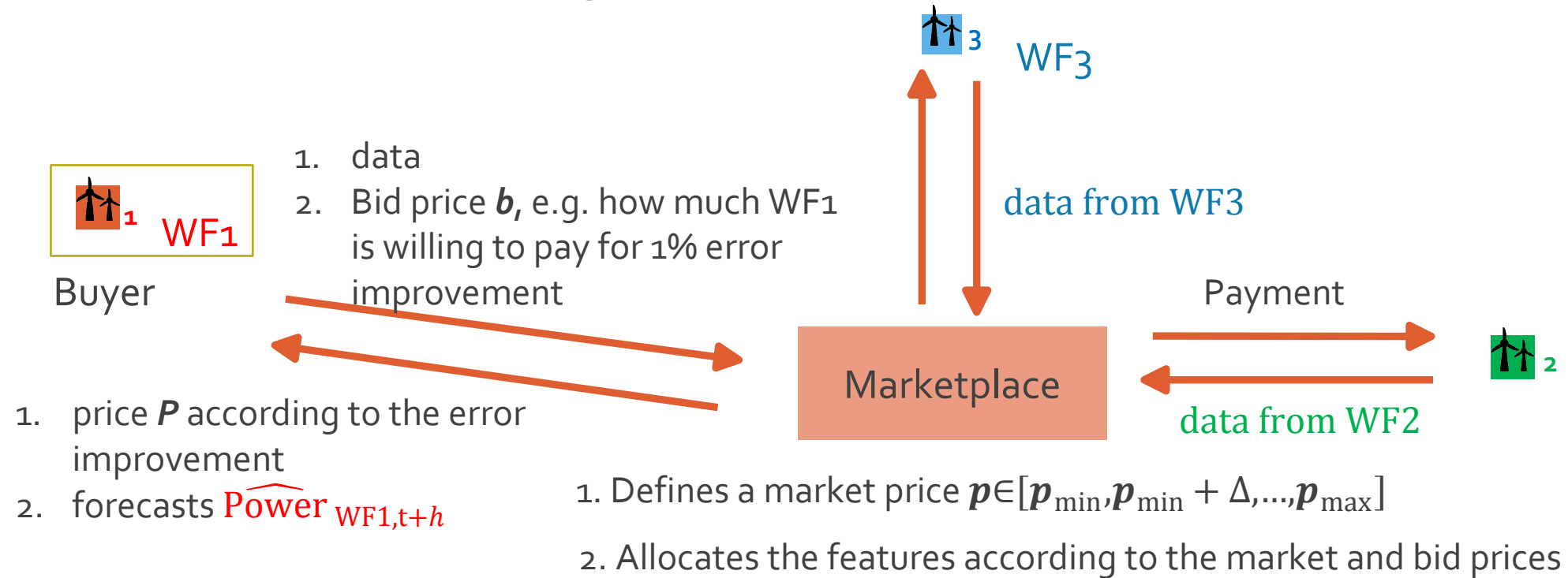


Economic control vs Reference-Tracking control :  
+1% average revenue, -87% degradation cost

- High-quality wind power forecast is crucial for control
- An economic predictive control enables to minimize storage degradation

## 4. Collaborative analytics and data monetization

- Data marketplace incentivizing collaboration between data owners



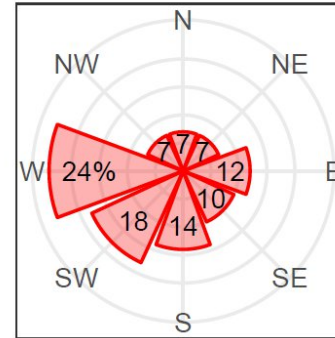
$$\widehat{\text{Power}}_{\text{WF1},t} = \hat{f}_{\text{WF1}}(\text{data from WF1}, \text{allocated data from WF2}, \text{allocated data from WF3})$$

C. Goncalves, P. Pinson, and R. J. Bessa, "Towards Data Markets in Renewable Energy Forecasting," *IEEE Trans. Sustain. Energy*, vol. 3029, no. c, pp. 1–1, 2020, doi: 10.1109/tste.2020.3009615.

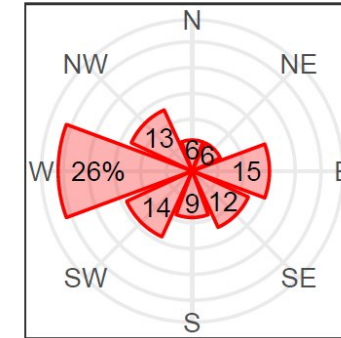
## 4. Collaborative analytics and data monetization



Copenhagen (DK2)

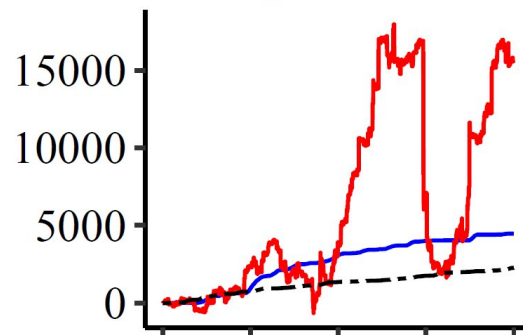


Malmo (SE4)



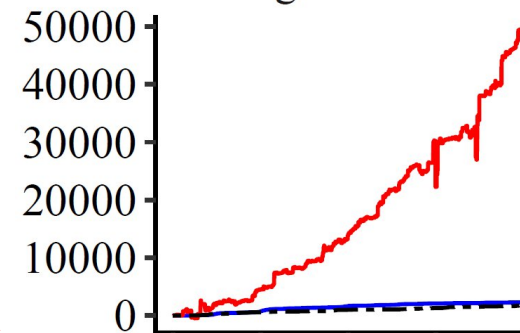
— Cumulative Data Market Revenue — Cumulative Extra Revenue from Electricity Market - - - Cumulative Payment

Agent with highest reward for data sharing  
Agent DK1

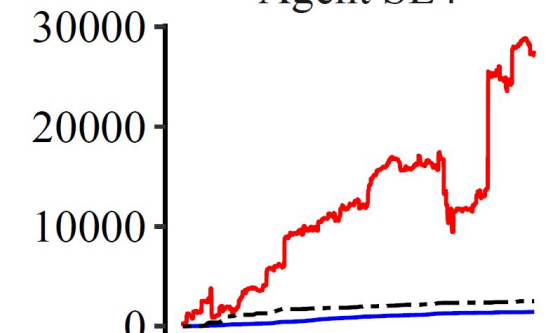


Agents that maximize electricity market revenue due to "extra" data

Agent DK2



Agent SE4



New revenue stream for data owners, respecting privacy constraints (encryption)

## 5. Conclusions

- Smart4RES: a multi-disciplinary approach to provide solutions for forecasting and related decision making under renewable uncertainty
- High-resolution weather forecasts provide detailed information about wind production variability at global and local scale
- Seamless wind power forecasting is essential for the optimized operation of wind farms in temporally-coupled problems, eg. combination with storage
- Collaboration is fostered by data markets, leading to new revenue streams and increased forecasting performance
- To know more, visit [www.smart4res.eu](http://www.smart4res.eu): use cases, deliverables, webinars.



Smart4RES-project



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# THANK YOU !



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