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ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK

ISGAN –
International Smart Grid Action Network

Smart4RES Project

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ISGAN in a Nutshell

INTERNATIONAL SMART GRID ACTION NETWORK

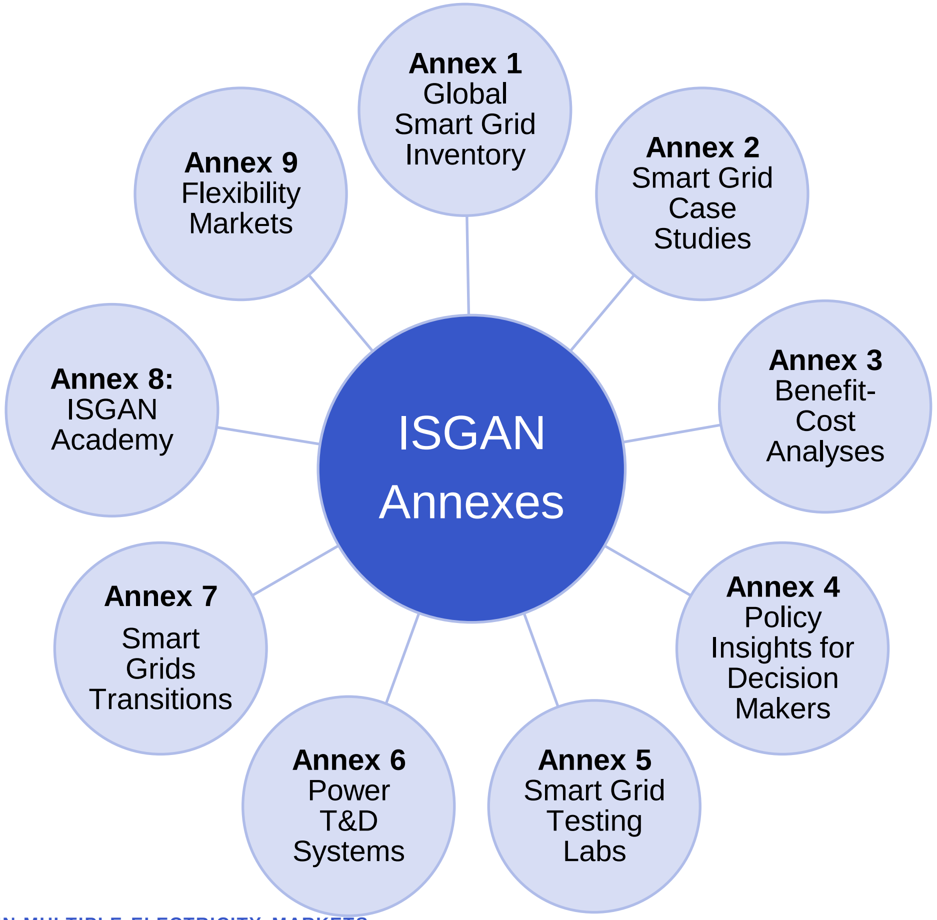
International Smart Grid Action Network is the only global government-to-government forum on smart grids.

Created under the auspices of:

the Implementing Agreement for a Co-operative Programme on Smart Grids

an initiative of the Clean Energy Ministerial (CEM)

Strategic platform to support high-level government knowledge transfer and action for the accelerated development and deployment of smarter, cleaner electricity grids around the world



ISGAN
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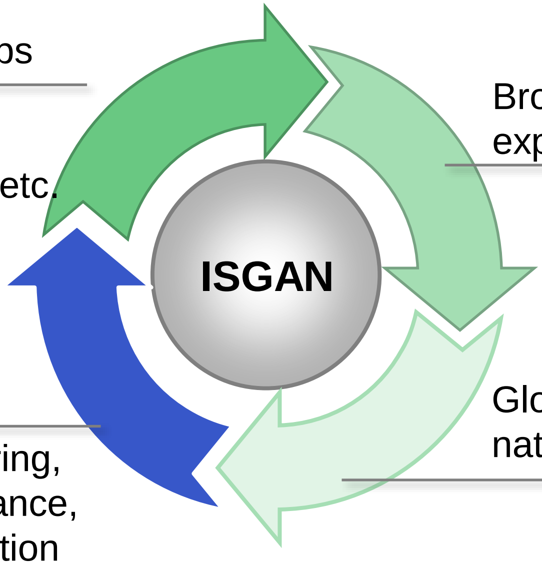
ISGAN's worldwide presence

Value proposition

Strategic partnerships

IEA, CEM, GSGF, Mission Innovation, etc.



Broad international expert network

Global, regional & national policy support

Knowledge sharing, technical assistance, project coordination

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Optimising participation of renewables generation in multiple electricity markets: Smart4RES vision, opportunities and role of forecasting

<u>Agenda</u>

- Smart4RES in a nutshell
- Current status of Virtual Power Plants (VPPs) to integrate RES into electricity markets
- The role of forecasting in trading strategies for RES and Virtual Power Plants
- Current challenges and necessary focus areas for RES in electricity markets

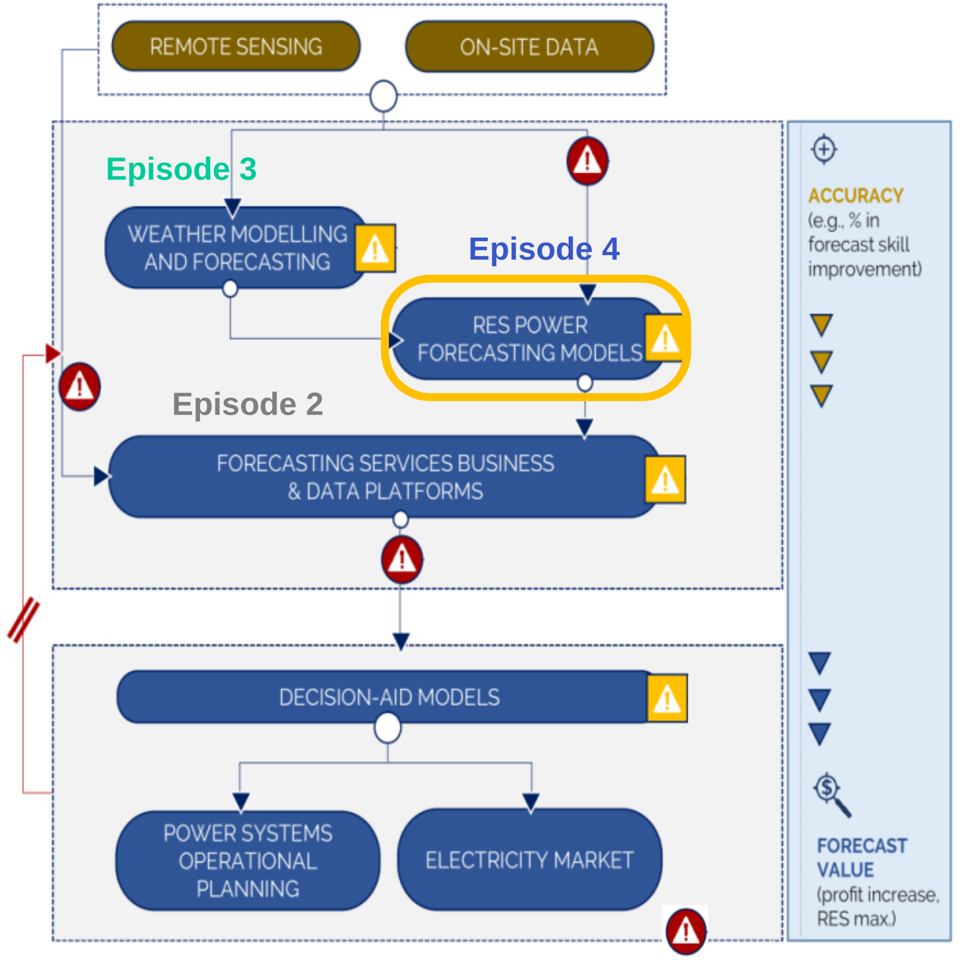
Smart4RES in a nutshell

Smart4RES in a nutshell

- RES forecasting is a mature technology with operational tools and commercial services used by different actors
- However, we want to make progress to improve the forecasting accuracy and to further integrate RES into the market processes.

Smart4RES vision

Science and industry closely co-operate to achieve outstanding improvements of RES forecasting by considering the whole model and value chain.



Smart4RES webinar series

Season1: Towards a new Standard for the entire RES forecasting value chain

#1 June 2020	#2 Dec 2020	#3 March & April 2021	#4 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

Smart4RES consortium

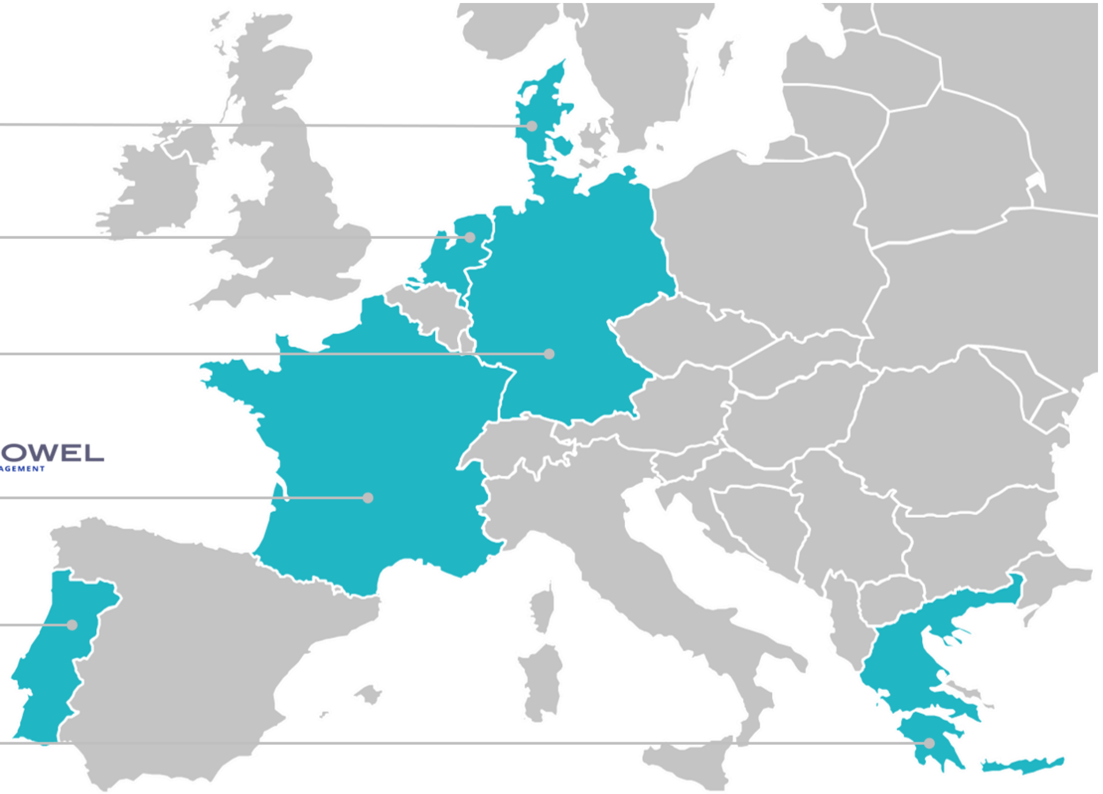
6 countries
12 partners

End-users
Industry
Research
Universities
Meteorologists

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

11/2019-4/2023

Denmark	DTU
Netherlands	WHIFFLE, DNV·GL
Germany	DLR, energy & meteo systems
France	ARMINES, MINES ParisTech, METEO FRANCE, DOWEL MANAGEMENT
Portugal	INESCTEC, NEW
Greece	HEDNO, ICCS



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Current status of Virtual Power Plants (VPPs) to integrate RES into electricity markets

Energy markets accessible by RES

Energy from RES is typically traded on short term electricity markets, i.e. day-ahead or shorter

- **Day-ahead market**

  e.g. EPEX Spot day-ahead: market with auction process, hourly blocks, prices fixed once per day (D-1)
- **Intraday market**

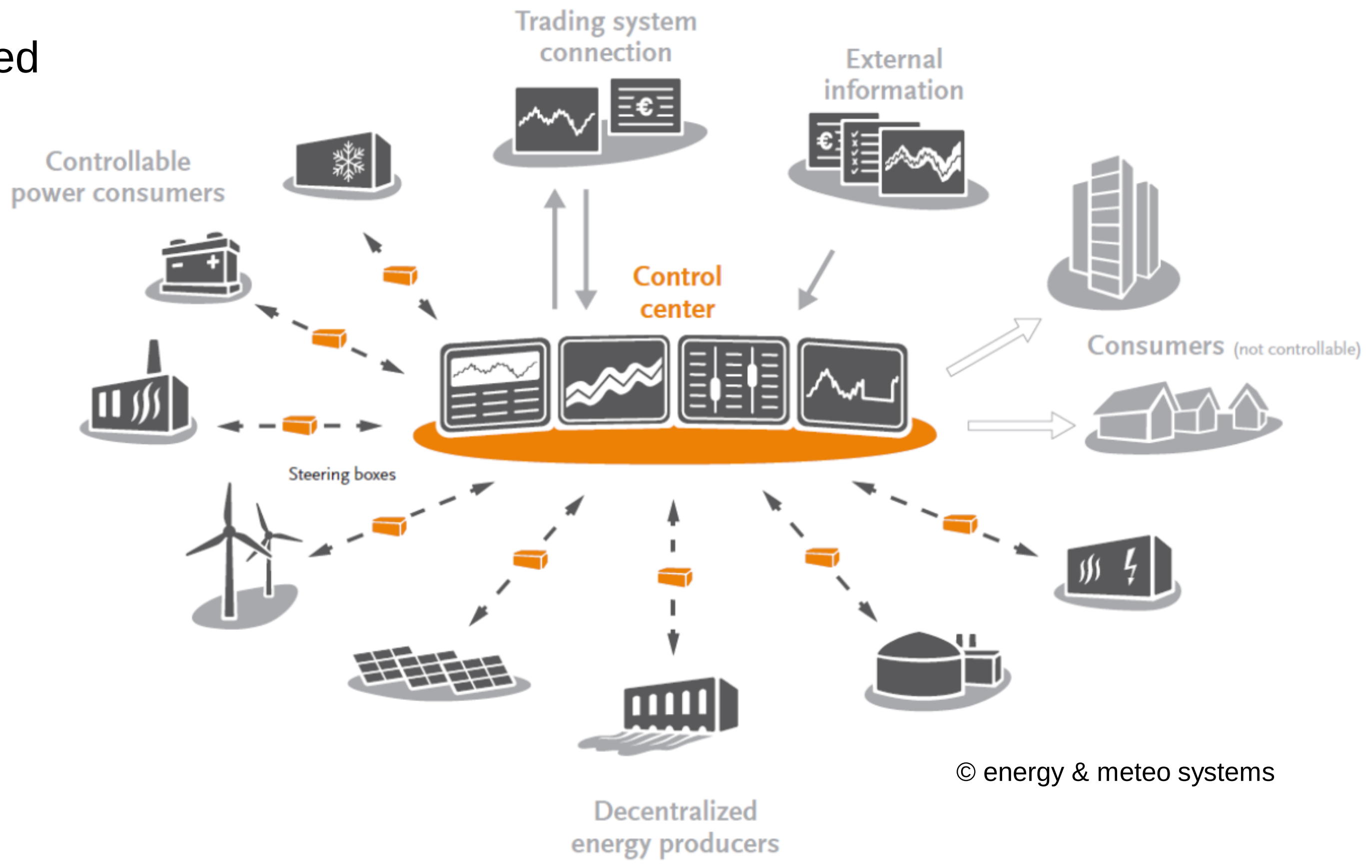
  e.g. EPEX Spot intraday: continuous trading of 15 min blocks with lead time around 15 min
- **Market for balancing power / ancillary services**

  organized by transmission system operators
- **Flexibility markets**

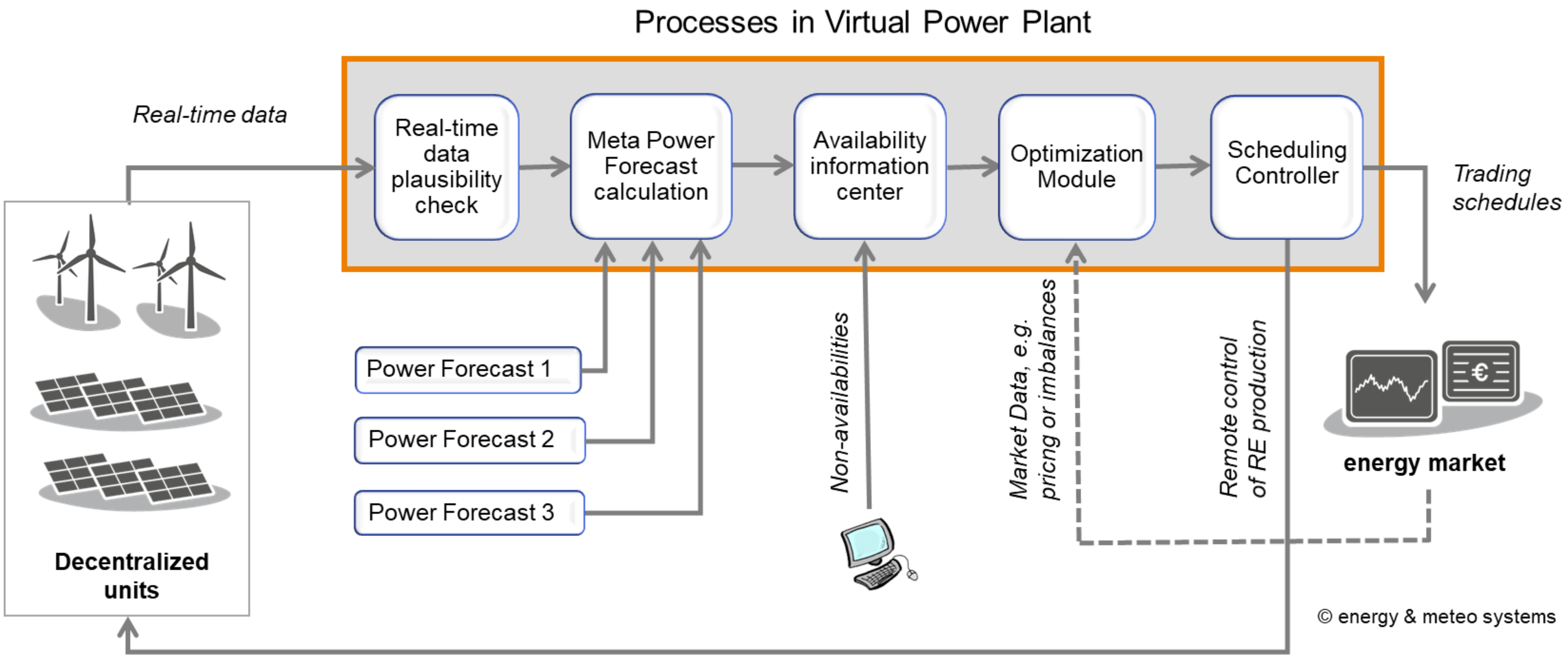
  upcoming

Current status of Virtual Power Plants (VPPs) to integrate RES into electricity markets

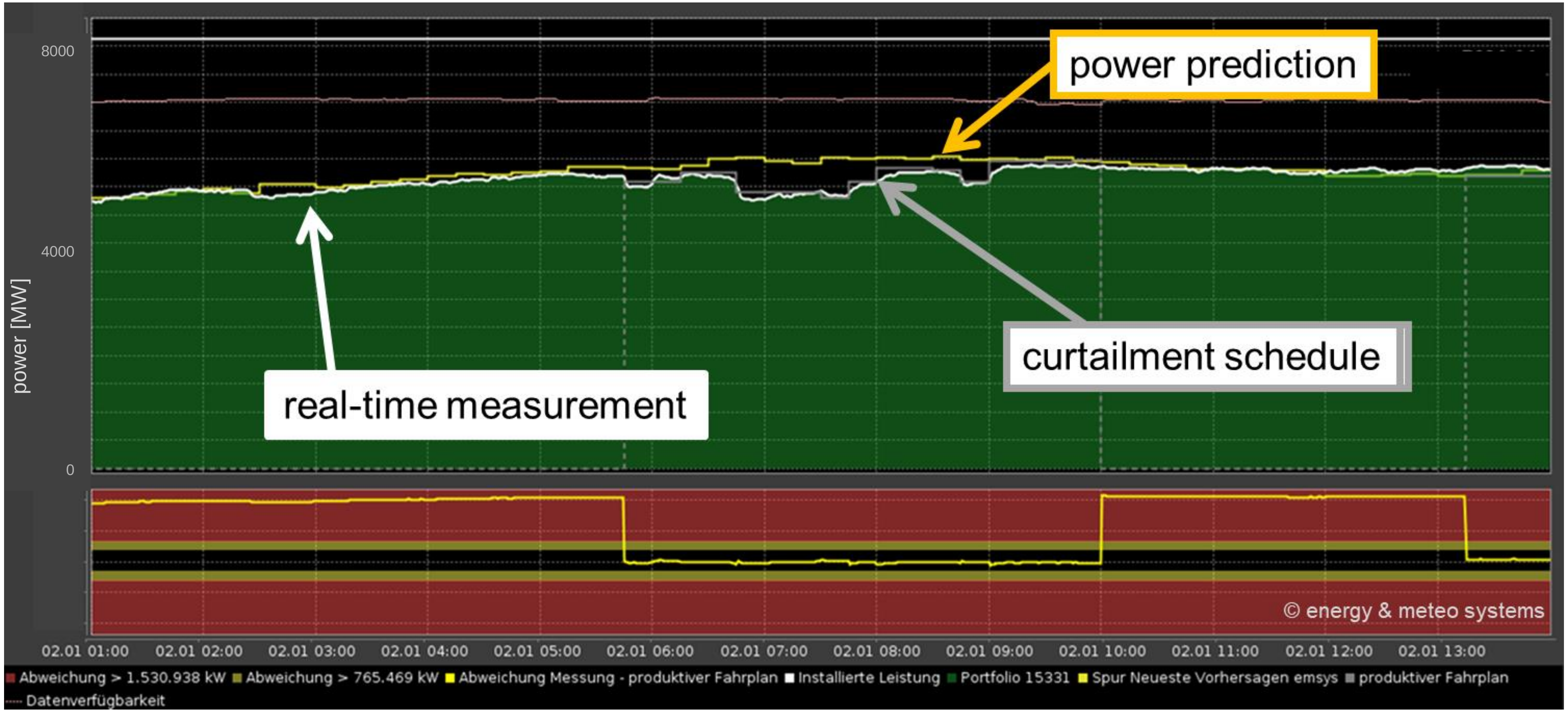
- The Virtual Power Plant is an IT platform to digitally bundle a large number of decentralized assets to one portfolio (“aggregation”)
- Connects to solar, wind onshore & offshore, hydro, storage systems, flexible consumers, substations
- Retrieves real-time operational data (production, status codes) from assets
- Integrates solar and wind power forecasts for connected RES generators
- Remote-control of power output
- Enables aggregators to access different markets: energy, balancing power, ancillary services, flexibility



VPP and RES forecasting used by energy traders



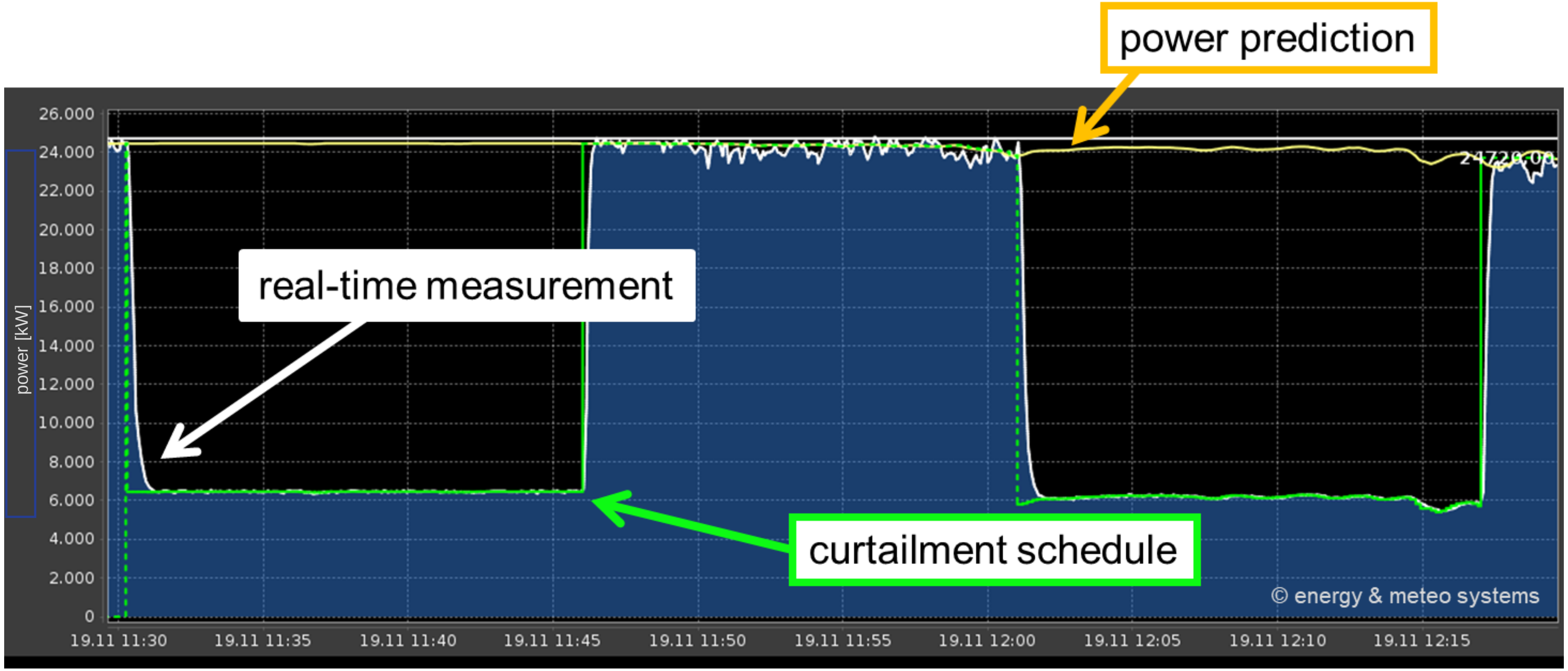
VPP and RES forecasting used by energy traders



Trading wind power on electricity markets:

To optimize the portfolio output during periods with negative prices traders can adjust the production very precisely through VPP.

VPP and RES forecasting used by energy traders



Wind farms do already contribute to ancillary services, e.g. tertiary reserve power.

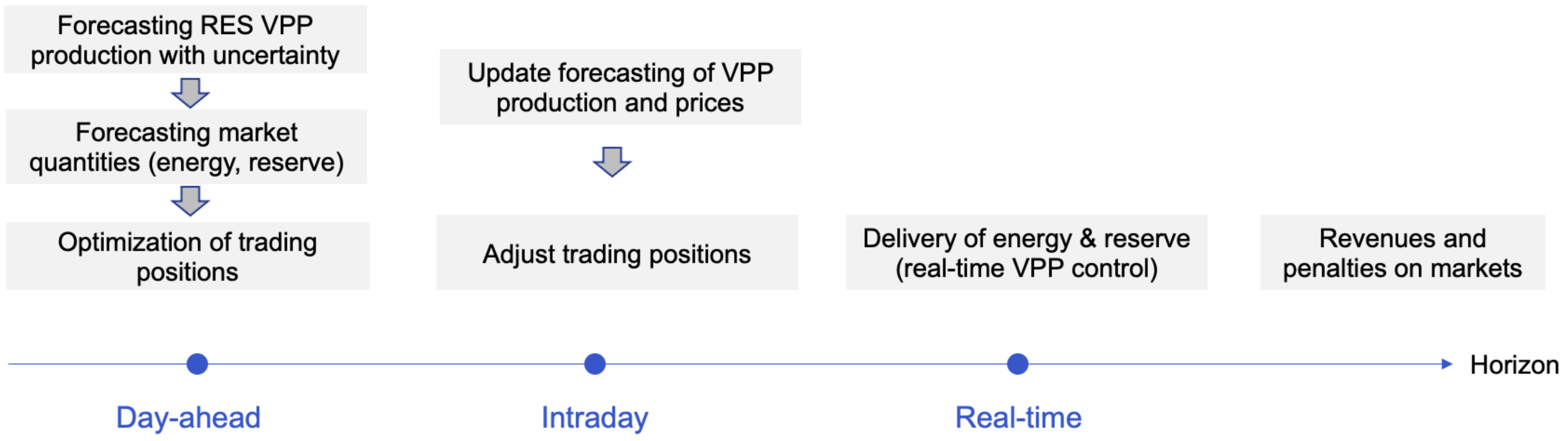
This requires high data availability, outstanding accuracy of RES forecasts and reliable remote control.

The role of forecasting in trading strategies for RES and Virtual Power Plants

- Forecasting production of a renewable VPP
- Modelling chain of trading VPP production

Operational timeline of VPP trading

- Focus on a renewable VPP trading in energy and reserve markets
- Forecasting errors of renewable production and prices increase with the horizon

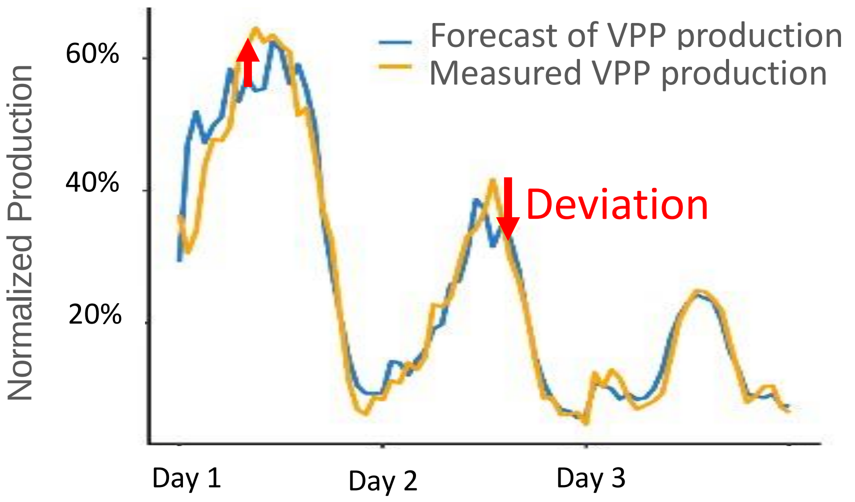


RES Forecasting accuracy for VPP trading

Consider a VPP controlling only variable RES (Wind, PV, Run-of-river Hydro)

- Offer in the day-ahead energy market is based on day-ahead RES-VPP power forecast
- Imbalance penalty = Imbalance price x Deviation
- Deviations can penalize significantly the revenue of RES producers

➲ **Objective:** reduce RES-VPP Forecasting errors

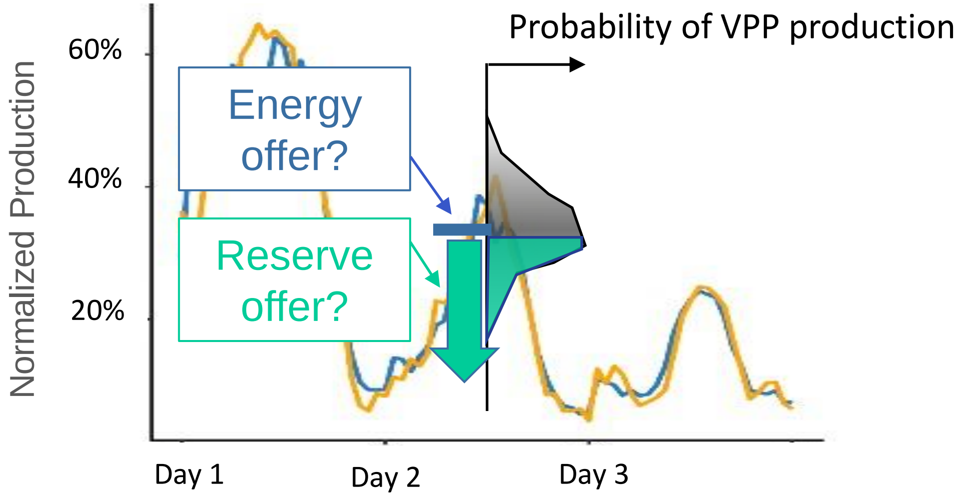


RES Forecasting with uncertainty

The RES-VPP offers on multiple markets, energy + reserve

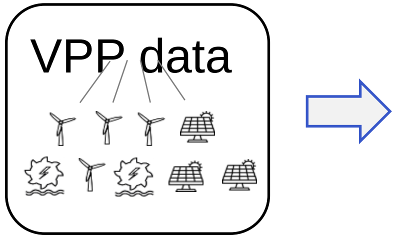
- State-of-the-art approaches to solve this trading problem require a prediction of RES with uncertainty [1]
- Under simplifying assumptions, the optimal reserve offer is a *quantile* of the predicted RES-VPP distribution depending on prices

➲ **Objective:** reliable forecasting of RES-VPP with uncertainty

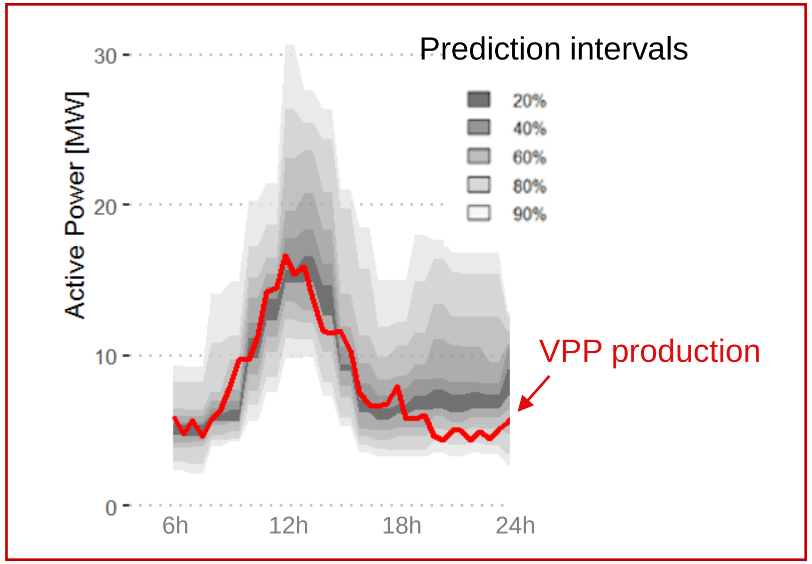


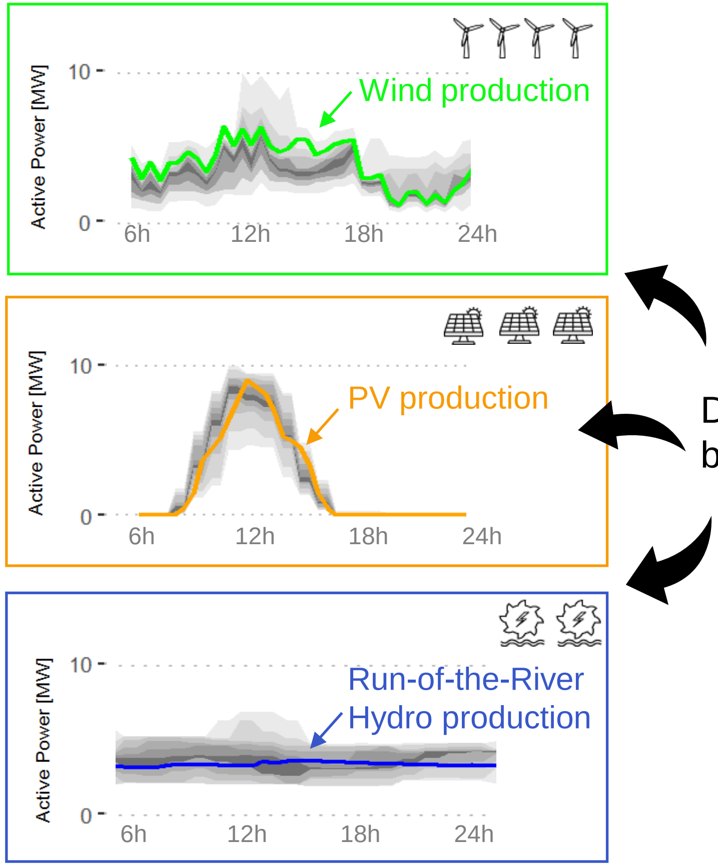
How to forecast RES-VPP production

Build a **scalable regression** model accounting for the dynamic contributions of energy sources in the VPP



Predict total RES-VPP production

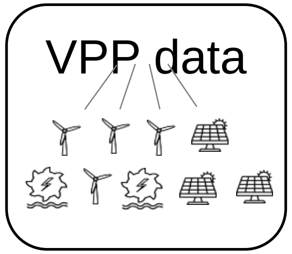




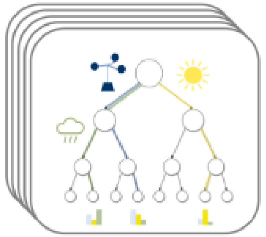
Dependences between sources?

How to forecast RES-VPP production

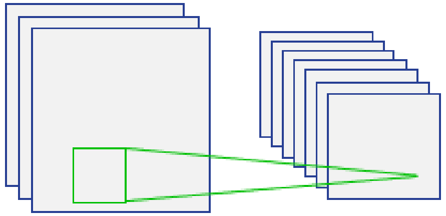
Machine Learning models are good candidates to predict RES-VPP production with uncertainty.



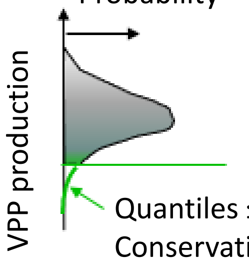
Quantile Regression Forest (QRF)



Convolutional Neural Network (CNN)



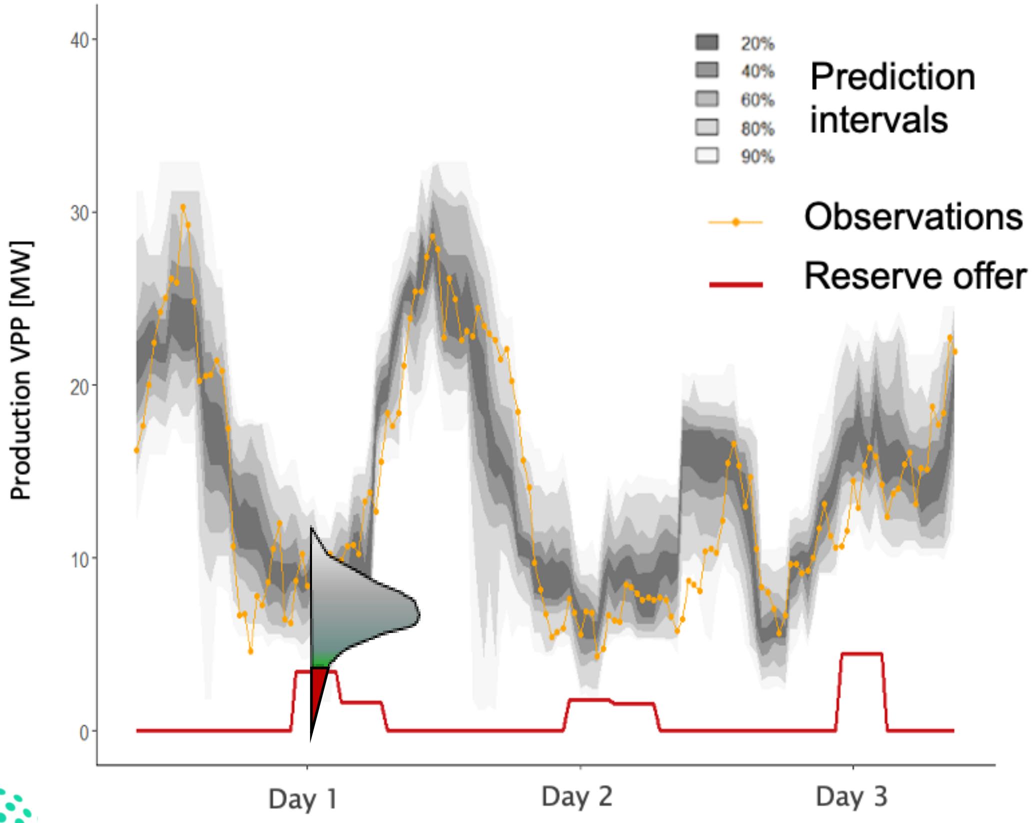
For high reliability of reserve, models on low quantiles



- ➲ CNN improves probabilistic Score (CRPS) by - 15% compared to the state-of-the-art QRF
- ➲ At low quantiles, adaptation of regression models or statistical models specific for extremes

Complete forecast-based trading model chain

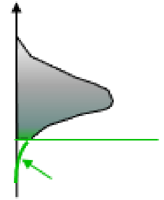
Probabilistic forecasting of RES-VPP production (here QRF) +
Deterministic forecasting of market quantities (here statistical / Machine Learning models)



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

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

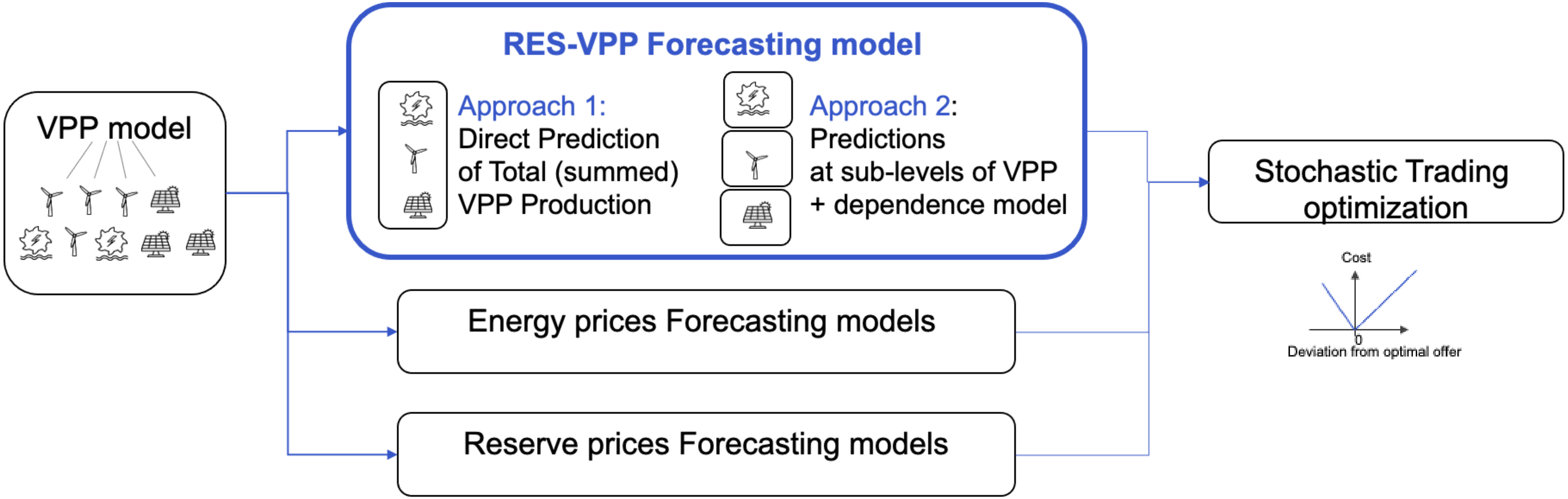
Identified periods when reserve is profitable [2].



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

Value of improving VPP Forecasting for trading

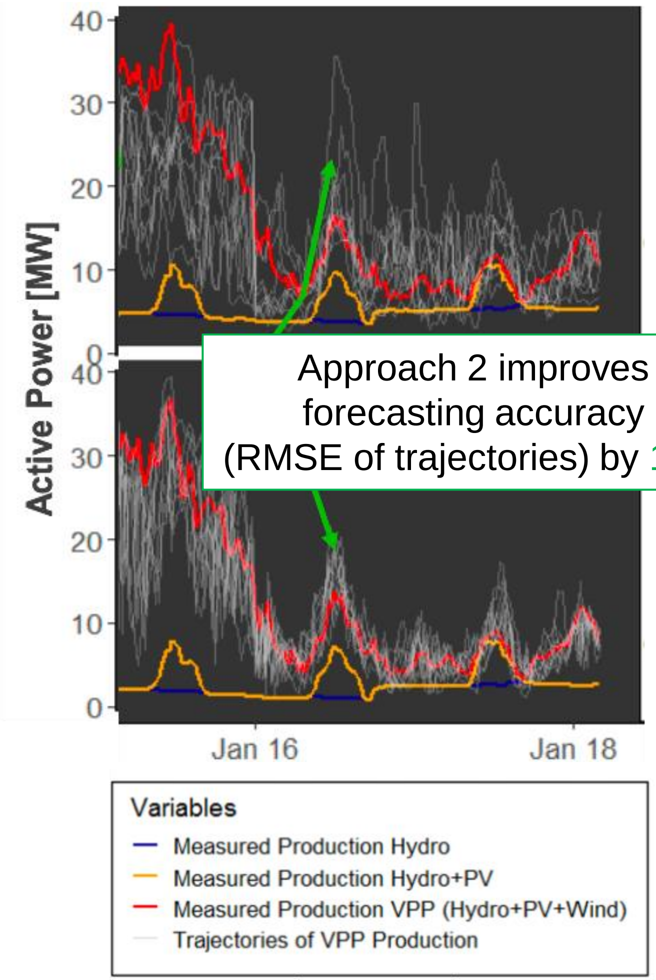
2 VPP Forecasting approaches tested: which one gives best trading outcomes [3] ?



Value of improving VPP Forecasting for trading

Approach 1

Approach 2



Source: [3]

Approach 2 improves forecasting accuracy (RMSE of trajectories) by 15%

→ Trading optimization →

Approach 2 improves worst-case revenue (Conditional Value at Risk) by **20%**

Nota Bene:

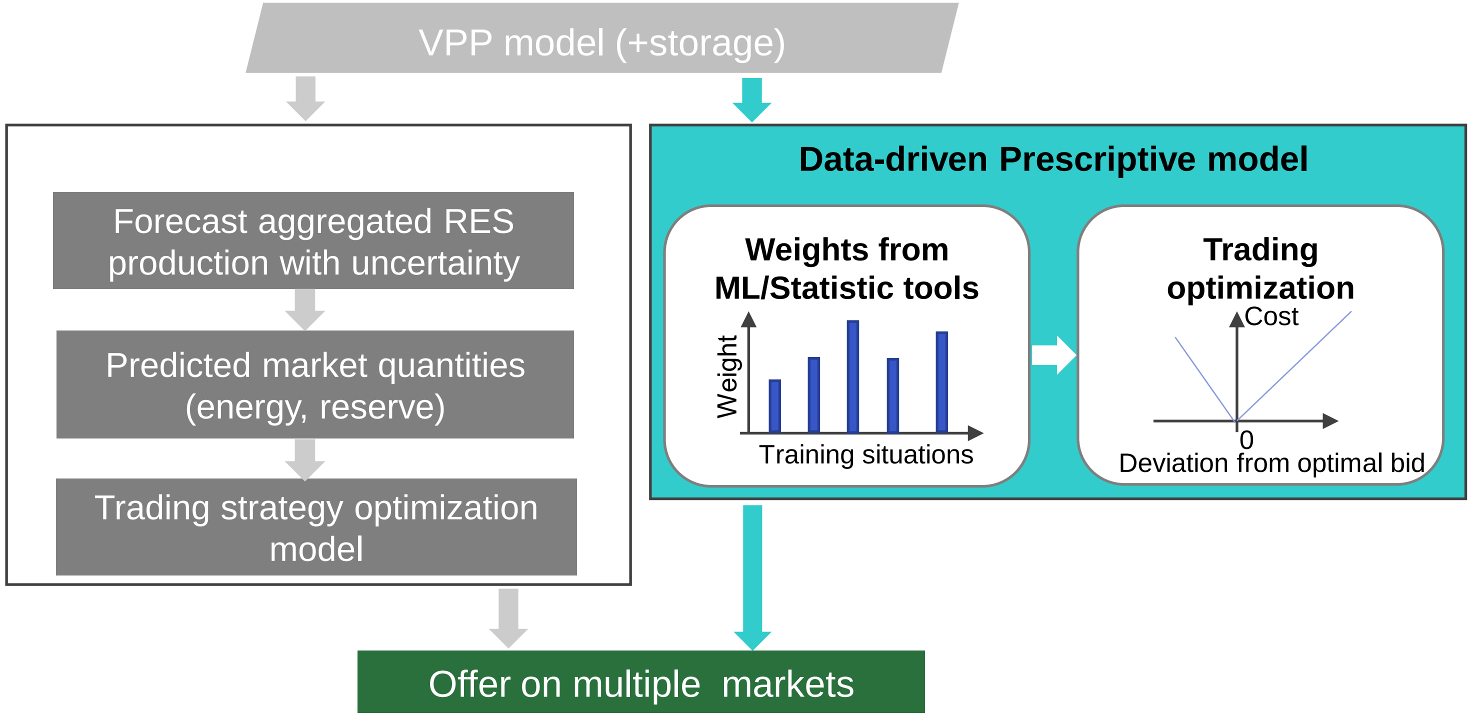
- There is no automatic link between forecasting accuracy and value in applications.
- One solution is value-oriented forecasting, where forecasting & application are tuned jointly to optimize value

Simplify the modelling chain by prescriptive analytics

In Smart4RES, we are currently developing a **prescriptive analytics** approach to streamline the model chain

- Use of optimization techniques
- Convergence guarantees
- Applicable to **constrained** problems
- Decision is taken according to **weights** applied to past situations

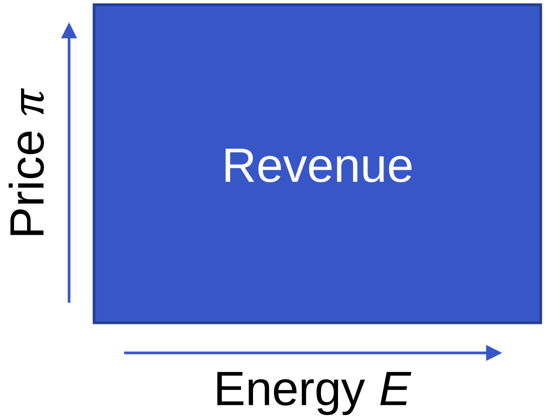
Objective: same revenue as with the Forecast-Optimize approach



Some current challenges and necessary focus areas for RES in electricity markets

- Understanding those challenges based on the basic trading setup
- Uncertainty aspects
- Price-maker and population-aware approaches

The classical problems, which never go away…



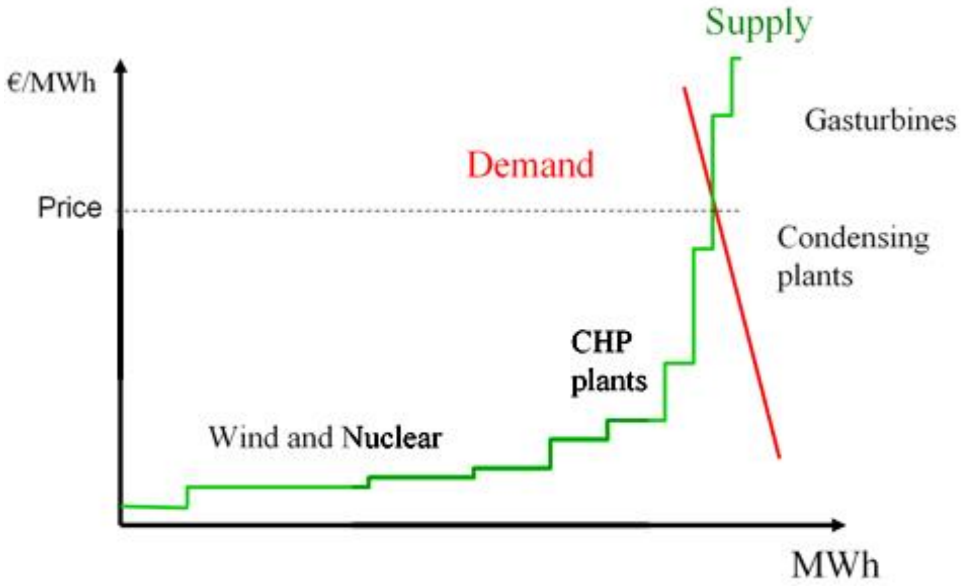
The revenue from electricity markets (focusing on energy),

$$R = \pi \times E$$

involves a **market price** and a **quantity**.

- On the **quantity** side we do our best to predict renewable energy generation (e.g., through Smart4RES)!

- On the **market (price)** side, one wants to predict
  - energy prices
  - system length
  - the supply stack
  - Etc.

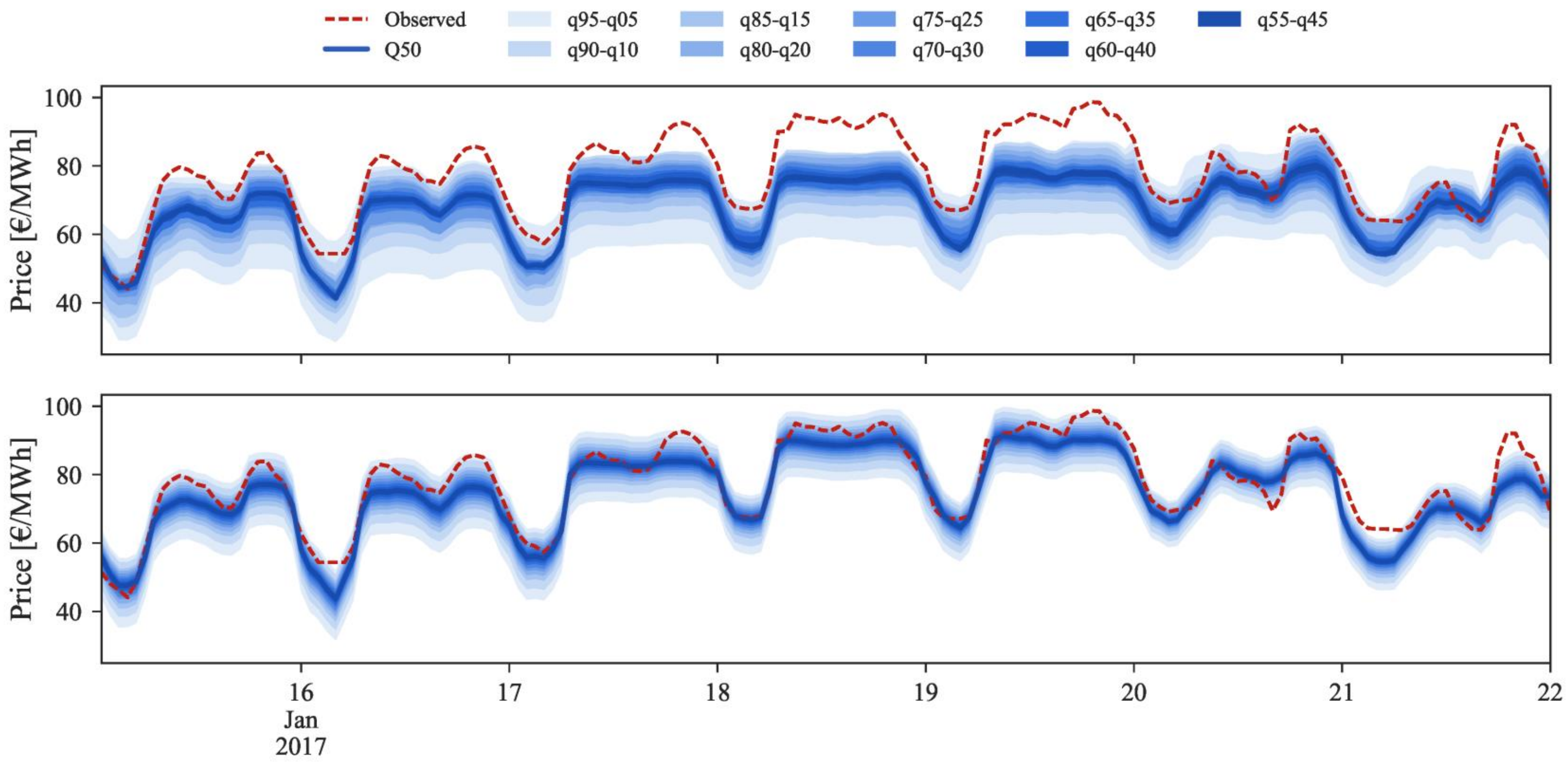


source: wind-energy-the-facts.org

Focusing on price forecasting

The development of **price forecasting approaches** has intensified over the last decade:

- within a **probablistic** framework,
- for **all market stages** involved,
- using more data and better information

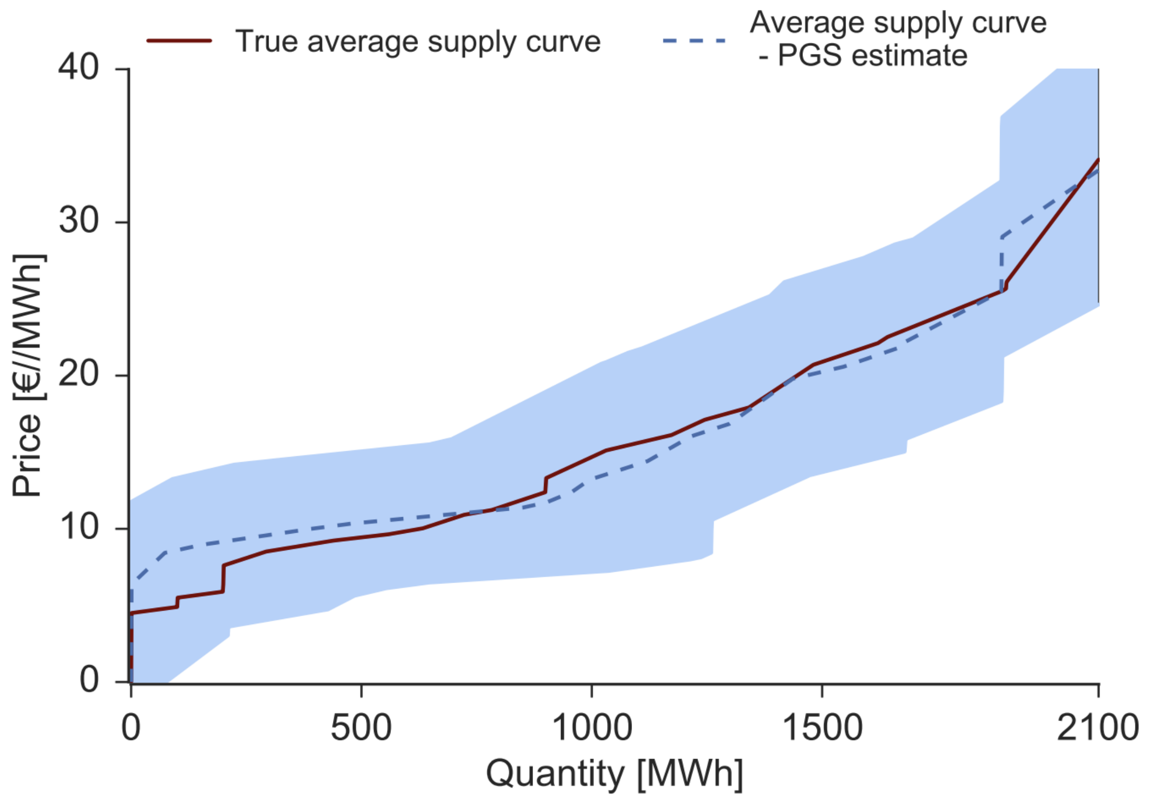


source: Andrade *et al.* (2017)

The classical problems, which never go away…

Other have looked at ways to reveal the **supply curve** (stack), e.g., with

- inverse optimization (Ruiz *et al.*, 2013),
- Bayesian estimation (Mitridati and Pinson, 2017),
- Etc.



source: Mitridati and Pinson (2017)

➲ Capturing those curves is key to market participation as **price-maker**, or **population-aware**!

Pushing the state-of-the-art using probabilistic information

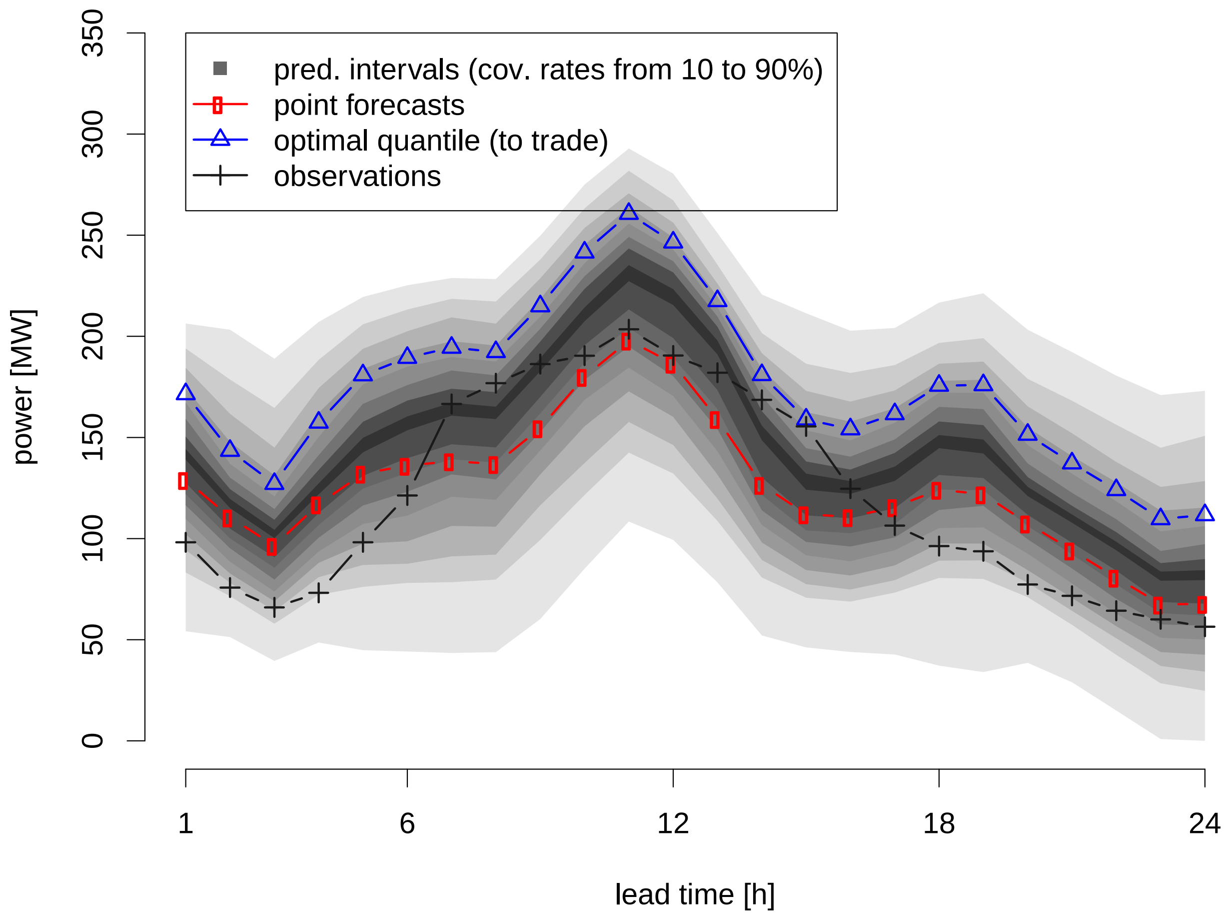
In a general sense, the *optimal offer* for renewables in electricity markets is

$$E^* = F^{-1}\left(\frac{\pi^+}{\pi^+ + \pi^-}\right)$$

where

F : probabilistic forecast for energy
π^+ : penalty for generating more than scheduled
π^- : penalty for generating less than scheduled

Are we really sure about knowing those 3 quantities??
-> use of Distributionally Robust Optimization



And what if you are not a price-taker?

Price-taker → Your offer ***will not*** affect market outcomes

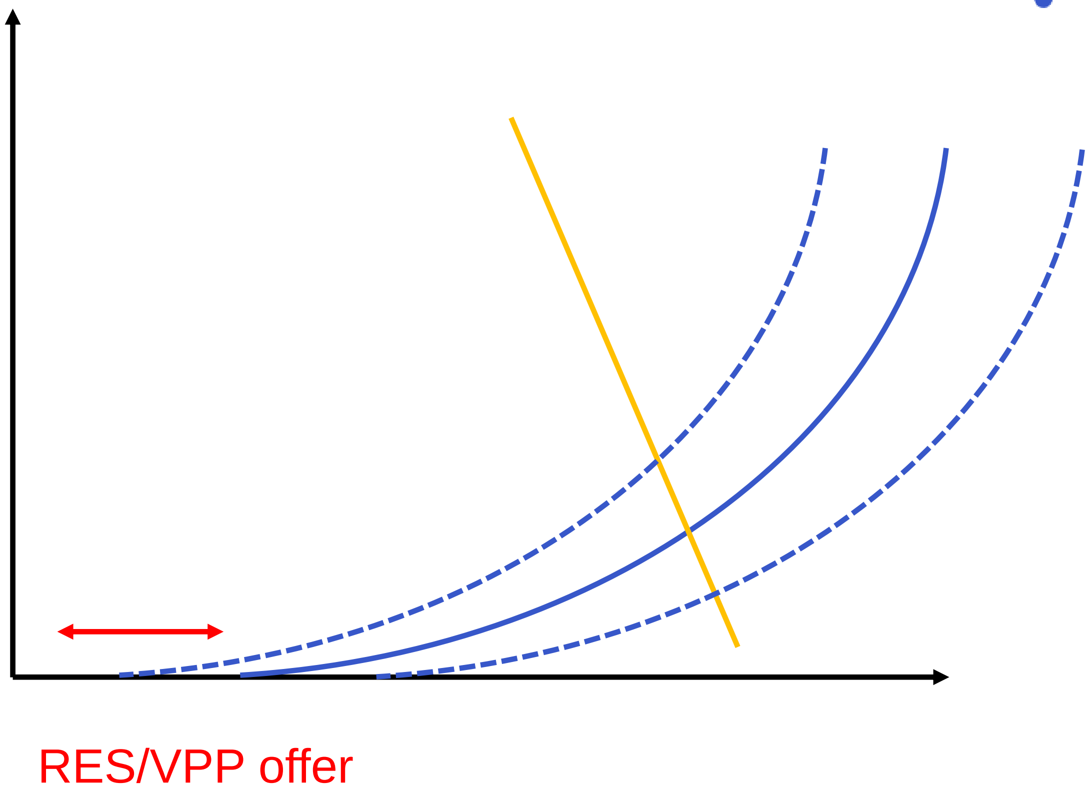
Price-maker → Your offer ***will*** affect market outcomes

What to do as a price-maker?

Somehow, one wants to model how market outcomes may change as a function of one‘s offer, i.e.

$\pi^{+}(E)$: penalty for generating more than scheduled
$\pi^{-}(E)$: penalty for generating less than scheduled

And this can be done by “drifting“ on the stack

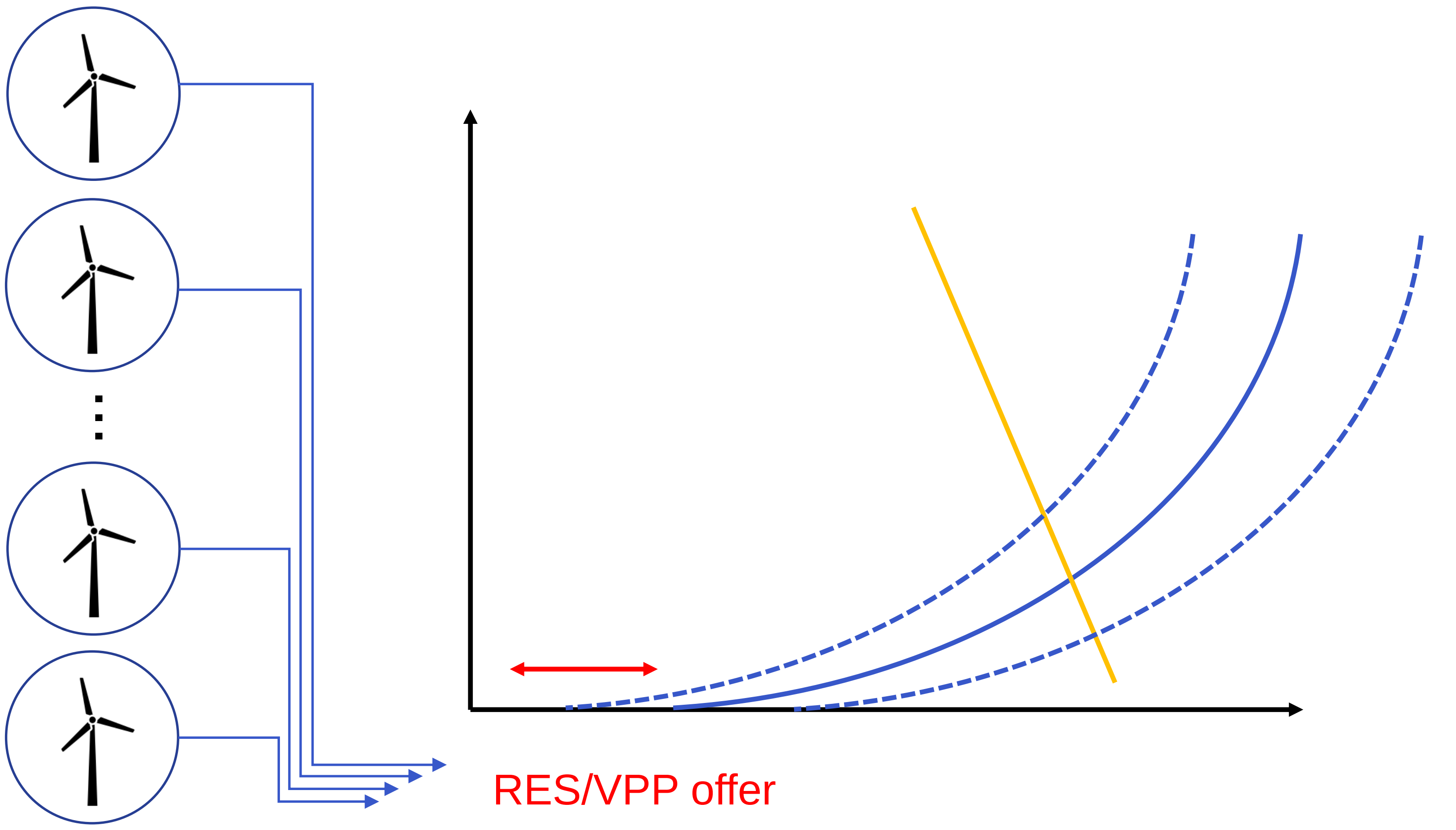


Alternative approaches: quadratic programming, and bilevel optimization (e.g., Baringo and Conejo (2013), Zugno *et al.* (2013))

Are you really a price-maker though?

A single wind farm (/solar power plant) may **not** be a **price-maker on its own**

However, there are **obvious dependencies** that will add up:
- in the *actual production*
- in the *forecasts* and their *errors*
- in the *education* and *strategy* of the traders



Key messages

- **VPP is a mature technology**.
- **Forecasting of RES production and market quantities is key for profitable VPP trading**
  - Accurate VPP production forecasting improves revenue
  - Perspective: contribution of storage for ancillary services provision

*** Smart4RES webinar serie season 2*

- There are still **many new challenges and areas to focus on**, e.g.
  - How to further improve trading within a probabilistic framework?
  - Am I a price-taker or price maker with my VPP?
  - How to account for population effect?
  - Etc.

Further reading

[1]: T. Soares, P. Pinson, T. V. Jensen, and H. Morais, "Optimal Offering Strategies for Wind Power in Energy and Primary Reserve Markets," *IEEE Trans. Sustain. Energy*, vol. 7, no. 3, pp. 1036–1045, Jul. 2016, doi: 10.1109/TSTE.2016.2516767.

[2]: S. Camal, A. Michiorri, and G. Kariniotakis, "Optimal Offer of Automatic Frequency Restoration Reserve from a Combined PV/Wind Virtual Power Plant," *IEEE Trans. Power Syst.*, vol. 99, 2018, doi: 10.1109/TPWRS.2018.2847239.

[3]: S. Camal, F. Teng, A. Michiorri, G. Kariniotakis, and L. Badesa, "Scenario generation of aggregated Wind, Photovoltaics and small Hydro production for power systems applications," *Appl. Energy*, vol. 242, pp. 1396–1406, May 2019, doi: 10.1016/j.apenergy.2019.03.112.

[4]: C Ruiz, AJ Conejo, DJ Bertsimas, "Revealing rival marginal offer prices via inverse optimization," *IEEE Trans. Power Syst.*, vol. 28, no. 3, pp. 3056-3064, 2013

[5]: L. Mitridati, P. Pinson, "A Bayesian inference approach to unveil supply curves in electricity markets, *IEEE Trans. Power Syst.*, vol. 33, no. 3, pp. 2610-2620, 2017, doi: 10.1109/TPWRS.2017.2757980

[6]: M. Zugno, J. M. Morales, P. Pinson, H. Madsen, "Pool strategy of a price-maker wind power producer," *IEEE Trans. Power Syst.*, vol. 28, no. 3, pp. 3440-3450, 2013, doi: 10.1109/TPWRS.2013.2252633

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Thank you

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