How are wind forecasts used operationally?

A tour of marketing wind energy

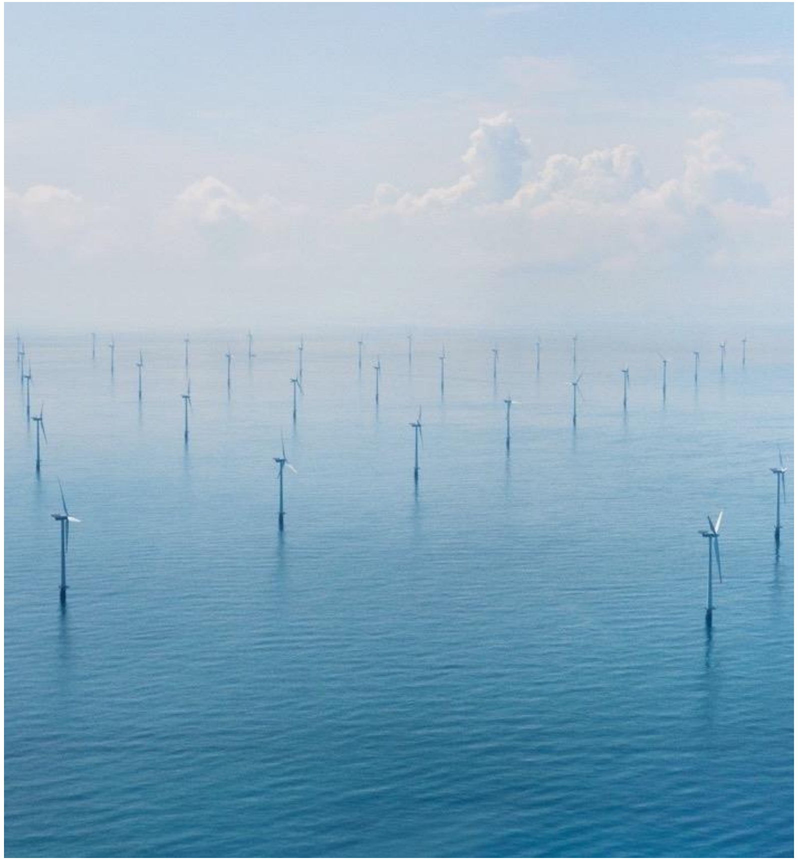
Malte Rieck - Vattenfall Energy Trading GmbH

2022-09-12 Dublin – IEA Task 51 Workshop

Outline

- Vattenfall
- Day-ahead market: bidding under uncertainty
- Intraday market: trading of forecast updates
- Imbalance market: avoiding imbalance risks
- Challenges for forecasting solutions

#european-markets, #wind-energy, #short-term markets



Vattenfall Wind Power Portfolio

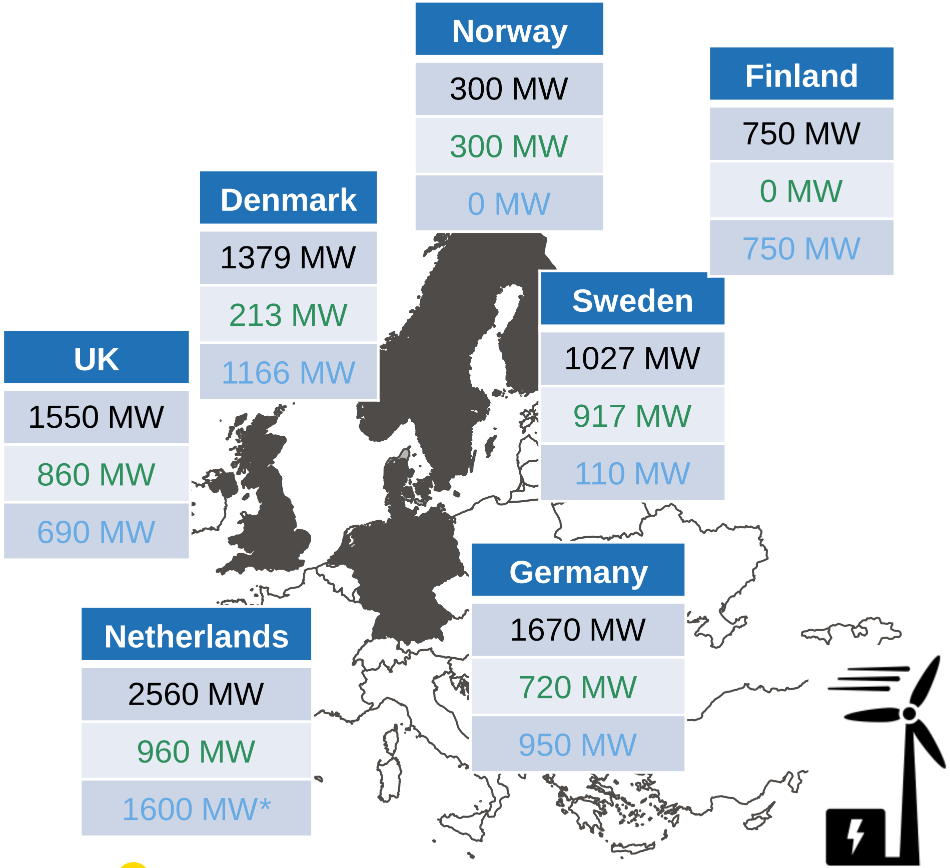
“Fossil free within one generation”

Vattenfall maximises value of wind portfolio

- Capacity under mgmt. 9236 MW (incl. PPA)
- Onshore: 3970 MW
- Offshore: 5266 MW

Forecasting & Optimisation of ~5000 turbines from own assets and third party PPAs

▸ Wind power plays a key role in Vattenfall's strategy



* Includes HKZ (not fully operative yet)

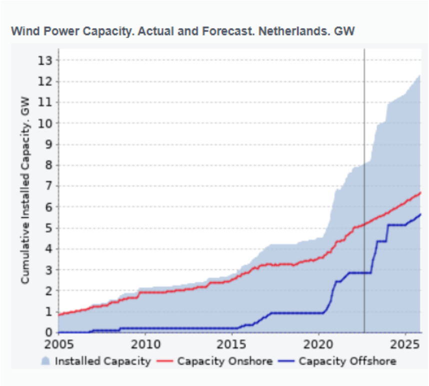
Offshore Wind Park *Hollandse Kust*

Largest and first subsidy-free offshore wind park

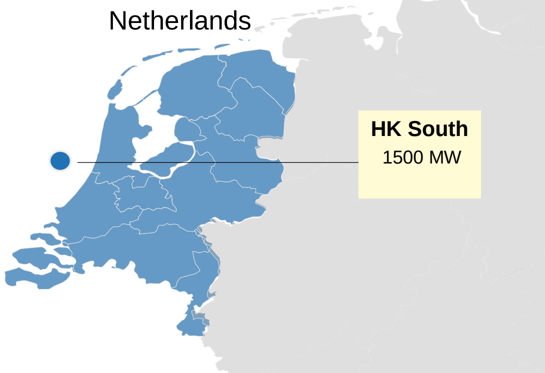
South (1500 MW, Vattenfall)
North (750 MW, Cross Wind)
West (1500 MW, tender)

Mitigate concentration risk

- Improved forecasting
- Steering
- Green hydrogen
- Floating solar
- Battery storage



Source: volue.com



Ancillary Service Capacity vs. Market size

1.200 MW	300 MW	900 MW	18.000 MW
FCR	aFRR	mFRR	Market Demand in Total

▸ Takes forecasting requirements and imbalance management to the next level

Onshore Hybrid Park *Haringvliet*

- Combined assets Wind-Solar-Battery (72MW)
- Sharing grid connection: Wind power depending on additional assets (solar, battery, grid etc.)
- Automated controller to optimize revenues
- Forecast model training becomes a challenge

▸ Wind power schedule may depended on other meteorological and market parameters

How is Wind Energy Traded?

Day-Ahead Auction (12:00)	Continuous Intraday Market	Before delivery	Balancing Market
sell expected wind volumes at day-ahead market ⇒ **Day-Ahead Forecast**	adjust position according to intraday weather updates ⇒ **Intraday Forecast**	adjust position to actual derived from real-time ⇒ **Nowcast**	net imbalance between actual production and nowcast ⇒ **settlement grid provider**

Spot Auction e.g. EPEX, APX, Nordpool

e.g. EPEX Continuous Intraday

Balancing Market

- **Purpose of wind power trader is to maximize revenue between different markets**

Day-ahead Market: Bidding Under Uncertainty

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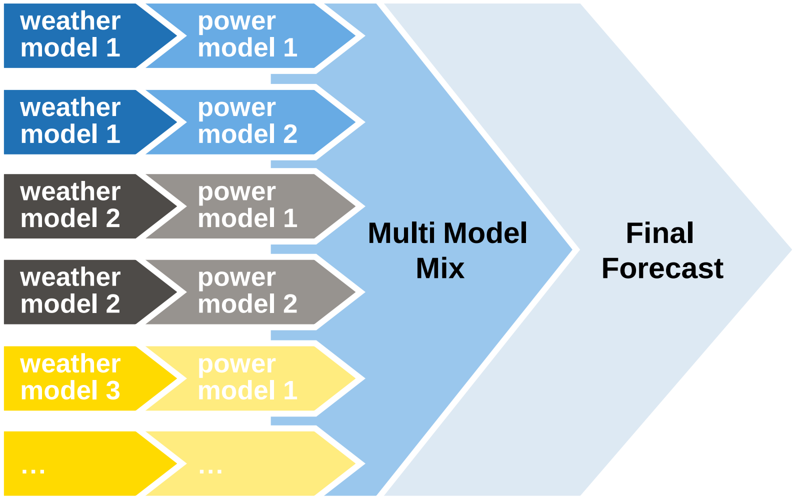
Challenges Day-ahead Forecast

NWP problems infiltrate wind power forecasts:

- Low pressure systems, large scale wind ramps **(resolved scales)**
- Diurnal cycle, low-level jets, thunderstorms, cold pools, land-sea breeze, convection/turbulence etc. **(unresolved scales)**
- Technical restrictions: overwind shutdown, (grid, noise, bird) curtailment, icing, maintenance

▸ Multiple possibilities to improve day-ahead forecasting

Multi Model Forecast Combination



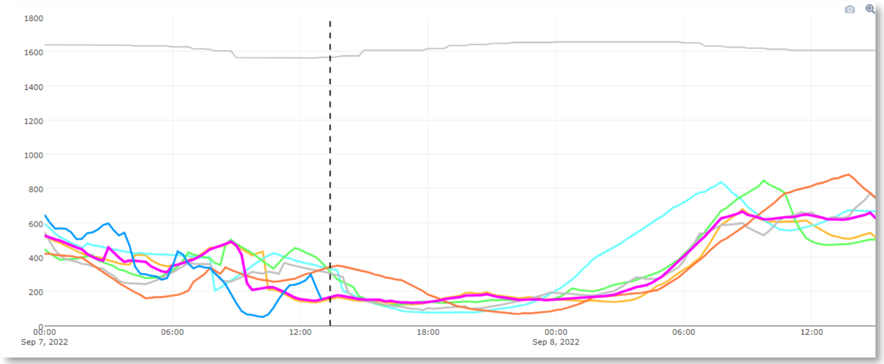
Mix depending on latest performance and weather regime

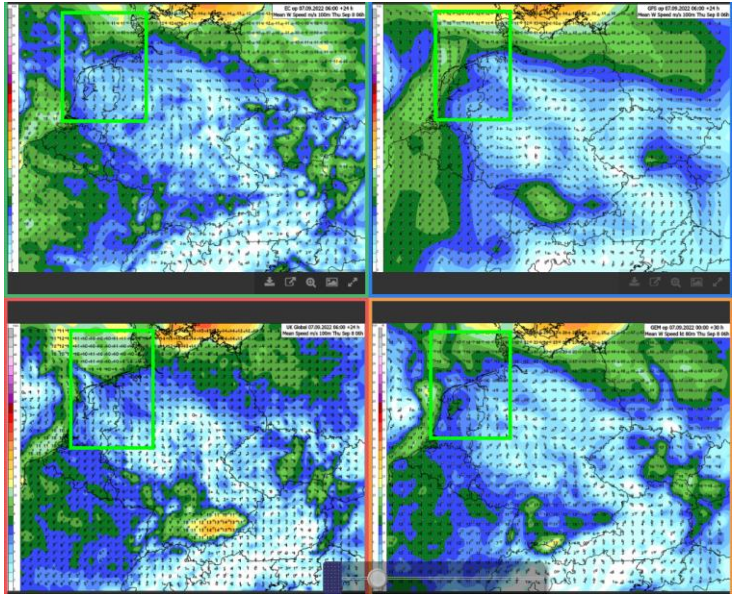
Day-ahead Forecast Uncertainty

Uncertainty analysis is key to a successful day-ahead bidding

Classical ensemble forecasts deliver limited value

1) ML techniques using historic data (statistical, e.g. k-nn)
2) “Poor man’s” model ensemble
3) Analysis by meteorologist





Source: MetDesk.com

▸ Adjust bidding based on uncertainty

Intraday Market (1): Continuous Algorithmic Trading

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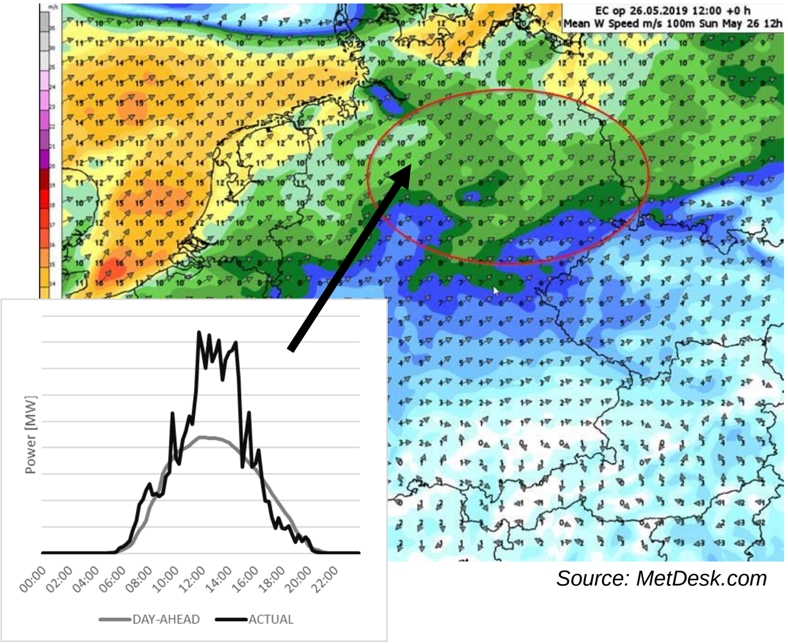
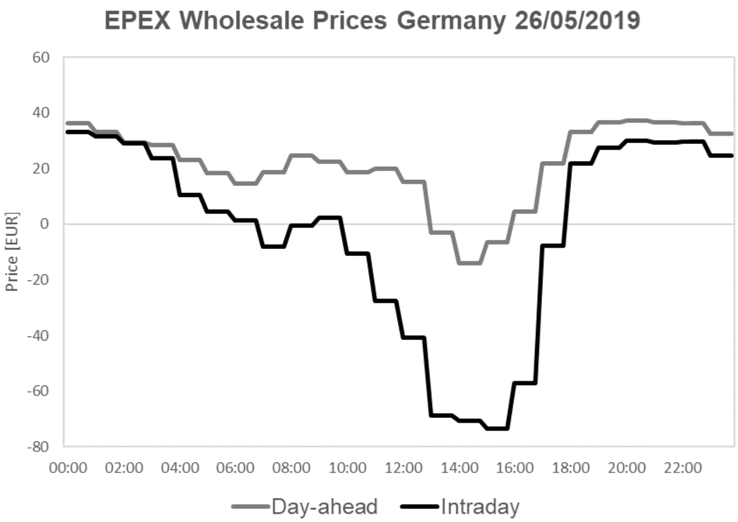
Forecast Change Causes Prices to Drop

- Wind front underestimated (~20 %)
- Radiation underestimated (stratus clouds)



Source: MetDesk.com



Source: wattsight.com

- Utilities sell wind & solar volumes intraday
- Customers enjoy sunshine
- Feedback radiation -> demand

⇒ Negative intraday prices

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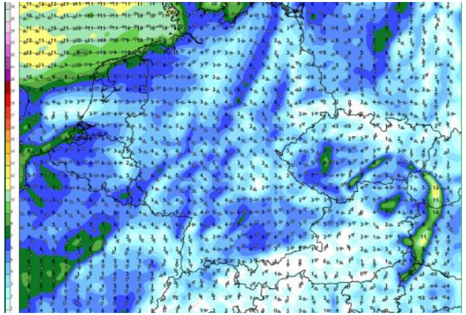
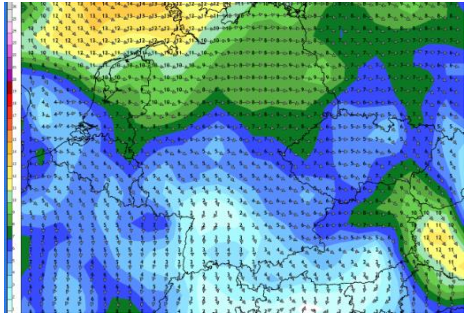
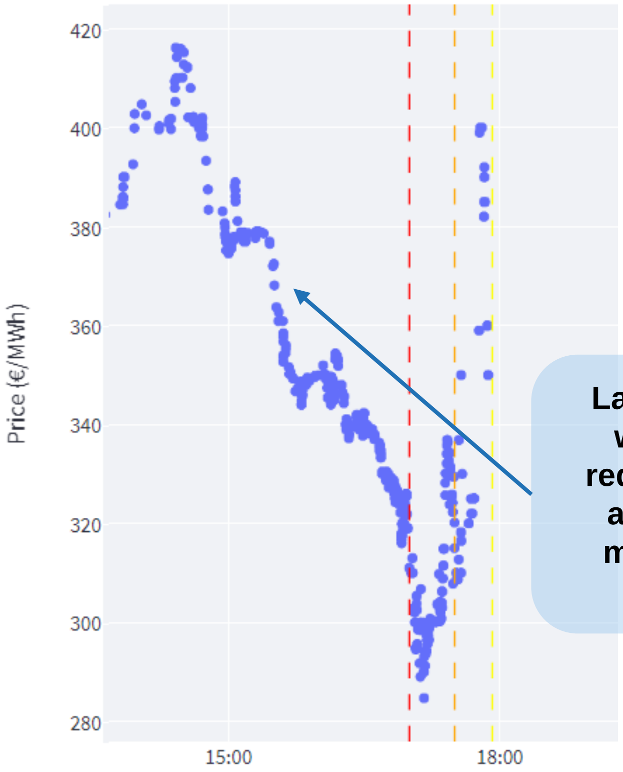
The Fast and the Furious





weather update: changing position of low pressure system



Large price drops within minutes require end-to-end automation and minimal time-to-market

- Speed is key factor in intraday markets

Algorithmic Trading Reduces Costs

Automate the position closing process

- Python Algorithmic Trading System (PATS)
- Using advanced forecasting and optimisation models and infrastructure
- Utilize rapid forecast updates
- Overshoot problem from weather models

▸ Trade out the forecast updates of managed wind assets in a fully automated way

Intraday Market (2) – Nowcast Adjustment

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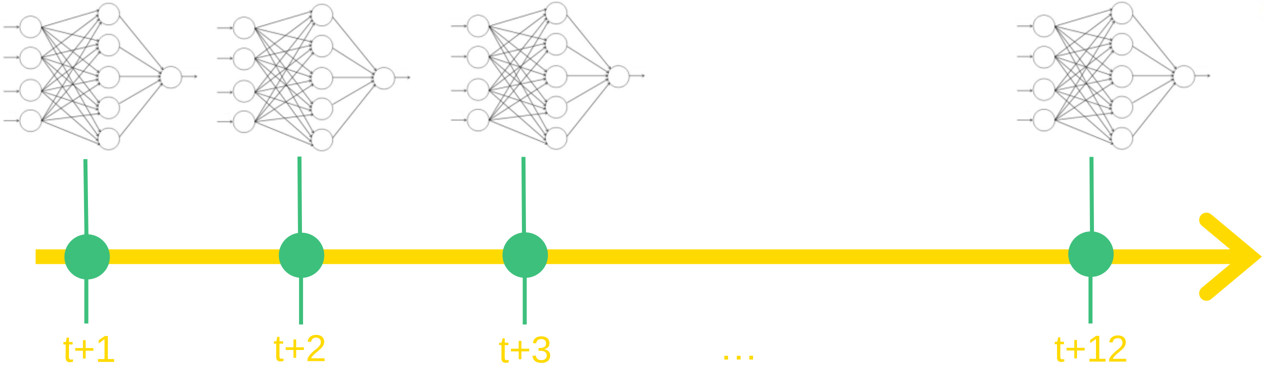
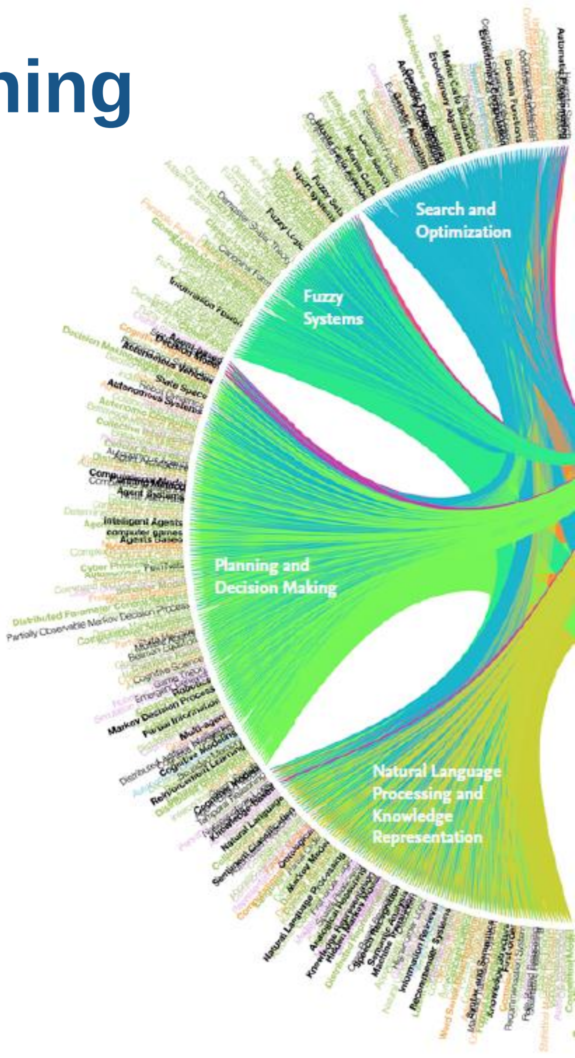
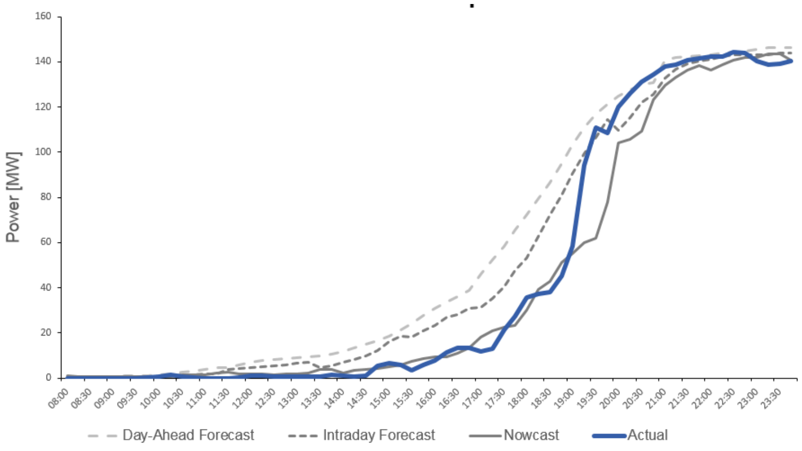
Real-Time Data Meets Machine Learning

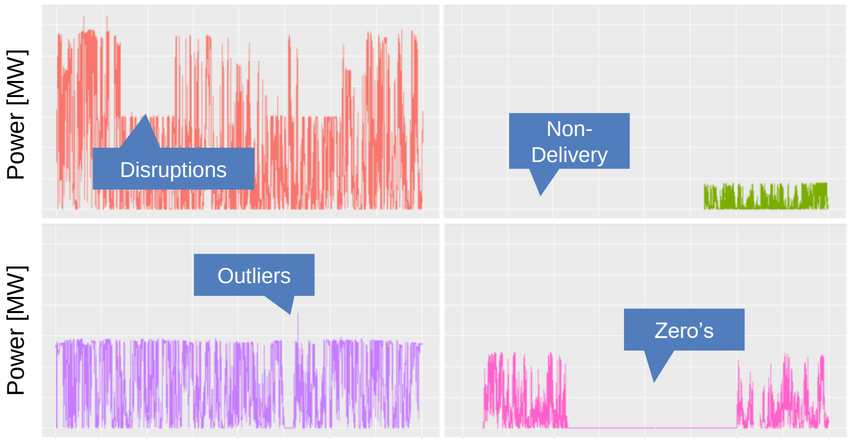
- Artificial neural net models trained per lead-time
- Input: Weather based forecasts, real-time information
- Scaling methods to account for missing real-time data
- Output: real-time corrected wind power production forecast





Data Quality is Key to Improve Forecasts





Nowcast (real-time corrected forecast)

- Use ML to adjust forecast for 0-3h ahead
- Reduces error by 20-30% on average

Key input for nowcasting

- Turbine/park data in near real-time (validation & quality assurance)
- Delivery speed

Imbalance Market: Trading After Delivery

Day-Ahead Auction (12:00) → Continuous Intraday Market → Before delivery → Balancing Market

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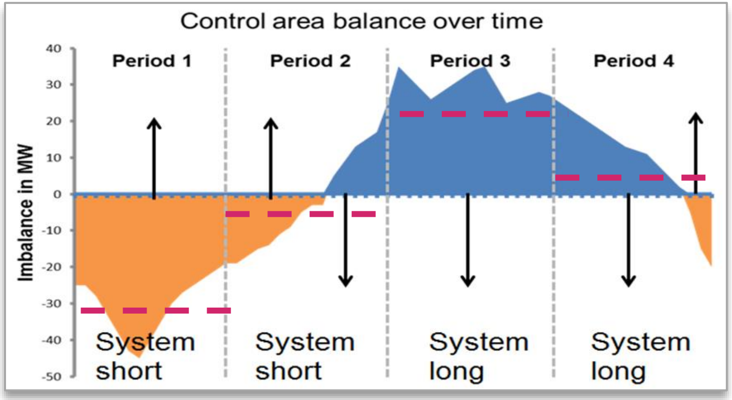
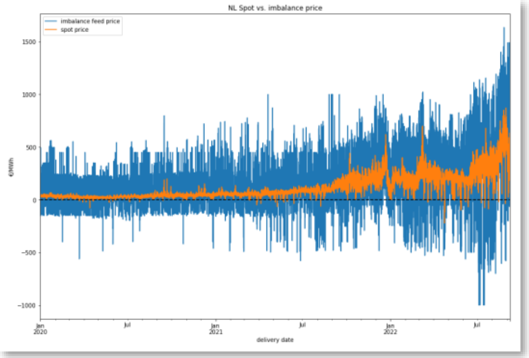
Volatile Imbalance Markets are High Risk for Dispatching Wind Energy

- Imbalance is the difference between **actual-** and **scheduled** supply & demand
- measured on different settlement periods
  - 5 min (parts of US, DK), 15 min (DE, NL), 30 min (UK), 60 min (Sweden)
- helper will earn
- causer will pay out (wind correlated with system)
- Energy crisis -> markets more volatile

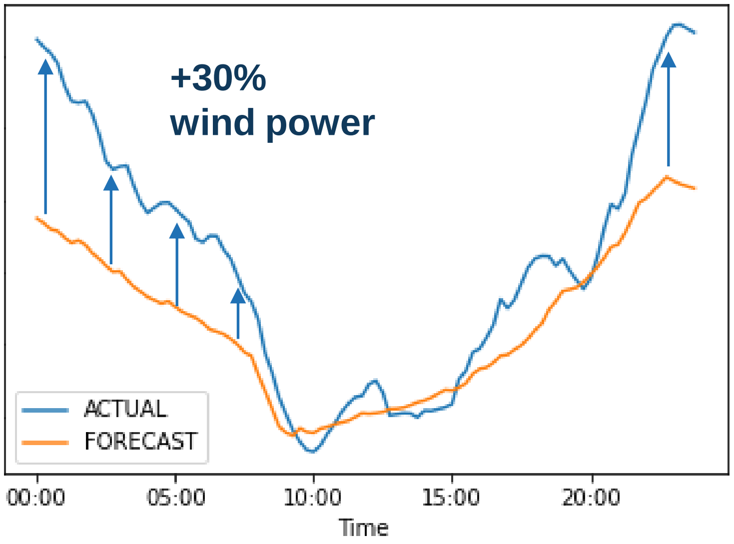




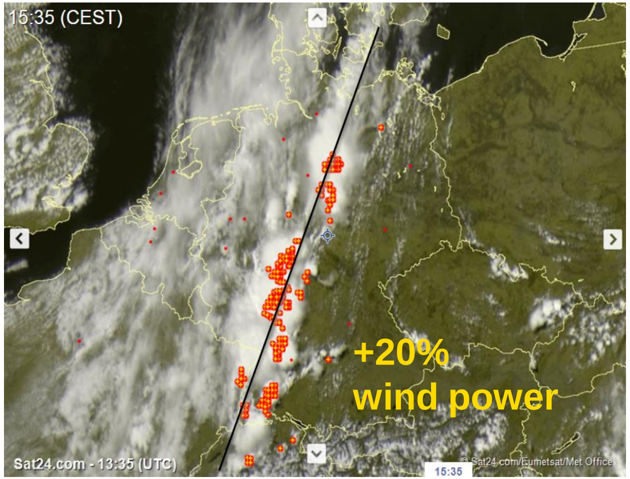
Your Imbalance cost **=** *System Imbalance Price* **x** *Your Forecast Error*

Option 1: Adjust Forecasts to Minimize Imbalance

Diurnal cycle wind power - Germany August 2022



T-storms passing over Germany



-> non-optimized forecasts underestimate winds

▸ Adjust for meteorological biases as good as possible

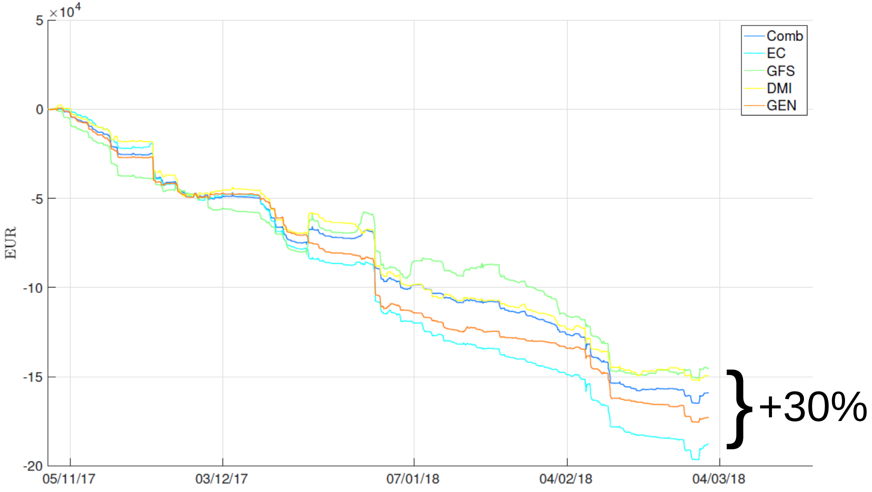
Option 2: Optimize Forecast by Value

- DK wind farm HornsRev simulated on day-ahead auction using different weather models
- Simple power curve approach using forecasts from ECMWF, GFS, HIRLAM (DMI) and combinations

SPOT	NBIAS	NMAE	NRMSE
COMB	1.47	11.65	17.33
DMI	1.10	12.44	18.69
GFS	3.10	14.19	21.79
ECMWF	0.79	11.75	18.10
GEN	1.08	9.94	15.79

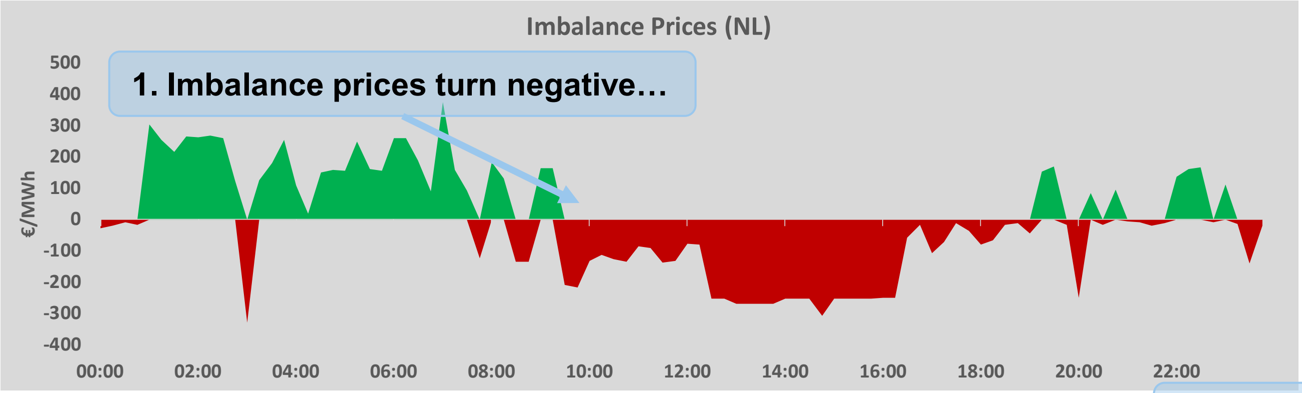
- Best trading results from GFS model.
- ECMWF shows lowest error but correlated with system imbalance -> errors are on average more expensive!

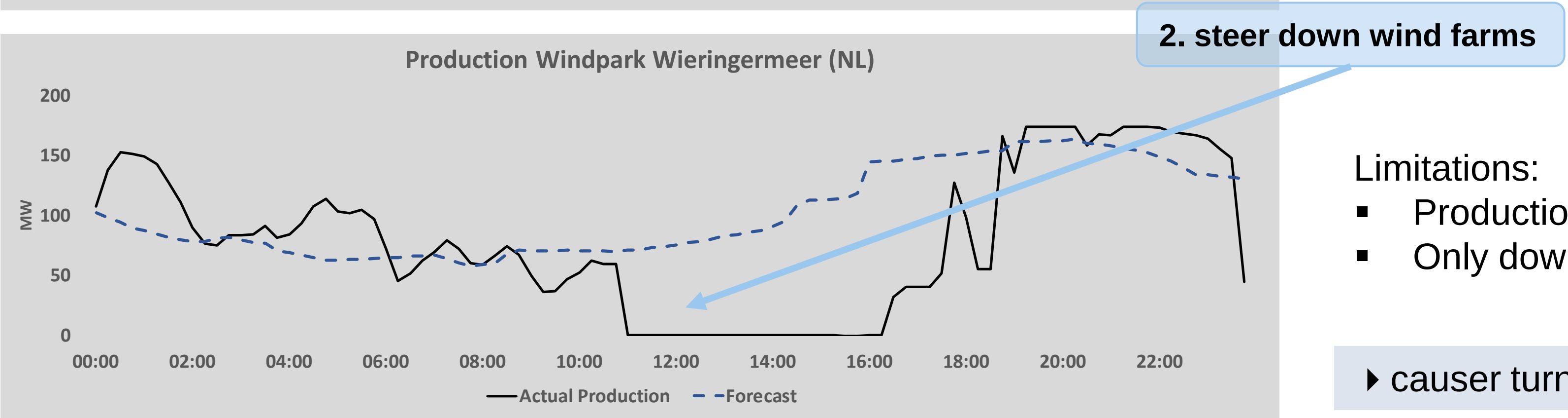
C. Hagberg, Vattenfall 2018: Verification of power prediction tools used for wind power forecasts - Cumulative imbalance costs HornsRev wind farm



▸ Best physical model not necessarily best trade!

Option 3: Steering – Turn Wind into Flexible Asset





Limitations:

- Production loss
- Only down regulation

▸ causer turns into helper

28-05-2022 Netherlands

Maximise Revenues Across Markets

Not discussed:
Term/futures markets
Ancillary service markets

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Wind Optimisation is About Managing Positions and Revenues Against Two-fold Uncertainty

Production uncertainty

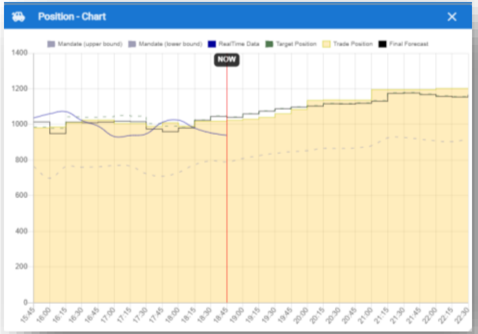
Manage and optimise the expected power production and its unavoidable uncertainty and volatility

Based on i.a. best forecast incl. multi-model-mixing etc, real time data, Nowcast; expert views

Price volatility

Manage and optimise the joint dynamics of the day-ahead, intra-day and imbalance **market prices**

Based on i.a. estimating future power prices**,** market data and historical price volatility, forecasted system’s electric load and renewables generation



Wind optimisation

Maximize expected revenues from selling power minus imbalance costs subject to market regulation, risk aversion and park constraints

Source: volue.com

Summary: How to Improve Wind Power Trading

Forecast Error

- Reduce NWP error (resolved & unresolved scales)
- Higher spatio-temporal resolution (skill)
- Near real-time data assimilation

Uncertainty

- Improve short-term probabilistic forecasts
- Develop independent forecast models (correlation)

Speed

- Rapid update cycles
- Fast access to weather forecast products

▸ Wind forecasting remains key factor for successful integration of renewables

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