Superiority of power system management utilizing uncertainty information in RES forecasts

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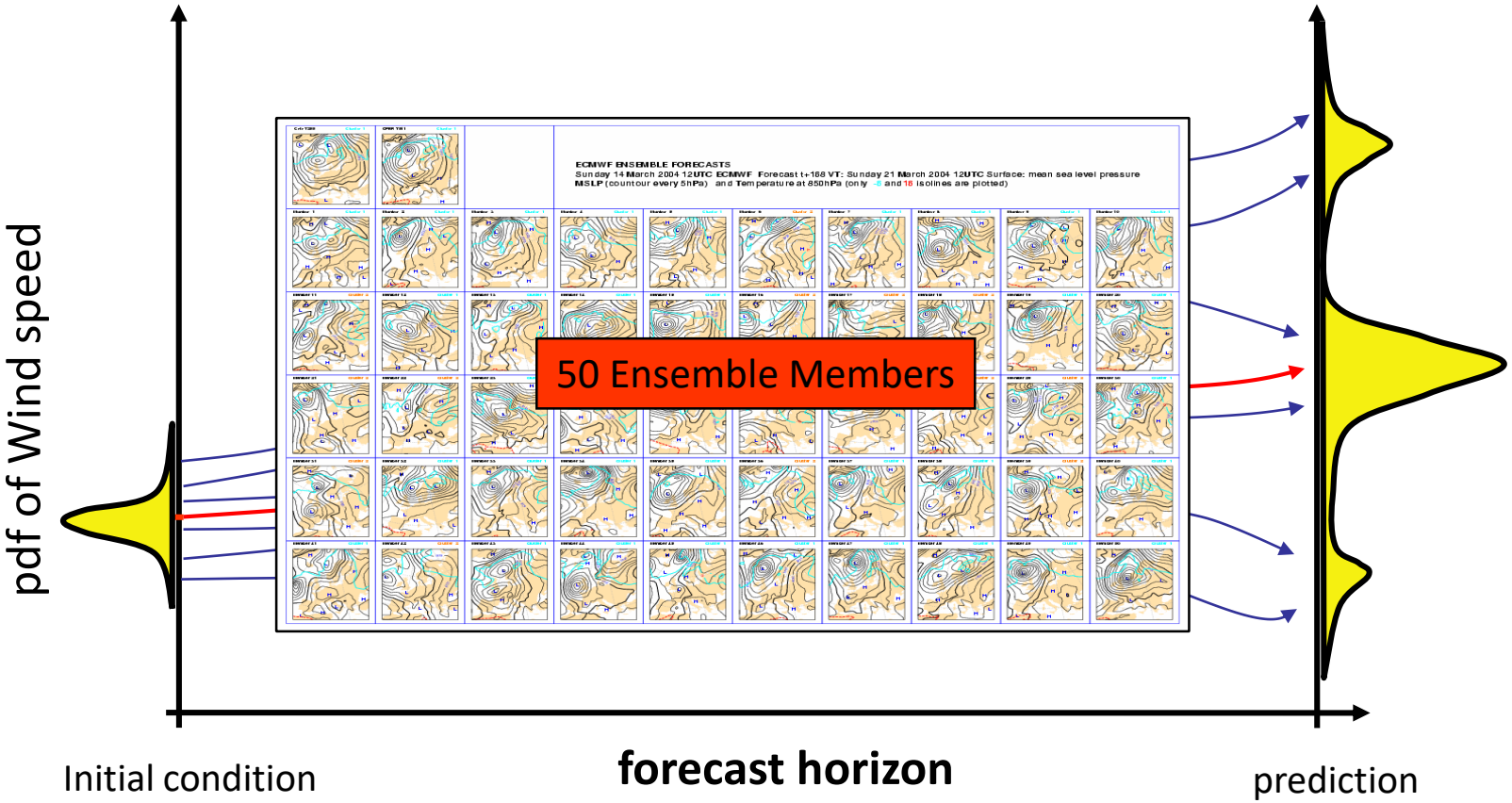
How to consider uncertain weather forecasts in power dispatching?

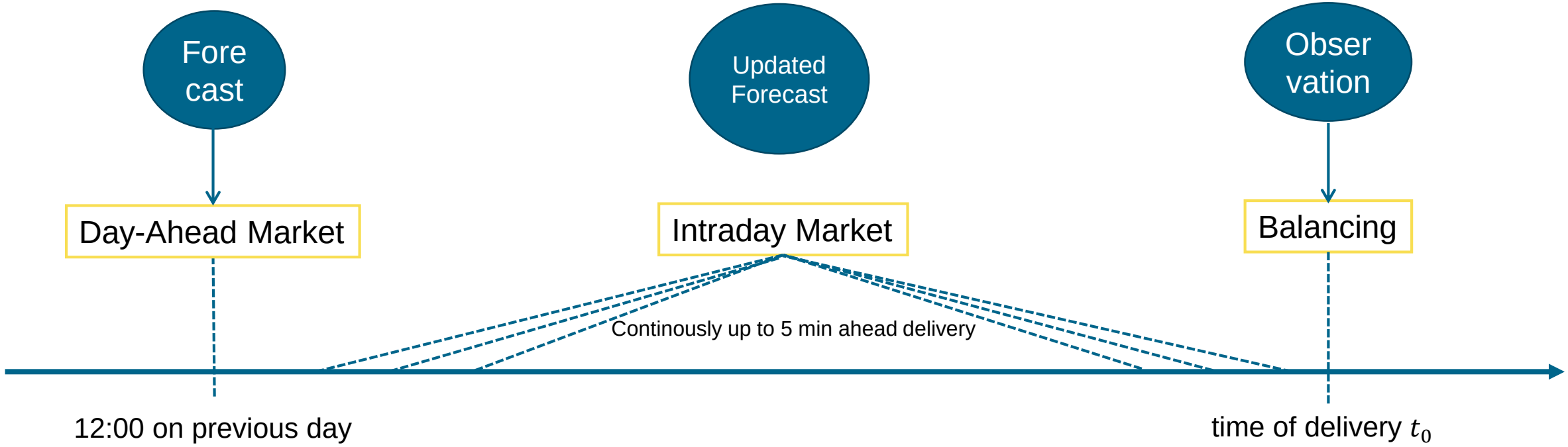
Solution from Numerical Weather Forecasting: Ensemble Prediction



Source: European Centre for Medium-Range Weather Forecasts (ECMWF)

- Lorenz Paradigm: Numerical Weather Forecasting is an initial state problem
- Quantify the uncertainty in the forecast to be aware of forecast errors
- **Major task:** Combine probabilistic forecasts with power dispatch model

Power dispatch model: Implemented Market Clearing



Determination of optimal day-ahead dispatch schedule based on forecast

Determination of optimal day-ahead dispatch schedule based on update forecast

Balancing of deviation between forecasts and observation to ensure balance between supply and demand

How to consider uncertain weather forecasts ?

- **Solution from power system modelling: Dispatch model that considers expected balancing costs→stochastic optimization**
- **Optimal power flow with transmission and ramping contraints**

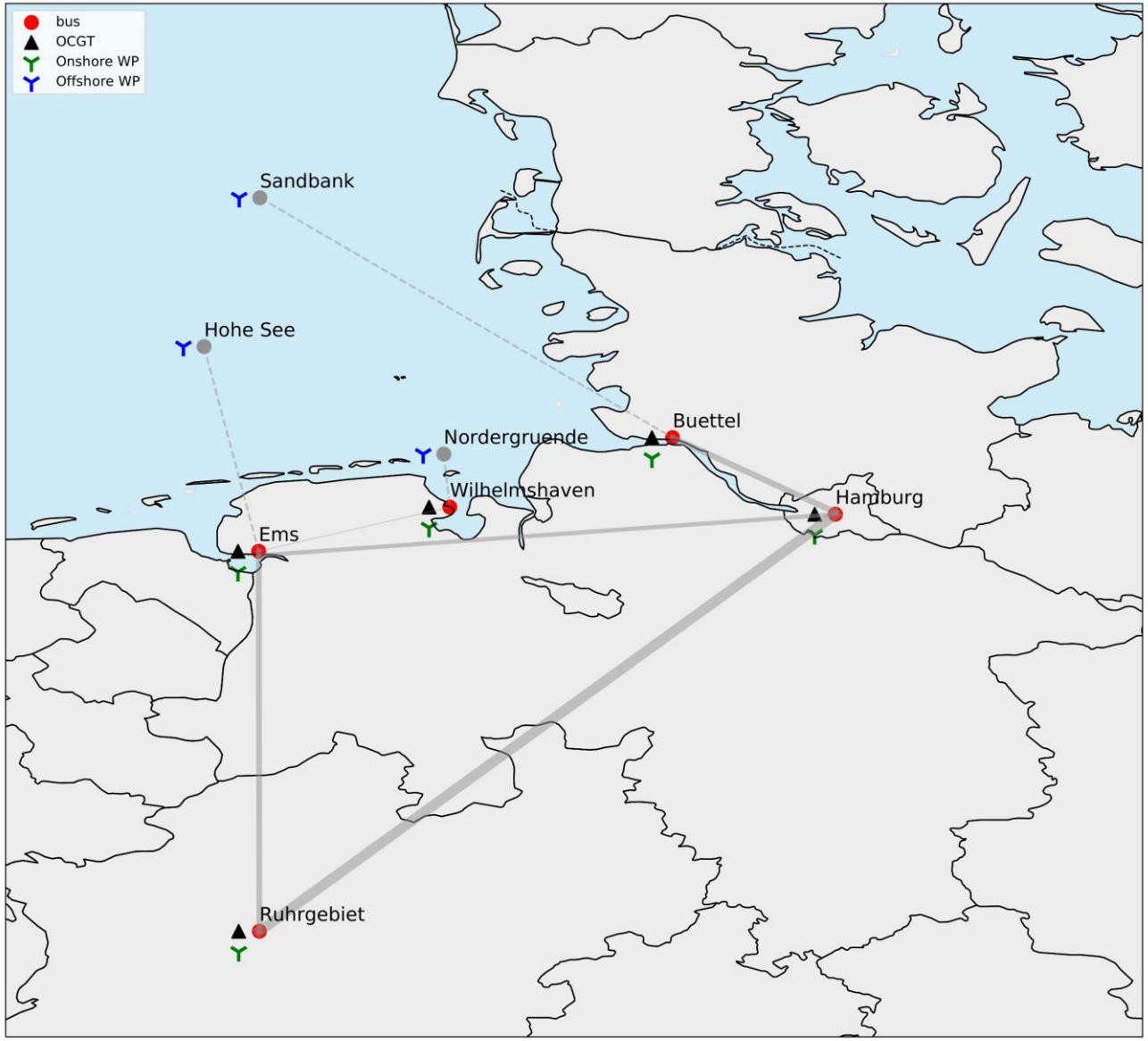
Current practise: Conventionl/Deterministic	Novel idea: Stochastic
Without forecast uncertainty	Forecast uncertainty is considered by implementing **expected balancing costs** in optimization problem
Potentially high system costs due to expensive balancing and expensive load shedding	System improves dispatch using uncertainty information. Less balancing is needed
Deterministic (best) forecast is used	50 ensemble member are used as potential occuring weather situation

Optimization:
min Day-ahead Dispatch Costs + intraday Dispatch Costs + Expected Balancing Costs

Simplified Network

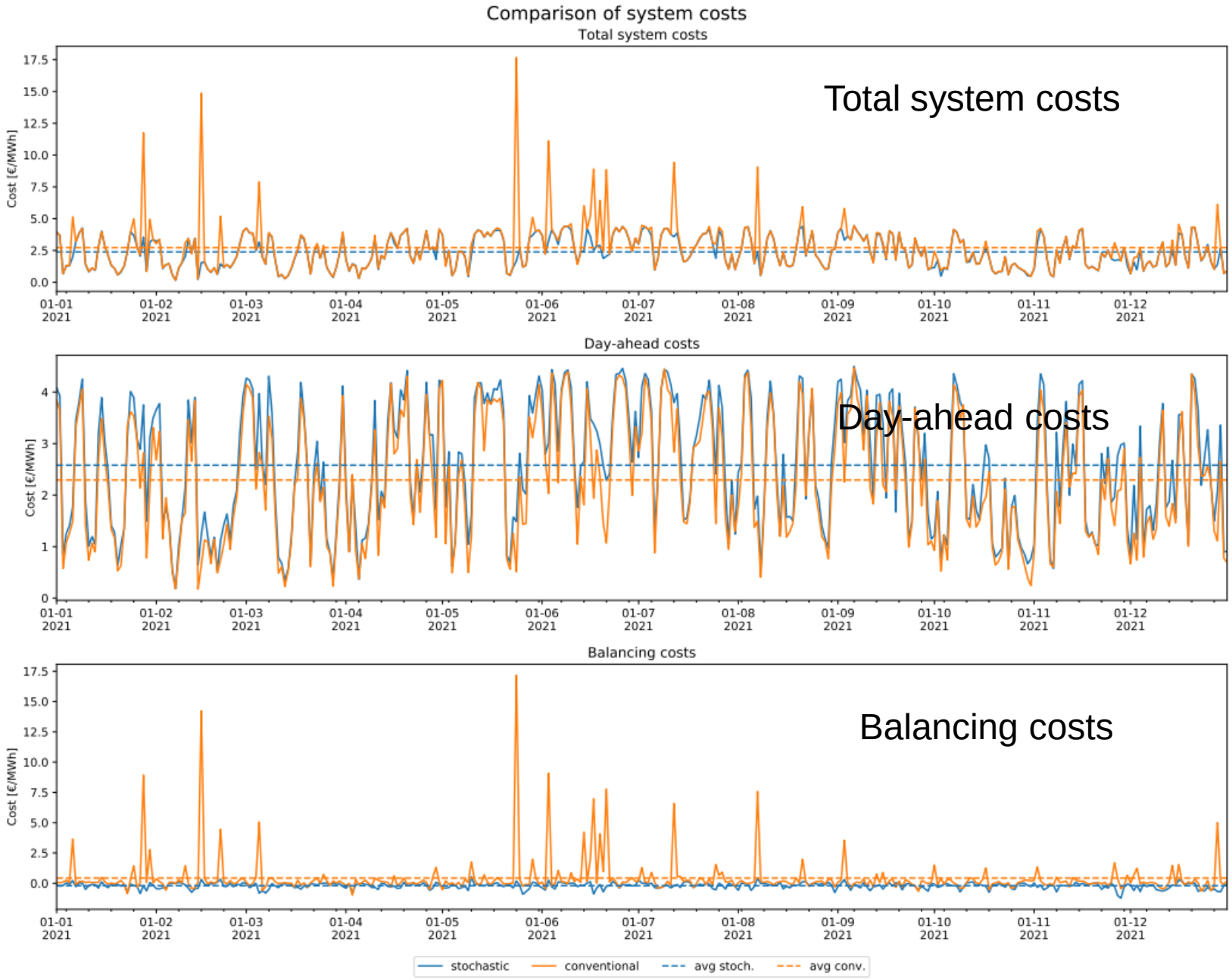
Properties:

- 3 Carrier types:
  - OCGT
  - Onshore wind parks
  - Offshore wind parks
- 5 Buses:
  - Load profile for each sector (Industry, CTS, Households)
- 13 Generators:
  - Nominal generator capacity
  - Marginal costs
  - Flexibility up/down
  - Flexibility price premium
- 5 Links:
  - Nominal link capacity



Results: Comparison of system costs

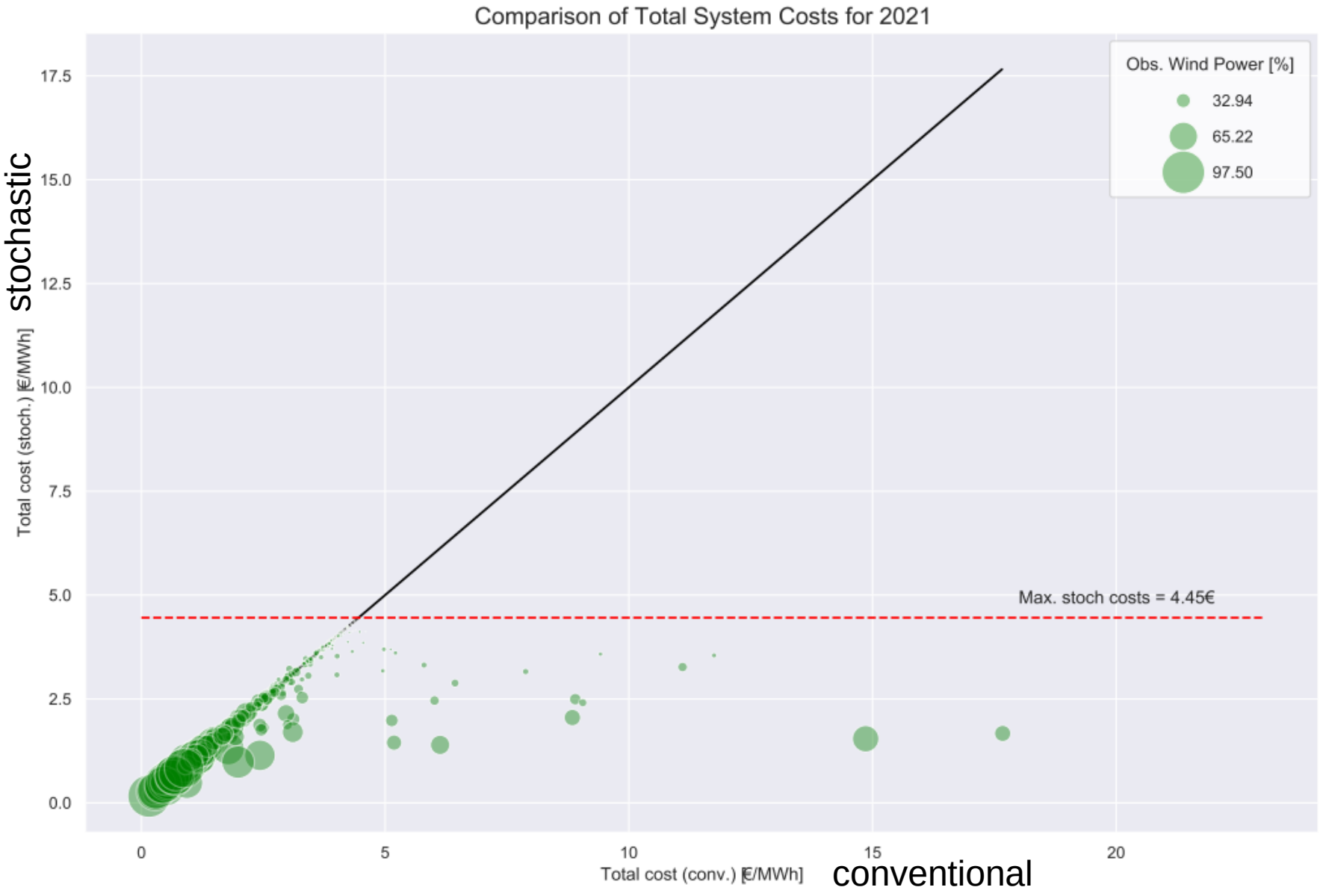
- Total system costs = day-ahead costs + balancing costs
- Stochastic model yields overall price reduction
- Higher day-ahead market costs for stoch. model as inclusive the expacted balancing
- Hence, very low balancing costs at time of delivery



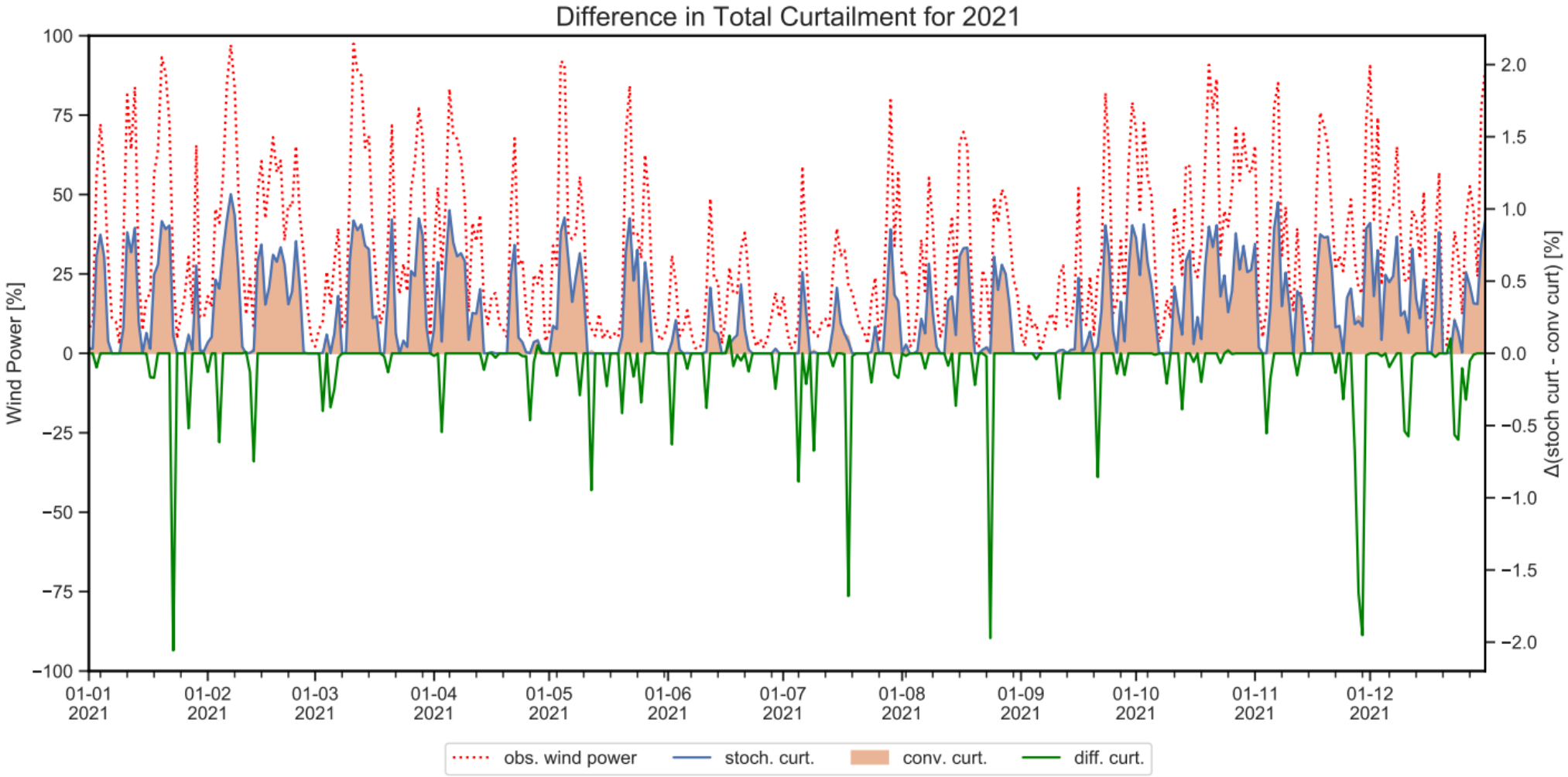
Half of balancing costs due to shedding, half due to higher balancing energy usage

Comparison of total system costs

- Negative correlation between total system costs and observed wind power
- Cap of costs in stochastic model of 4.46€ ~ marginal costs of conventional generators

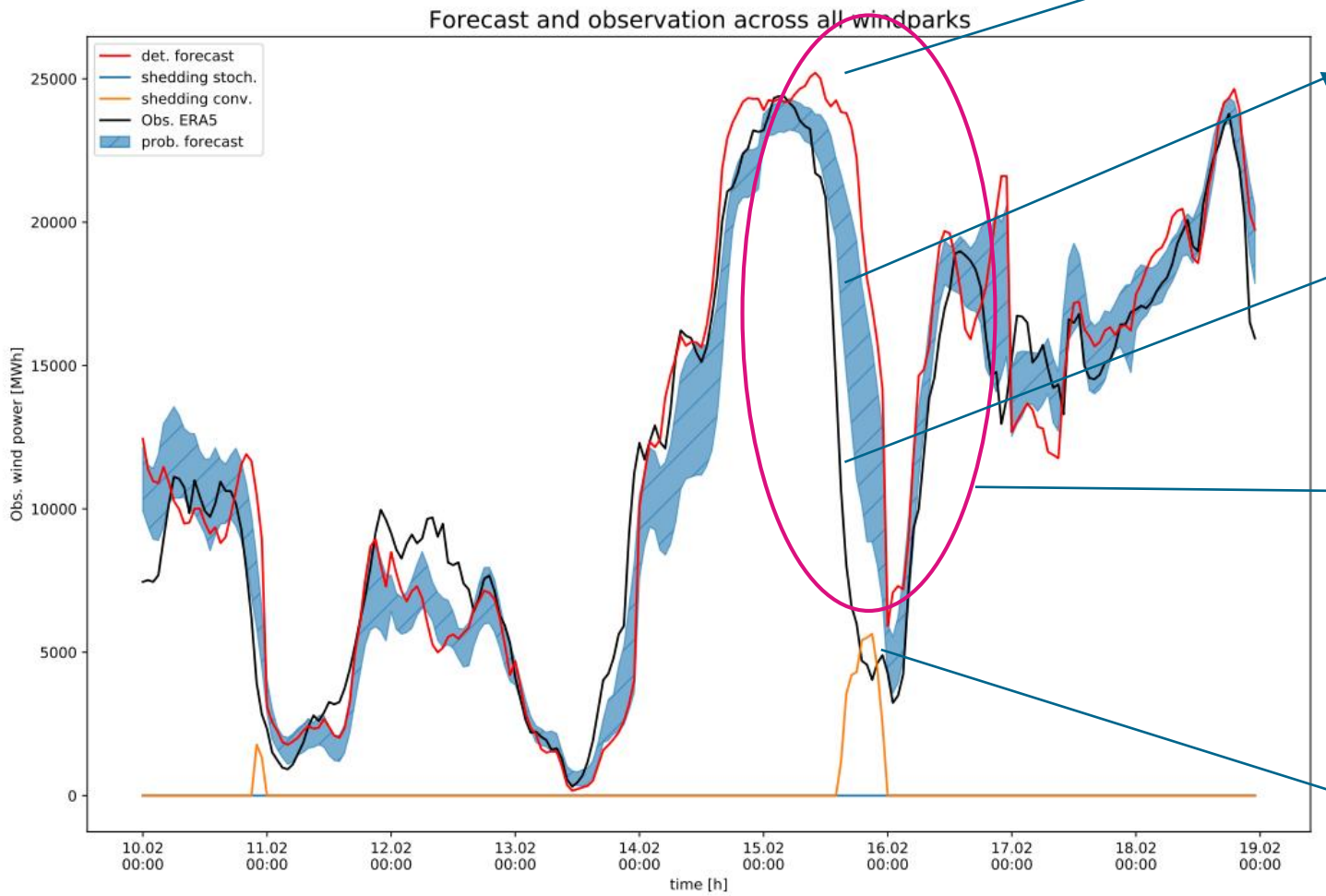


Comparison of Curtailment



- Similar level of curtailment for both models
- Differences more frequently and pronounced for lower observed wind power
- Less curtailment in stochastic clearing 184.0 x 10^5 MWh compared too 184.4 × 10^5 MWh MWh (total: 140x10^6 MWh)

Avoid load shedding when considering forecast uncertainty



Deterministic forecast

Prob.forecast

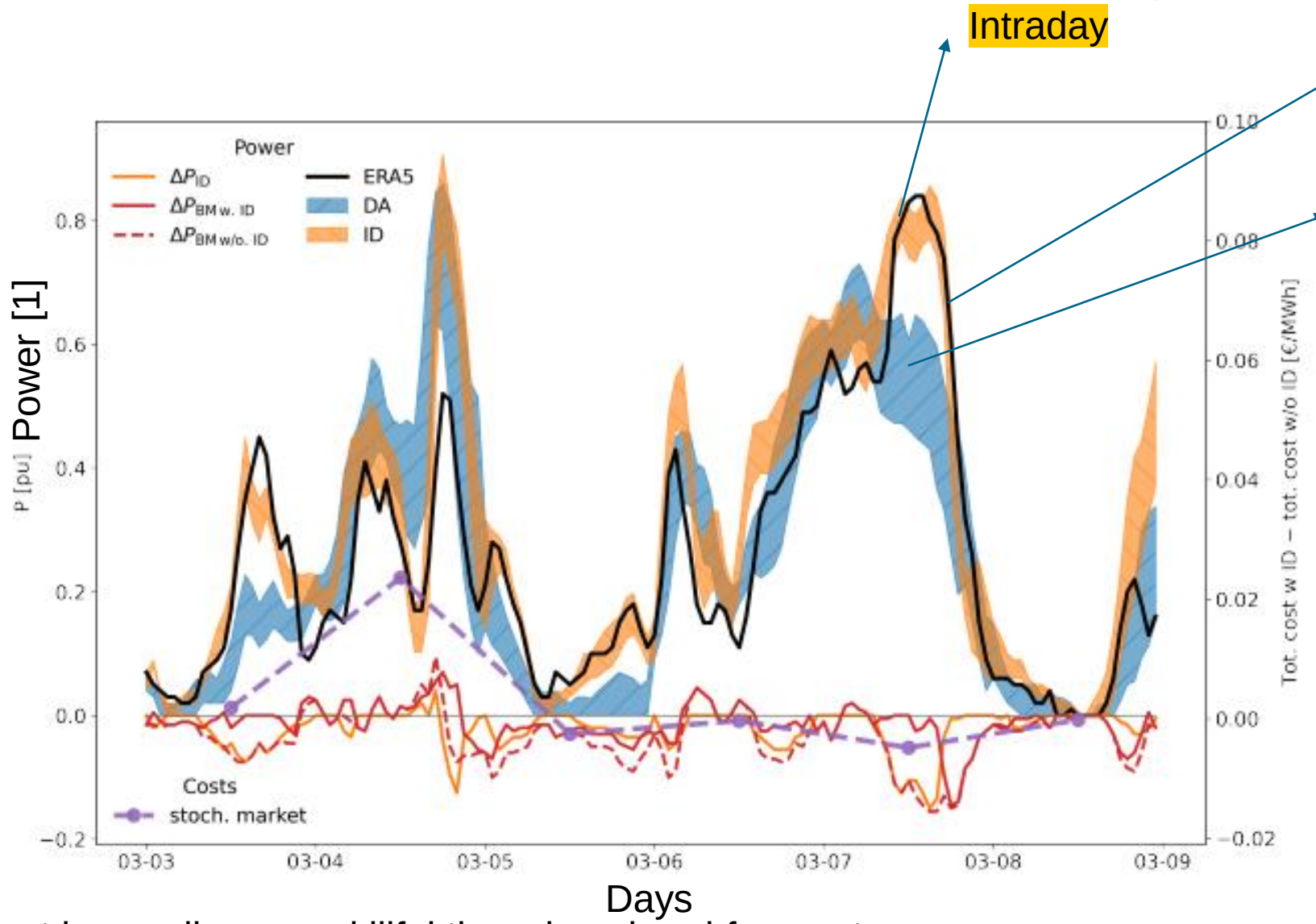
observation

Ramp earlier than expected in the deterministic forecast

Load shedding

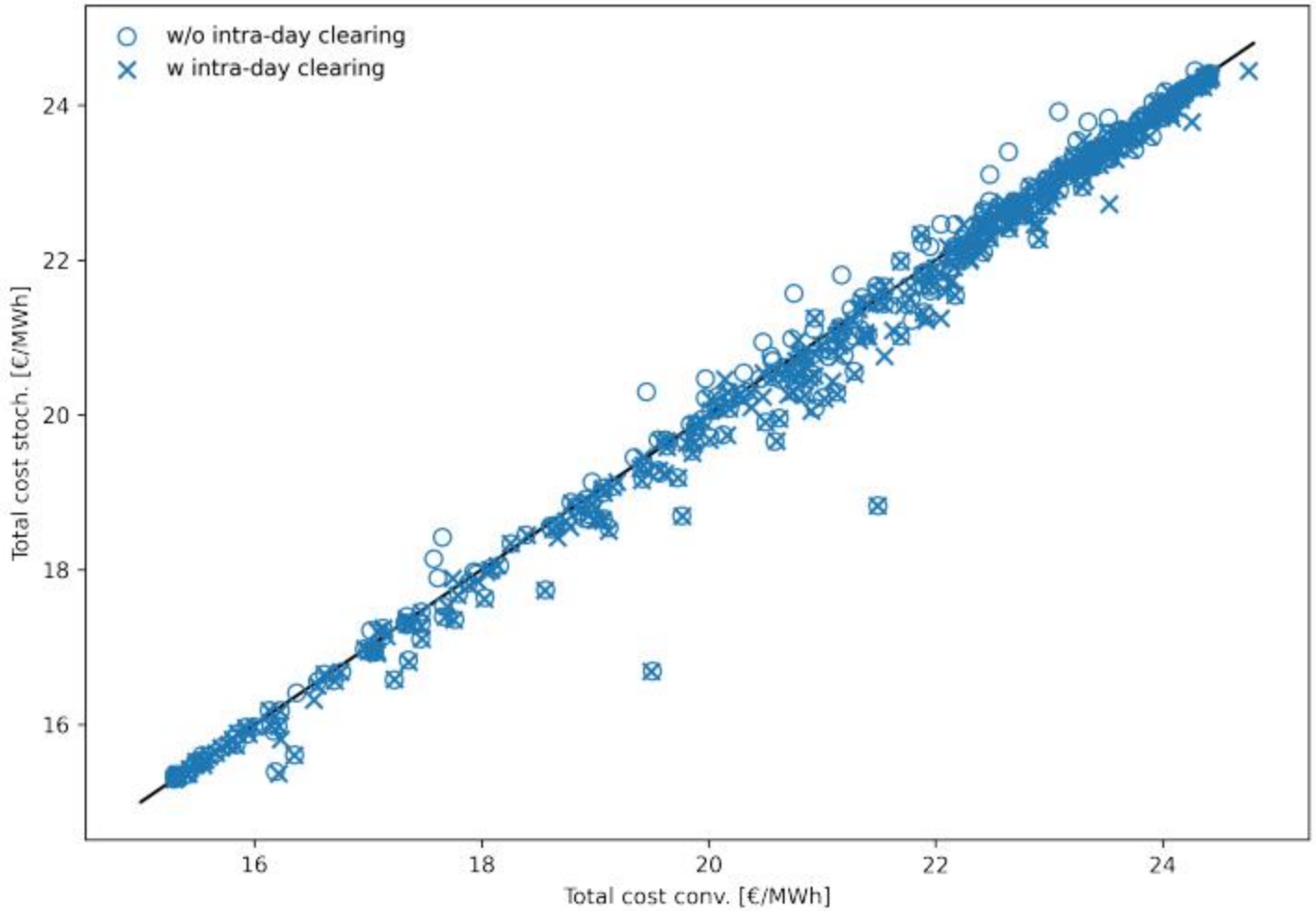
Ramping constraints are too strict to balance the sudden lack of wind power in the conventional clearing
Shedding in convential clearing: 318034 and 1448MWh in stochastic clearing

Include updated forecast for intraday (ID) clearing



Intraday forecast is usually more skillful than day-ahead forecast

Total cost reduction with intraday clearing in a 2-node network



- Stochastic clearing cheaper than conv./deterministic
- Often no effect of intraday clearing as enough wind power is in the system
- However, overall reduction of costs with intraday clearing

Take home messages

- Impact of forecast uncertainty can be modelled in an (idealized) application
- Total system costs decrease when considering weather forecast uncertainty due to reduced curtailment, load shedding and balancing costs
- Updated forecasts at the intraday-market reduces costs further
- Next steps: expand the network for better realism and study sensitivity on forecast skill

THANK YOU FOR YOUR ATTENTION.

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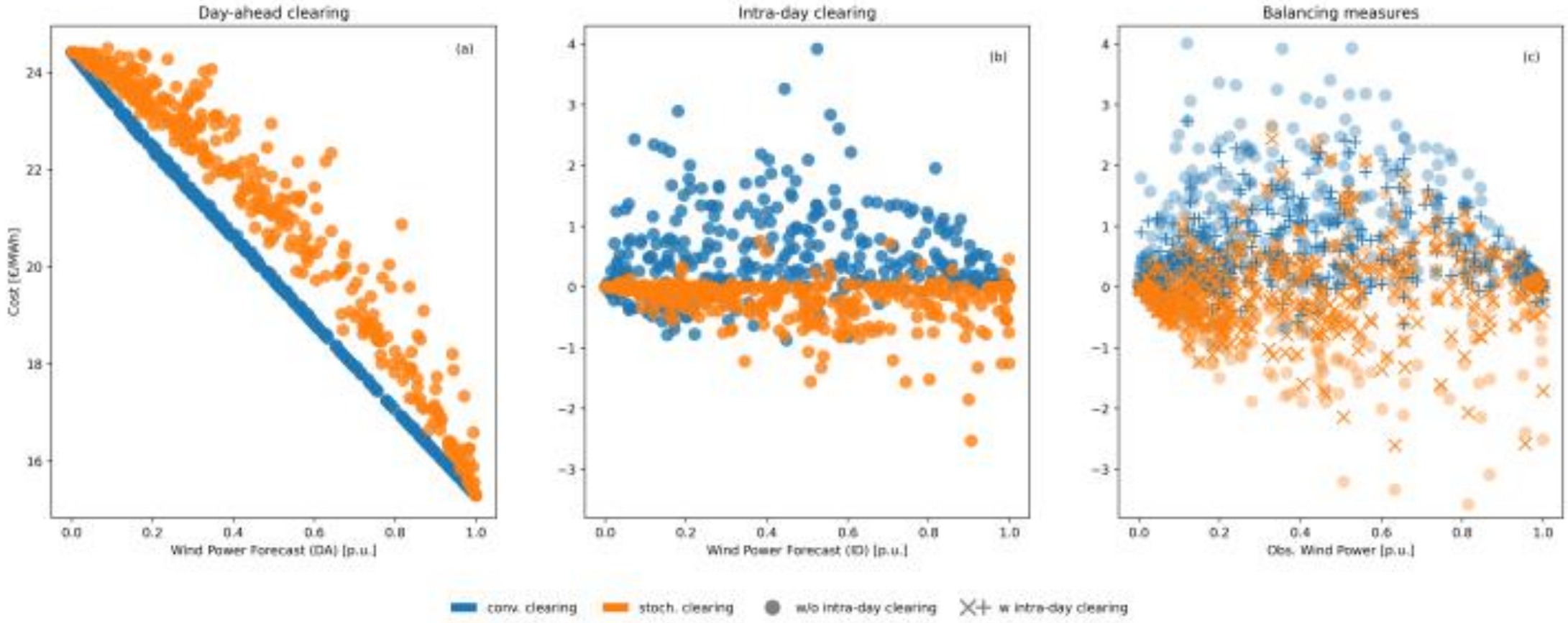
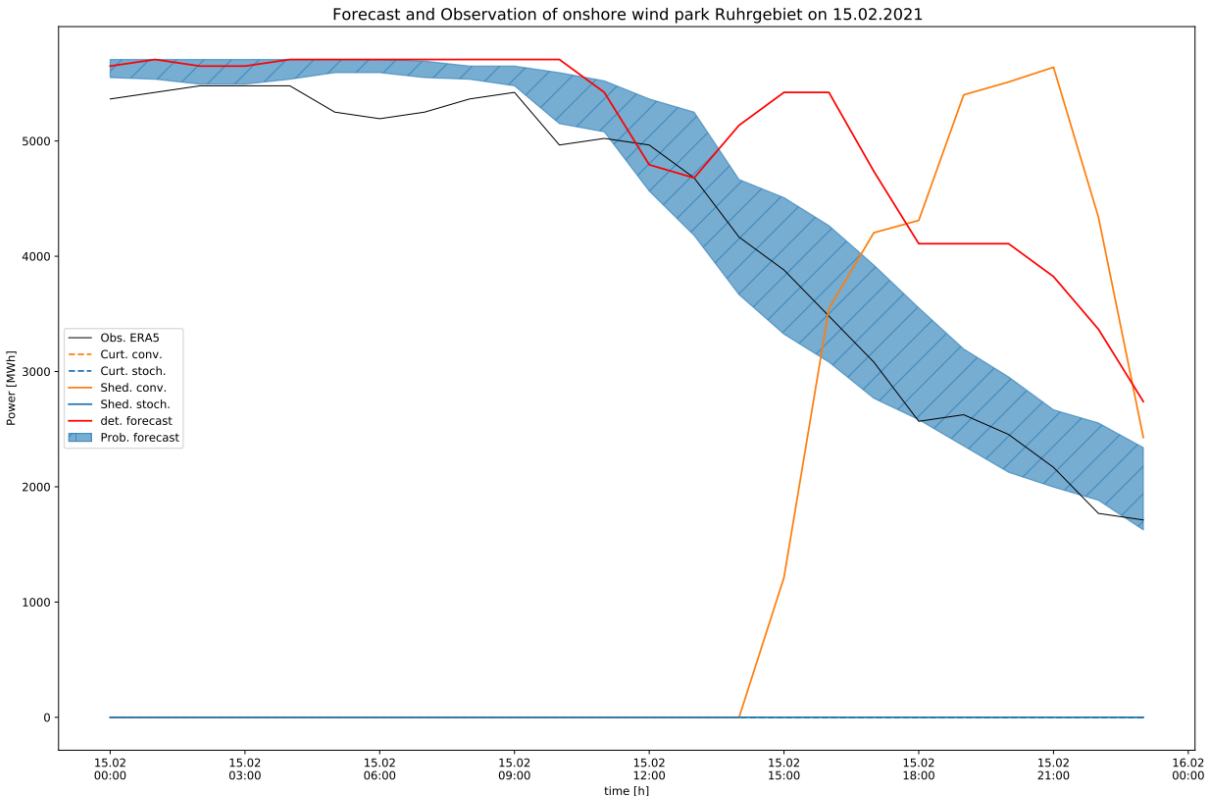
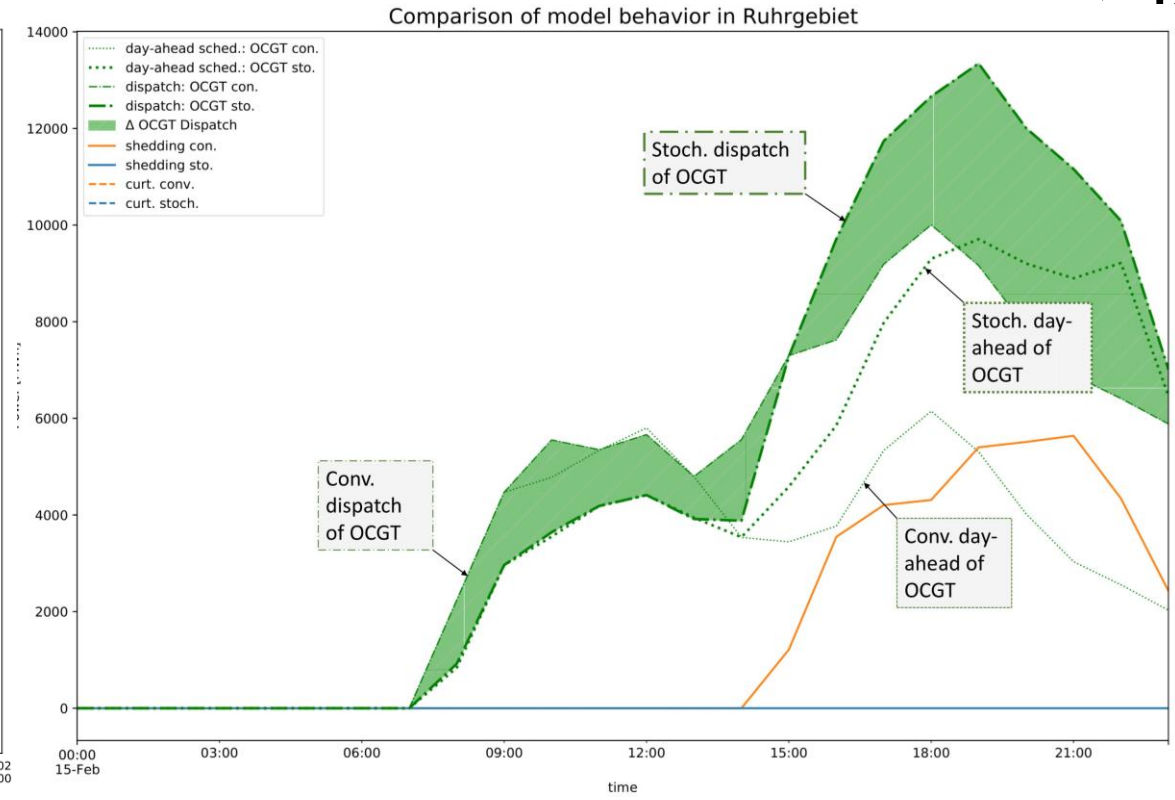
Intraday cost reduction explained



- Almost no difference in day-ahead costs for either no or full wind
- Reduction of dispatched OCGT at intraday clearing (stochastic model), but increase of dispatch of for conv.
- **Stochastic**: Less balancing saving with intraday (i.e. less money paid back by balancing provider)
- **Conv/Determinstic:** More balancing saving with intraday (i.e. less money paid to balancing provider)

Avoid load shedding when considering uncertainty

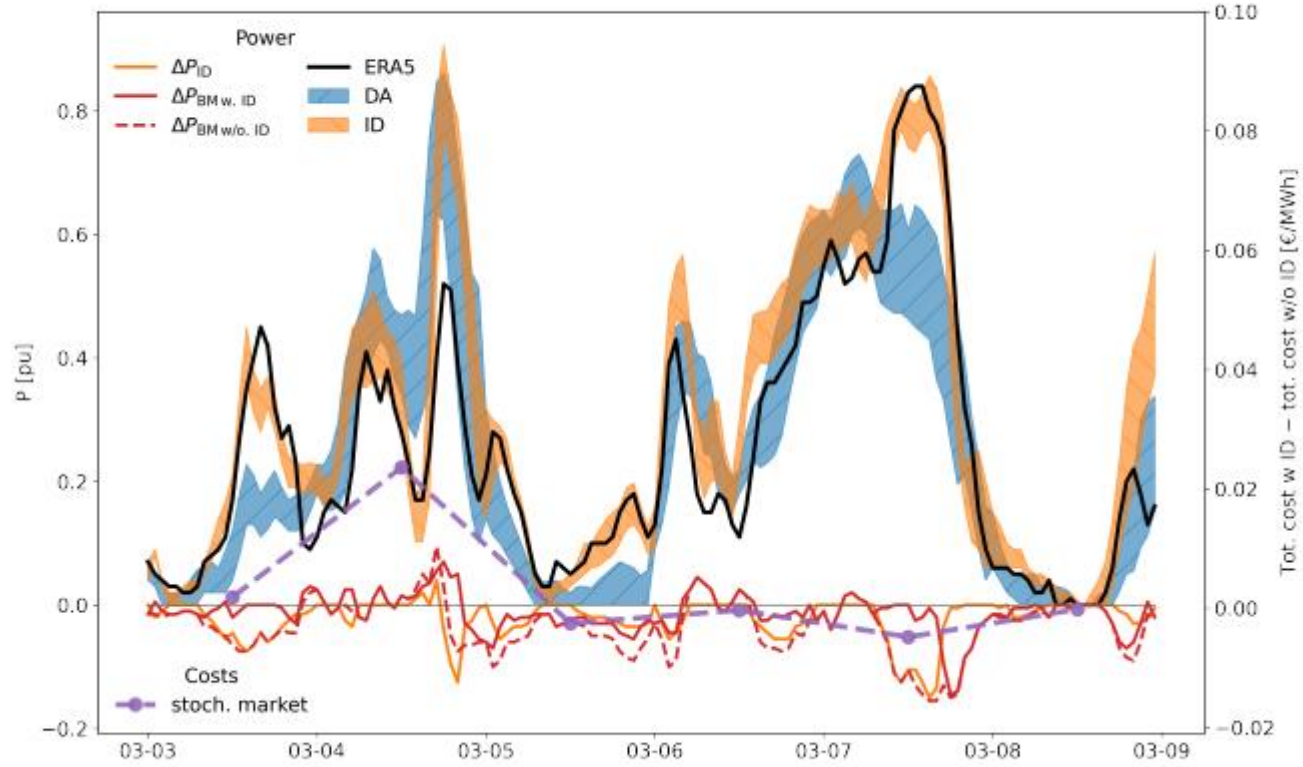




Det. forecasts overestimates available wind power

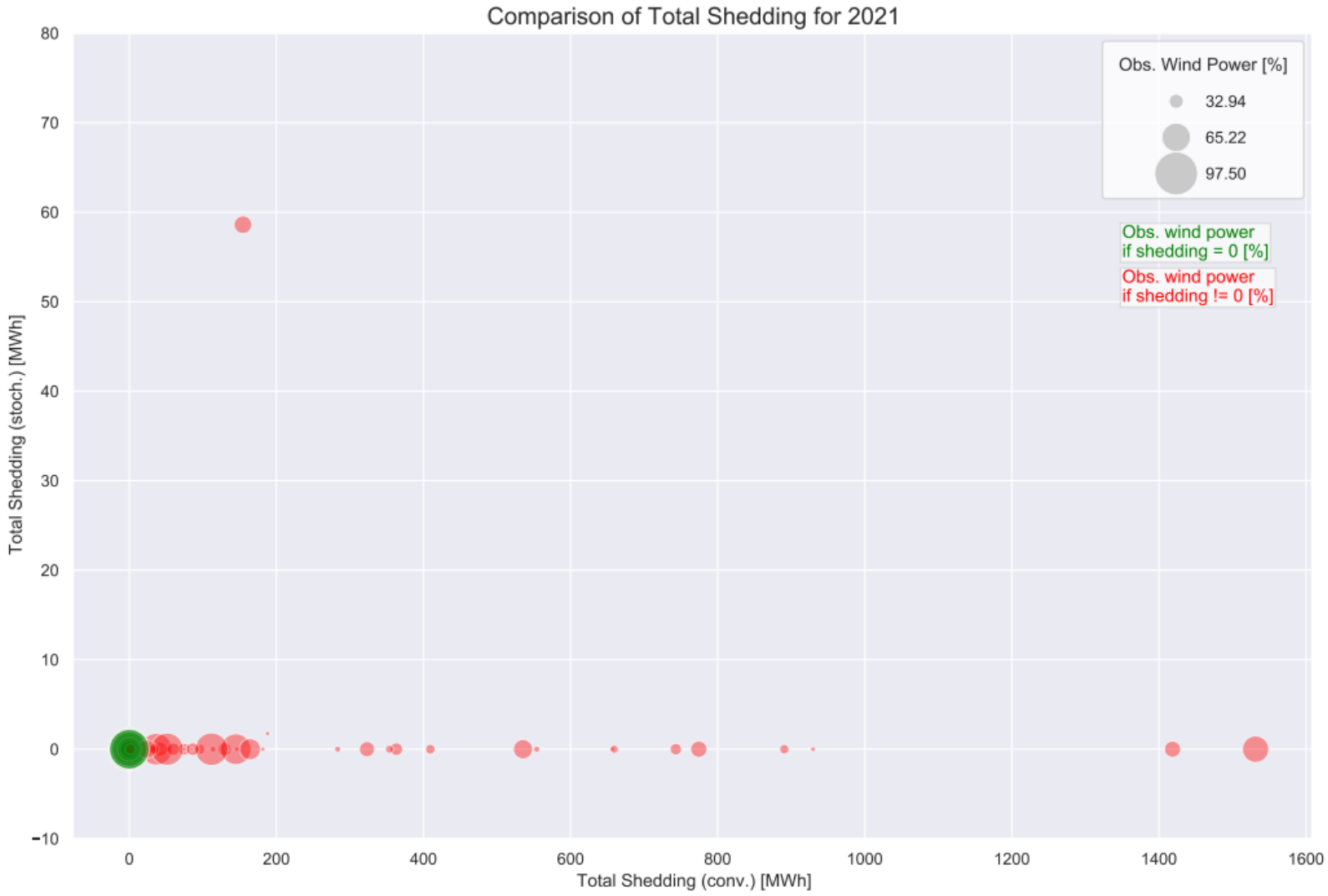
→ Low utilisation of flexible generator in day-ahead schedule

→ Insufficient OCGT flexibility to balance out missing wind power → shedding


Power
ΔP_{ID}
$\Delta P_{BM\ w.\ ID}$
$\Delta P_{BM\ w/o.\ ID}$
ERA5
DA
ID
Costs
stoch. market
P [pu]
Tot. cost w ID − tot. cost w/o ID [€/MWh]
0.8
0.6
0.4
0.2
0.0
−0.2
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
03-03
03-04
03-05
03-06
03-07
03-08
03-09

Comparison of Shedding

- Mainly, shedding events in deterministic model
- Most expensive balancing measure…



Optimizing Energy Dispatch utilizing Uncertainty Information in Probabilistic Forecasts

Ensemble Forecasts: