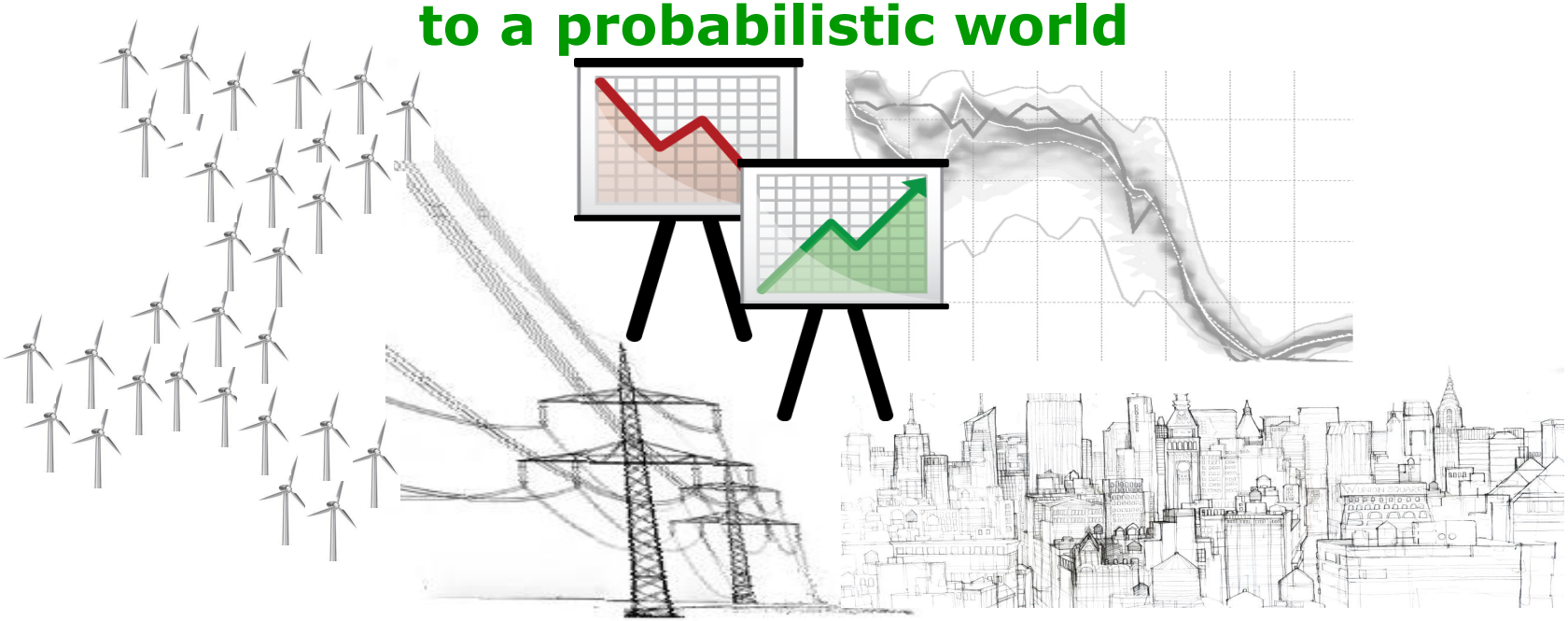
IEA Wind Task 36: Forecasting for Wind Energy
Workpackage 3

Understanding Uncertainty: the difficult move from a deterministic to a probabilistic world



Wind Integration Workshop 2018
Forecasting Session 9b

Berlin, 18th October 2018

Dr. Corinna Möhrlen, WEPROG
Dr. Ricardo Bessa, INESC TEC

Background of this investigation: IEA Task 36: Forecasting for Wind Energy

Task Objective is to encourage improvements in:
1) weather prediction
2) power conversion
3) use of forecasts

Task Organisation is to encourage international collaboration between:
- Research organisations and projects
- Forecast providers
- Policy Makers
- End-users and stakeholders

Task Work is divided into 3 work packages:
WP1: Weather Prediction Improvements inclusive data assimilation
WP2: Development of a benchmarking platform & best practice guidelines
WP3: Communication of best practice in the use of wind power forecasts

Follow us on our webpage: www.ieawindforecasting.dk
Publications: www.ieawindforecasting.dk/publications

iea wind

FROM THEORY TO PRACTICE

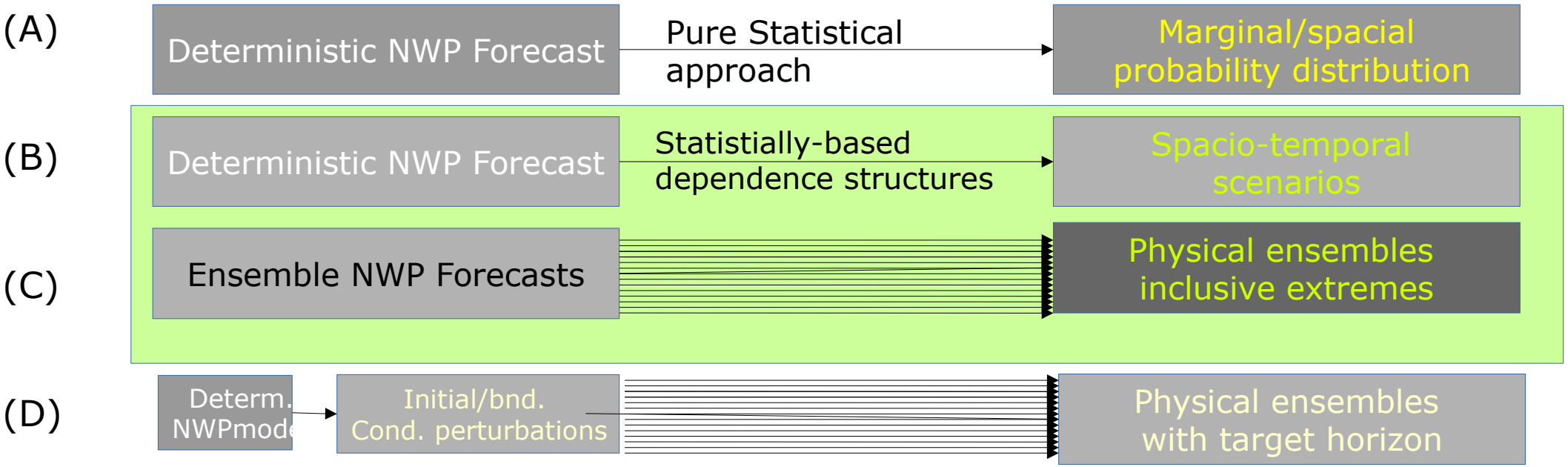
METHODS FOR GENERATING UNCERTAINTY FORECASTS

APPLICATIONS FOR UNCERTAINTY FORECASTS

- A. Using uncertainty forecasts for situational awareness in the control room
- B. Using uncertainty forecasts for trading and balancing
  - Trading Strategies
  - Critical Ramps
  - High-Speed Shut-down events
- C. Grid Technical Constraints Management

SUMMARY AND OUTLOOK

Methods for generating Uncertainty Forecasts



For details please see:

Bessa, R.J.; Möhrlen, C.; Fundel, V.; Siefert, M.; Browell, J.; Haglund El Gaidi, S.; Hodge, B.-M.; Cali, U.; Kariniotakis, G. **Towards Improved Understanding of the Applicability of Uncertainty Forecasts in the Electric Power Industry**. Energies 2017, 10, 1402.
https://www.mdpi.com/1996-1073/10/9/1402

http://www.ieawindforcasting.dk/publications

APPLICATIONS FOR UNCERTAINTY FORECASTS

Situational awareness in the Control Room

Operators understand probabilities quite well from their daily work!!!

When forecast is off multiple times:

→ operators loose trust & stop acting when using deterministic information

→ operators keep focus and confidence when using probabilistic information

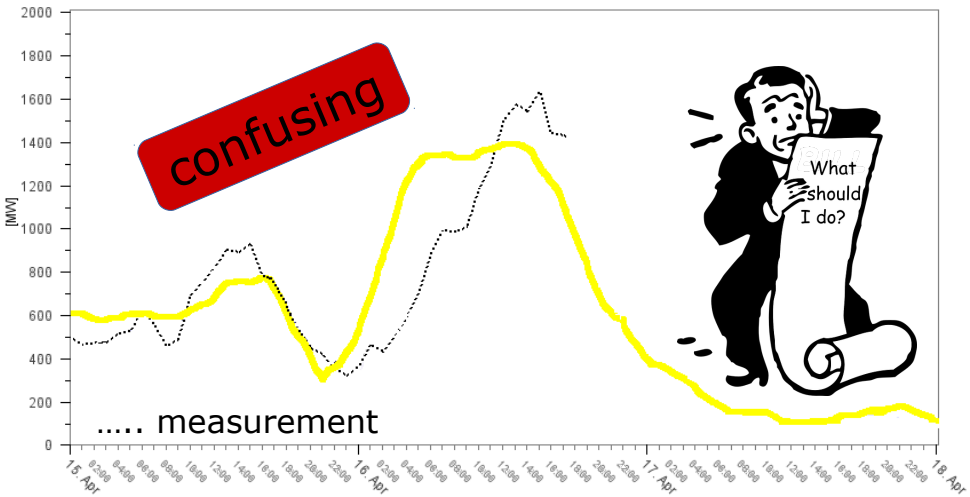
→ Deterministic methods “hide” uncertainty of forecast

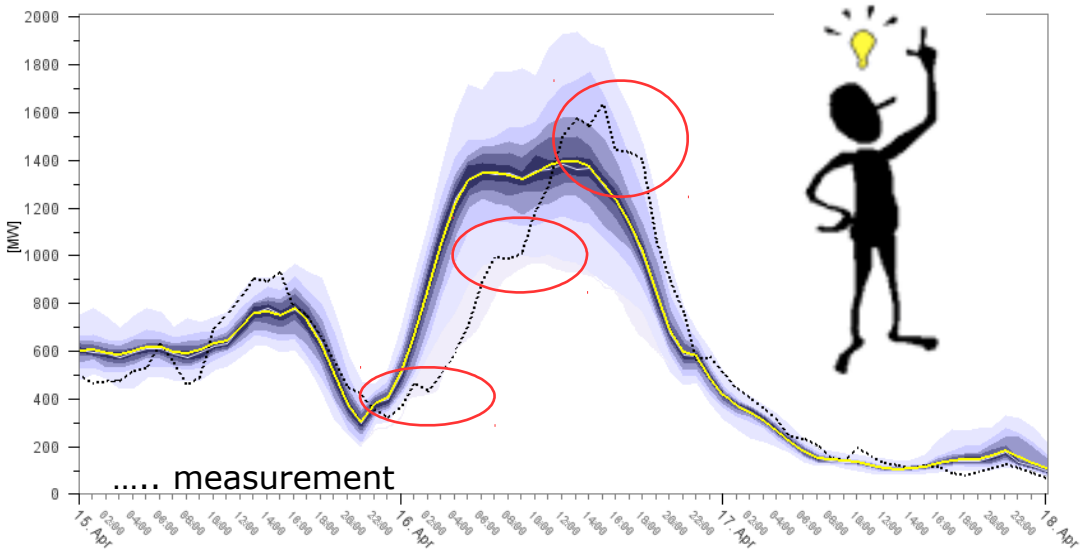
→ Decision making with probabilistic information is always better

→ Type of uncertainty forecast and appropriate communication is crucial

Situational awareness in the Control Room

Single deterministic forecast versus a probabilistic forecast





Situational Awareness amongst System operators has become important for those:

- not at all or weakly interconnected
- prone to variable weather conditions and high wind speeds
- penetration levels challanging traditional reserves (>25%)

KNOWING WHAT MAY HAPPEN HELPS PLANNING MORE SAFE AND ECONOMIC!!!

Situational awareness in the Control Room

Operators may understand probabilities better than the managers!!!

Making the uncertainty of forecasts visible is:

1) empowering the operators
2) should not be seen as a complication

Providing information to the operator about the **trustworthiness** of a forecast and **possible outliers** is exactly what is required to:

- be prepared
- be able to act in good time
- make operations more smooth
- make operations less expensive
- act under less stress

The two most important **requirements**:
(1) method being used to provide uncertainty indicators
(2) communication of the uncertainty

The pitfalls are that these two aspects are not taken serious enough in the planning and design phase.

How to practically change trading practices

Strategic Daily Spot Market Bidding

1. Split your pool into portions and become price maker
2. Optimize your trading volume with intra-day balancing
3. Base your bids on a preliminary plan for the balance process
4. Make sure you help to avoid negative prices

Why is this important ?

1. Reduces the day-ahead schedule error with approx. 50%
2. Reduces the need of peak reserve
3. Reduces the volatility of balancing costs
4. More volume in the market
5. Small pools may not need to be 24x7 in the market

How to become a price maker in the market

Recipe:

Know your pool's controllable and non-controllable generation

Use **appropriate uncertainty forecast intervals** to:

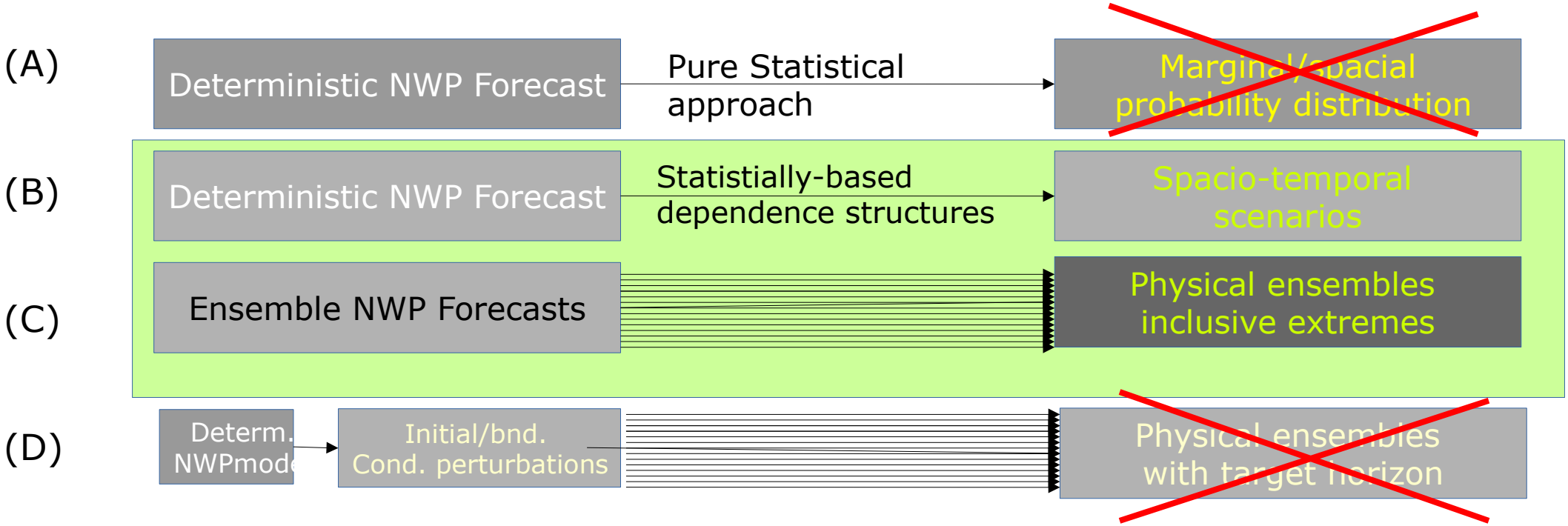
- trade the "safe" part with a mean or determinsitic day-ahead forecast
- trade uncertain parts with higher prices and control curtailment yourself
- trade in the intra-day market only difference outside uncertainty band

Design price levels considering

- time of the day
- current weather situation
- liquidity in the market
- expected load
- risk for negative prices
- risk for curtailment

How to become a price maker in the market

Know, which methodology works for your target problem !



For trading purposes you need an **hour-to-hour uncertainty**, approach:

(A) generating only a spacial probability distribution lacks the time dimension

(D) target horizons need calibration for the time component

Thumb rules for trading with uncertainties

Use the **appropriate approach** for your target:

- one that is looking forward in time
- not a statistical/climatology based forecast
- not one that has specific target times

The **incentive** MUST be **avoidance of imbalance costs** while increasing your income

Become a price maker to **reflect real system costs**

Only **trade when it make sense**

→ avoid trading every hour/time interval
→ only trade within the uncertainty band
→ the most current forecast is not always the best !!!

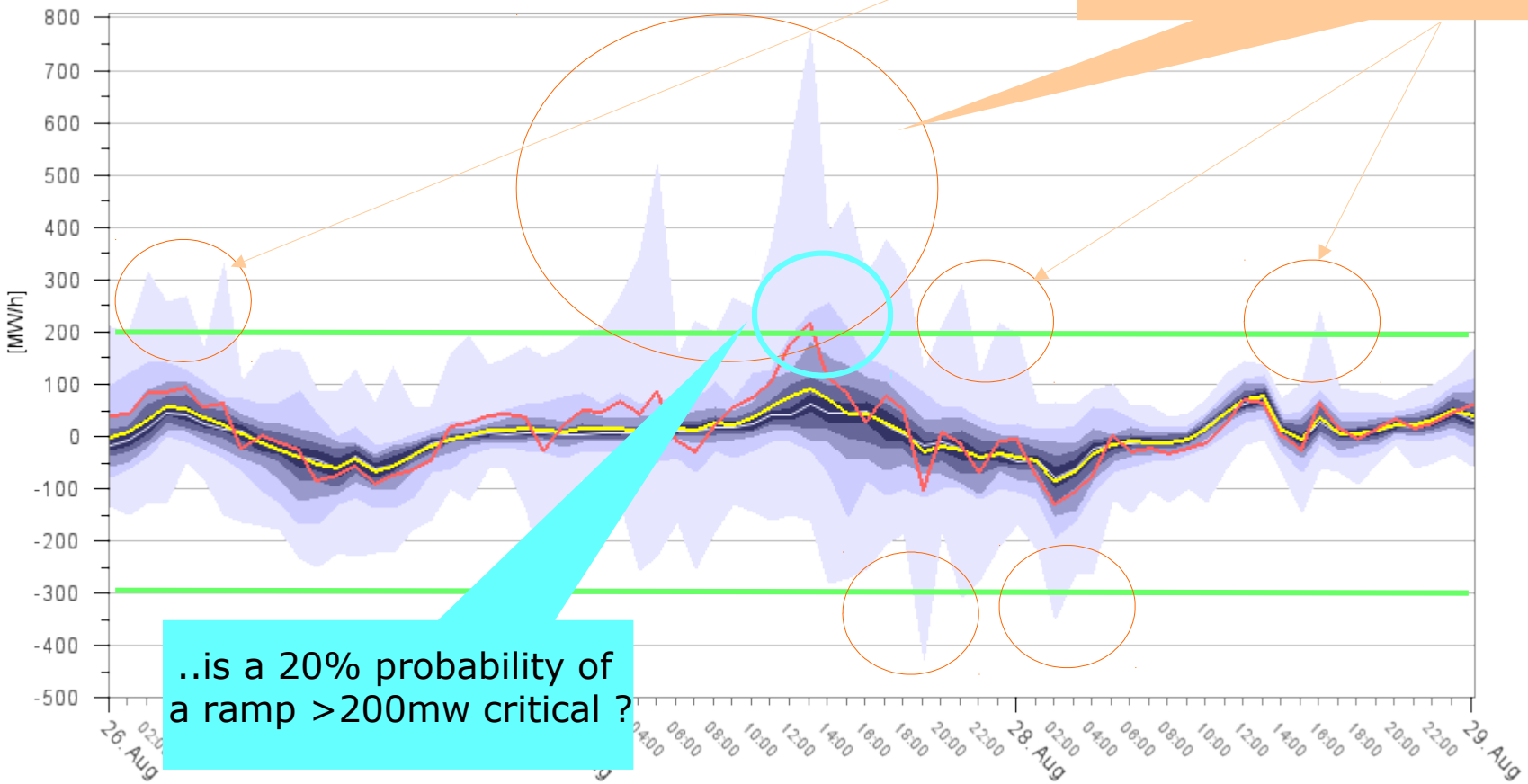
Critical Ramp Events – Definitions

Ramp Forecast
A Ramp forecast is a forecast that provides the possible power generation over a specific time interval

Risk index of critical Ramps
A risk index of critical ramps is a threshold value of power generation allowed over a pre-defined time interval. This can be boolean , probabilisitc or with sliding ends and tails.

Critical Ramp Events – Definition is key !

Is a 10% probability for a ramp >200MW/15min critical ?



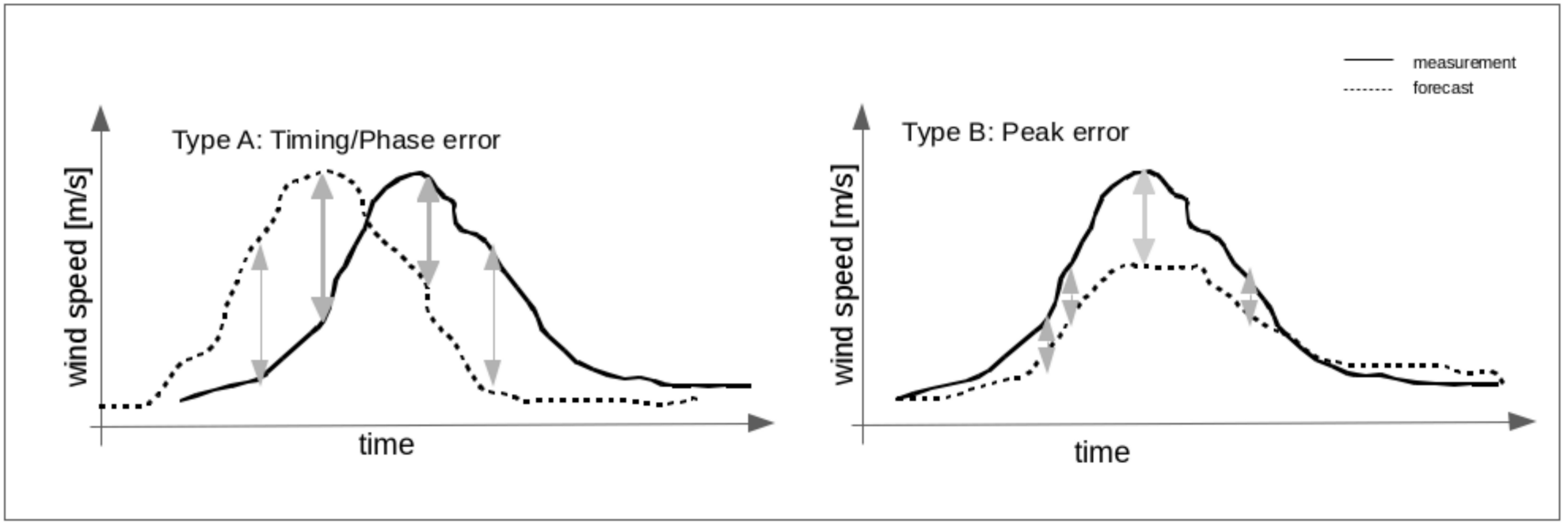
..is a 20% probability of a ramp >200mw critical ?

Threshold values must be used together with limits and rules, how to act...

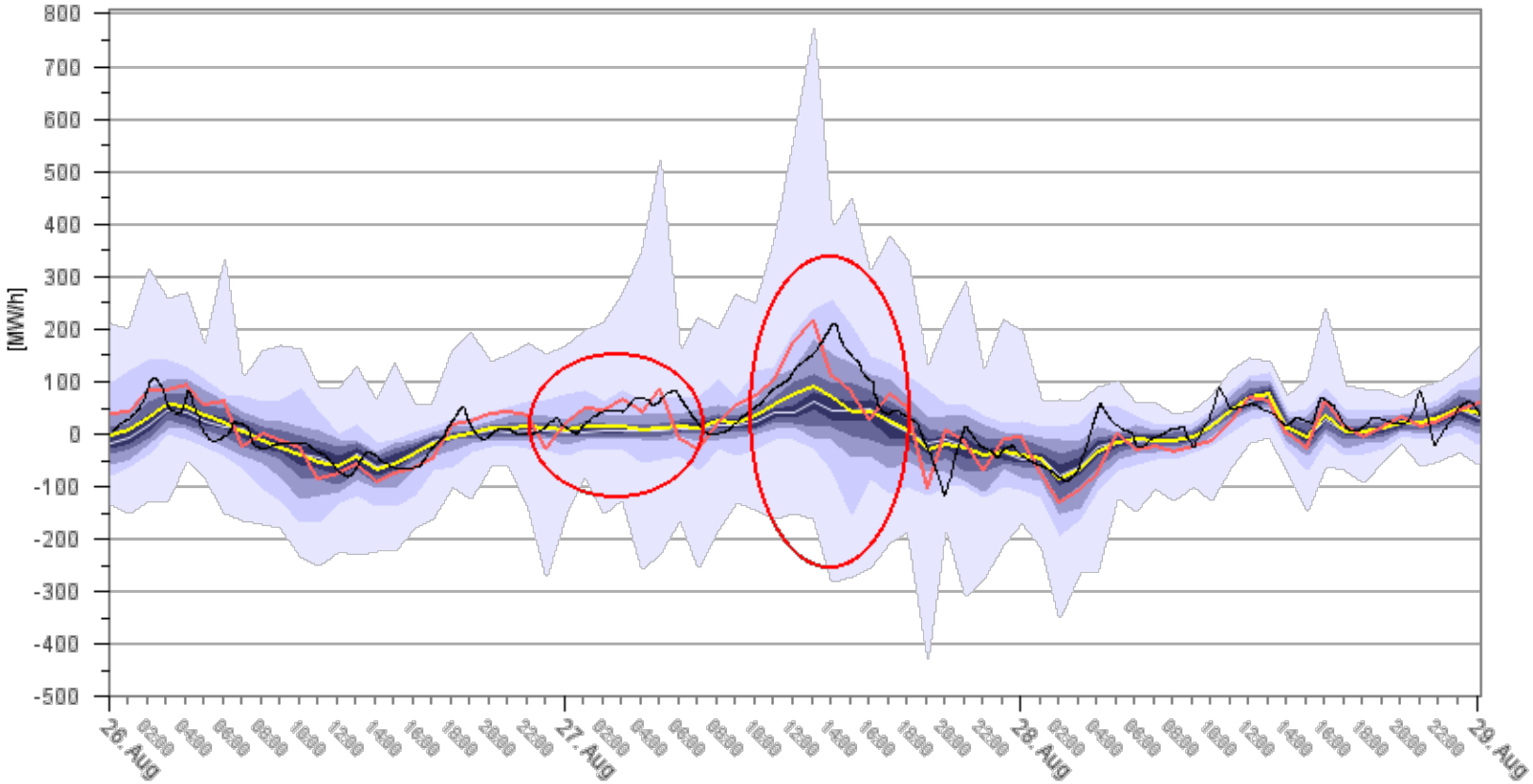
Critical Ramp Events – today's challenge

Statement from a Q&A session at a recent forecasting workshop by an end-user: "Communication of uncertainty in timing of ramp events is the most challenging. *It is not so much the uncertainty of the amplitude.* ***Getting the shape right*** *would already help, even if the timing is off*".

Let's have a look at that requirement in respect of forecasting method and evaluation:



Critical Ramp Events – an example



Beware: if you are interested in the shape - DON'T EVALUATE ON RMSE OR MAE

Phase errors are punished more than shape errors – forecasters listen, but if your choice is measured in MAE/RMSE they can't do what you ask for and be selected at the same time !!!

Critical Ramp Events – wrap up

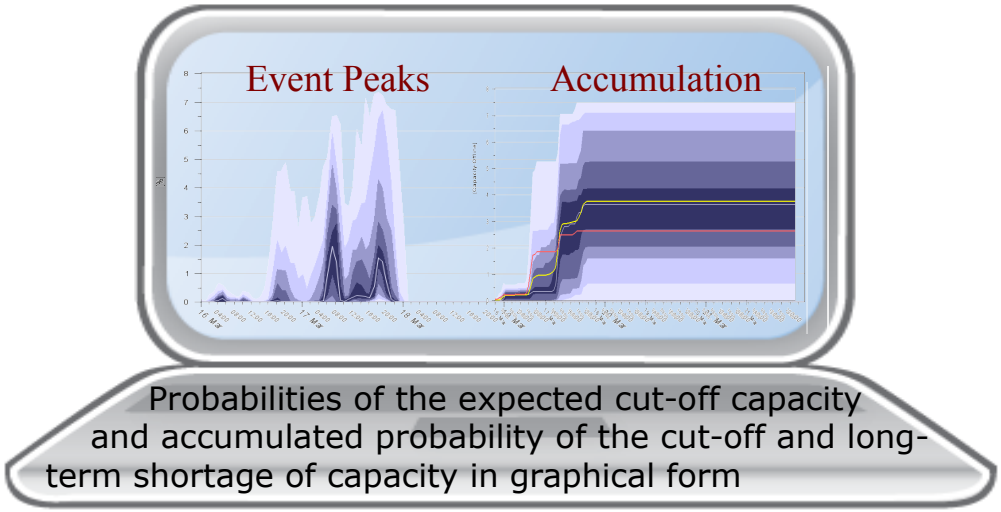
Requirement to establish ramp forecasting:

1) Rules (when and how to act...)
2) Thresholds (of critical probabilities and timing)
3) Limits (of critical MW ramp up/down per time interval)
4) A communication layer (to interact in real-time with the staff)

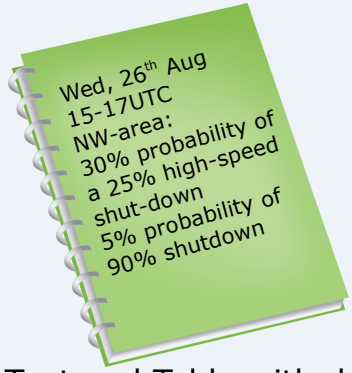
Without that, a forecaster cannot provide the necessary information to make such a risk index automatic and reliable!

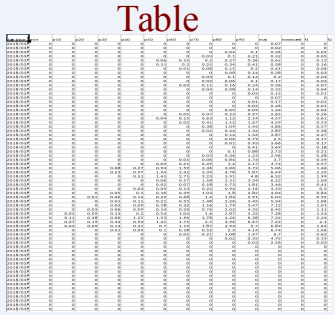
High-Speed Shutdown Event Forecasting

A warning system can be established in the form of graphics or text.



Probabilities of the expected cut-off capacity and accumulated probability of the cut-off and long-term shortage of capacity in graphical form





Text and Table with detailed information of the risk and the associated areas and timelines, send as Emails or via WebServices

The underlying instruments however should contain two components:

(1) Probability computation of the expected cut-off capacity

In cooperation with the end-user the system critical part of the capacity will be determined (e.g. 30% of the ...)

(2) Accumulation of the expected cut-off capacity

This component provides the accumulated cut-off probability of the expected temporal shortage of capacity and ramps

High-Speed Shutdown Event Forecasting

Communication is crucial for the alerts to be taken serious when required !

The frequency of alert generation need to be adjusted to:

- lead time of the alert
- initial and valid week day and time of day
- severity of the event computed from a ramp-rate

- change of severity level since previous alert
- the actions required
- the need and possibility to call back and/or revert actions

Strategy of alert issuing:

- ➔ issue every alert according to a simple scheme
  (e.g. probability exceeding 10% for more than 2 subsequent forecasts)
- ➔ reduce the amount of alerts to prevent critical alerts not to be overlooked
  (observe before an alarm is issued...)

Grid Technical Constraints Management

Goals

A. Anticipate technical problems (voltage problems, congestion, etc.)
B. Define remedial actions (e.g. grid reconfiguration, re-dispatch)

Current Practices

- ✓ Use of deterministic forecasts, e.g Day Ahead Congestion Forecast (DACF) - TSO
- ✓ DSO do not use forecasts in their management processes OR feed power flow tools with deterministic forecasts for loads/RES

Grid Technical Constraints Management
Barriers

Requires stochastic optimization tools with high computational time (slow advices to human operators)

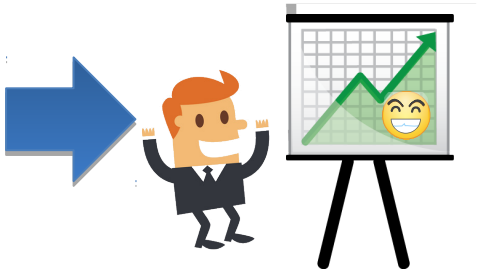
Lack of business cases that perform cost-benefit analysis of stochastic approaches for grid management

Cognitive load of human operators in the presence of probabilistic information for a large electrical network

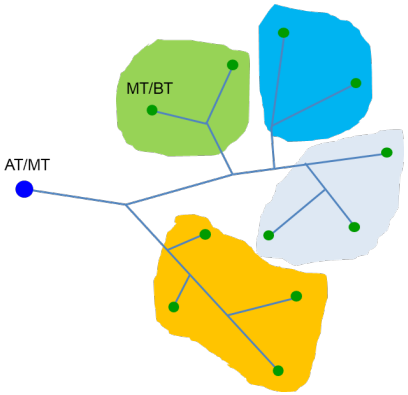
Grid Technical Constraints Management

Solutions

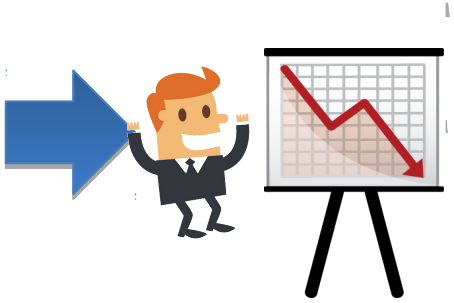
Integrate forecast uncertainty in "imitation learning" (imitate decisions made by experts)



Ease the acceptance of the information about uncertainty by the human operator



Design local (or segmented) stochastic optimization methods



Decrease the computational time, as well as complexity in visualizing forecasted information

Invest in new visualization techniques

Reduce information into a manageable amount of data and alarms

Key Takeaways…

Define your problem and request appropriate method

Ignoring uncertainty or using wrong tools leads to mistrust

Applying the right uncertainty tools provides confidence

Communicating uncertainty can be done in different ways:

Use visual as well as textual tools

Develop or request new visualisation tool

Remove concerns by understanding how information can be best condensed to be useful

THANK YOU FOR YOUR ATTENTION

Questions ?

Contact us:
Dr. Corinna Möhrlen, WEPROG
com@weprog.com

Dr. Ricardo J. Bessa, INESCTEC
ricardo.j.bessa@inesctec.pt

Follow us:

Project webpage

http://www.ieawindforecasting.dk/

Task-page:

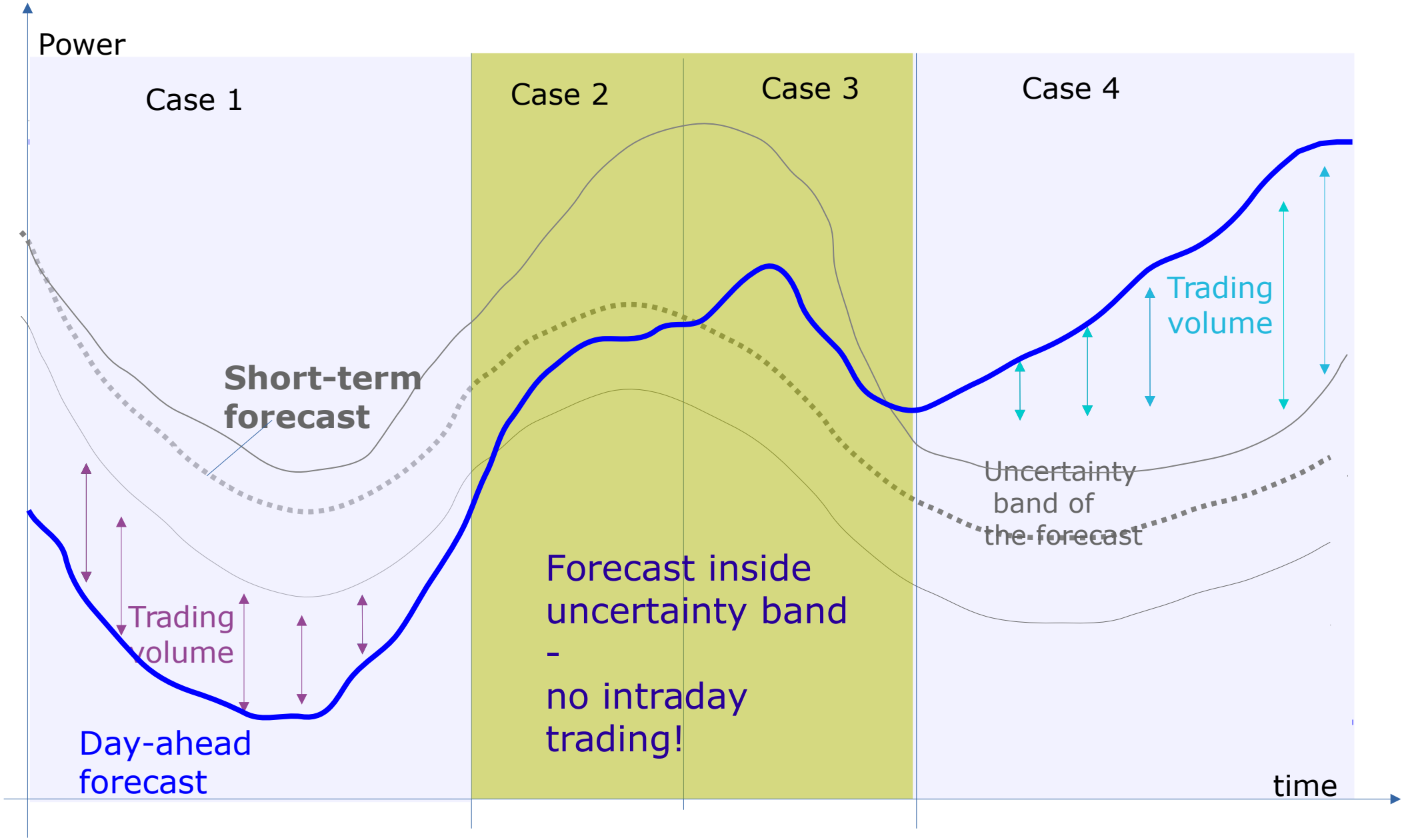
http://www.ieawindforecasting.dk/topics/workpackage-3/task-3-1

http://www.ieawindforecasting.dk/topics/workpackage-3/task-3-5

Publications:

Explanatory additional slides

How to practically work with uncertainty in Trading Applications



How to practically work with uncertainty in Trading Application

There are 4 cases to consider:

Case 1: Short-term forecast is higher than Day-ahead

Action: **Sell** the **volume between minimum short-term and day-ahead**

Case 2: Short-ahead forecast is higher than day-ahead, BUT lies within the uncertainty band of short-term forecast

Action: Do nothing!

Case 3: Short-ahead forecast is lower than day-ahead, BUT lies within the uncertainty band of short-term forecast

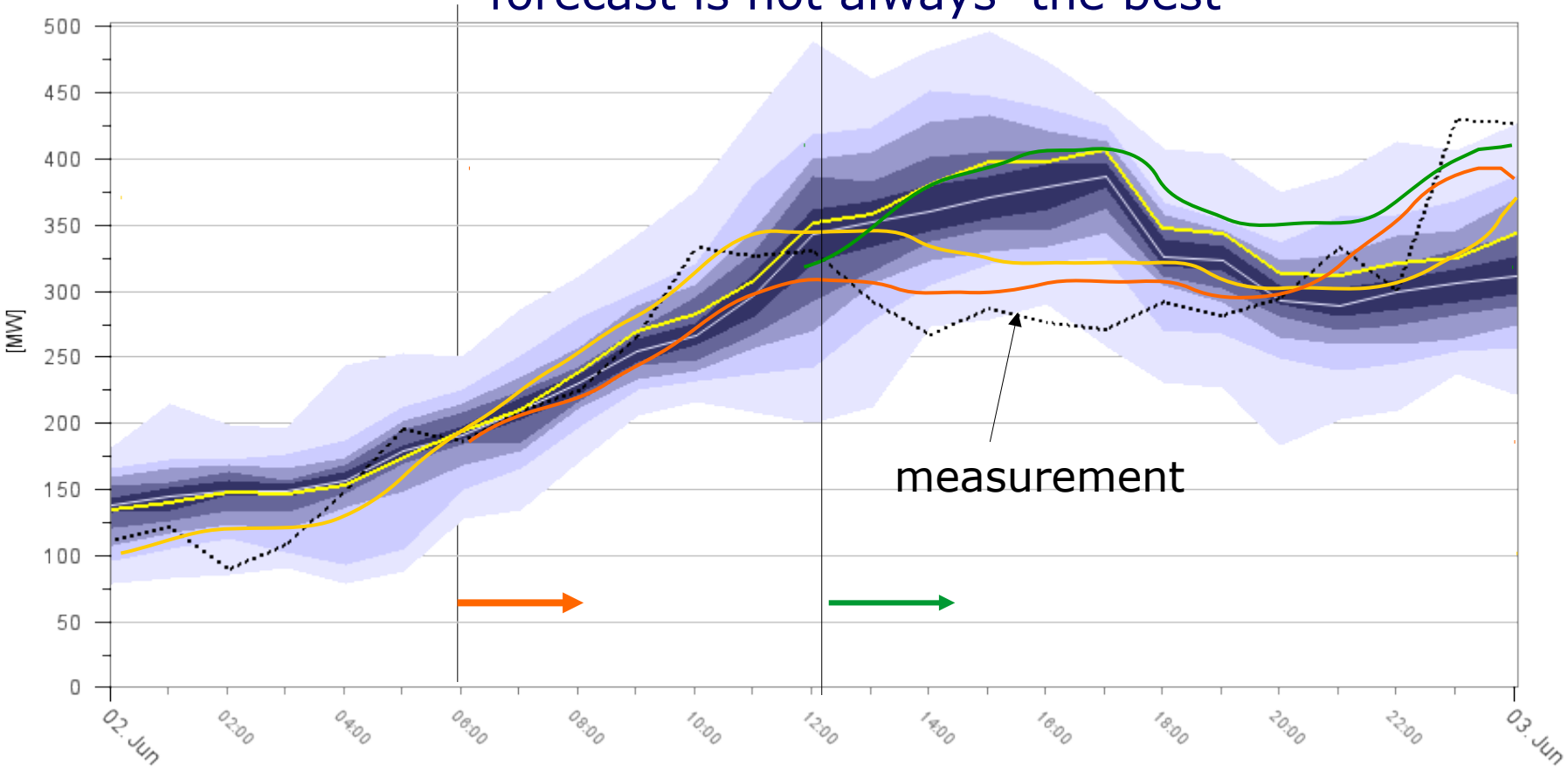
Action: Do nothing!

Case 4: Short-ahead forecast is lower than day-ahead, BUT lies within the uncertainty band of short-term forecast

Action: **Buy the volume between maximum short-term and day-ahead**

Thumb rule 1: decide objectively which forecast to trust

Forcasts change over time – the latest forecast is not always the best



Areas

- min – p10
- p10 – p20
- p20 – p30
- p30 – p40
- p40 – p50
- p50 – p60
- p60 – p70
- p70 – p80
- p80 – p90
- p90 – max

Lines

- min
- max
- measured

Last run's of LS-optim. fc:

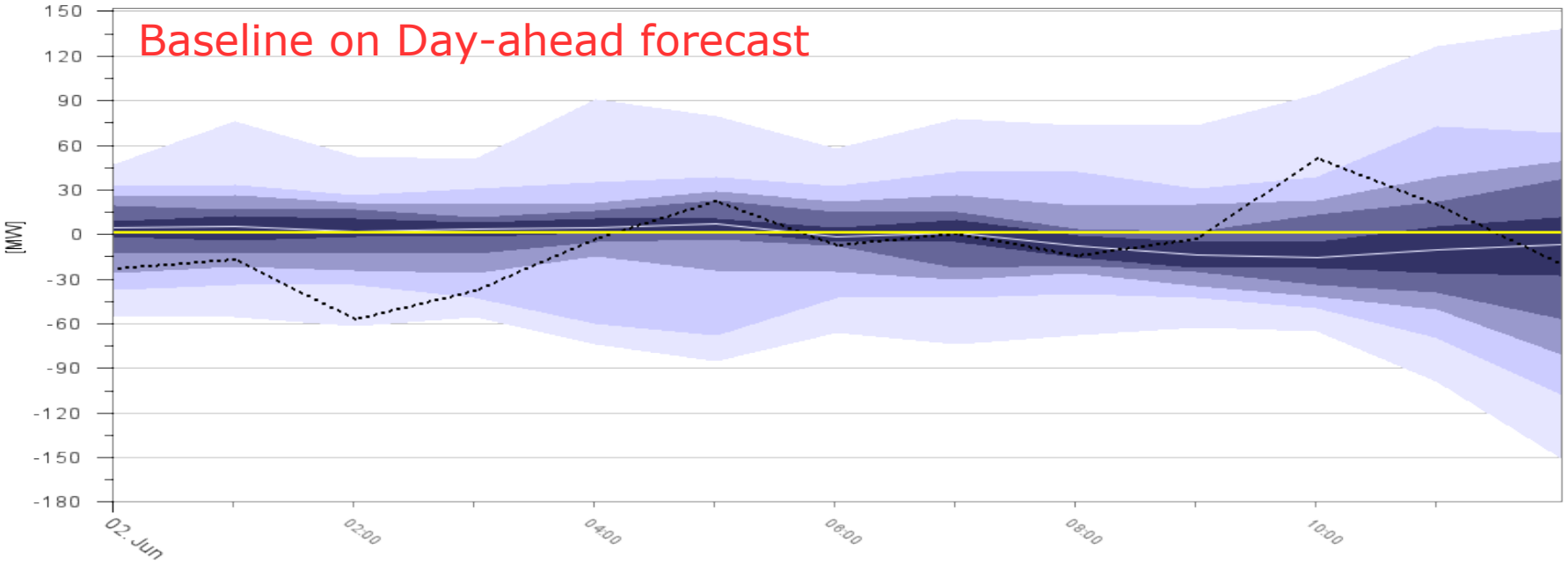
- FC1
- Fc2
- FC3
- FC4

Example: large difference and uncertainty between previous and latest forecasts, or between different providers

Solution:

Use physical uncertainty to make deterministic decisions decide objectively which forecast to trust/give high weight!

Thumb rule 2: a smooth forecast avoids double punishment and provides "opportunities"



Forecasts never really resemble the variability of measurements:
–> **makes it important to avoid double punishment !**

How to become a price maker in the market

What are the incentives to bid in with higher prices:

increase income

generate realistic prices that mirror the real costs

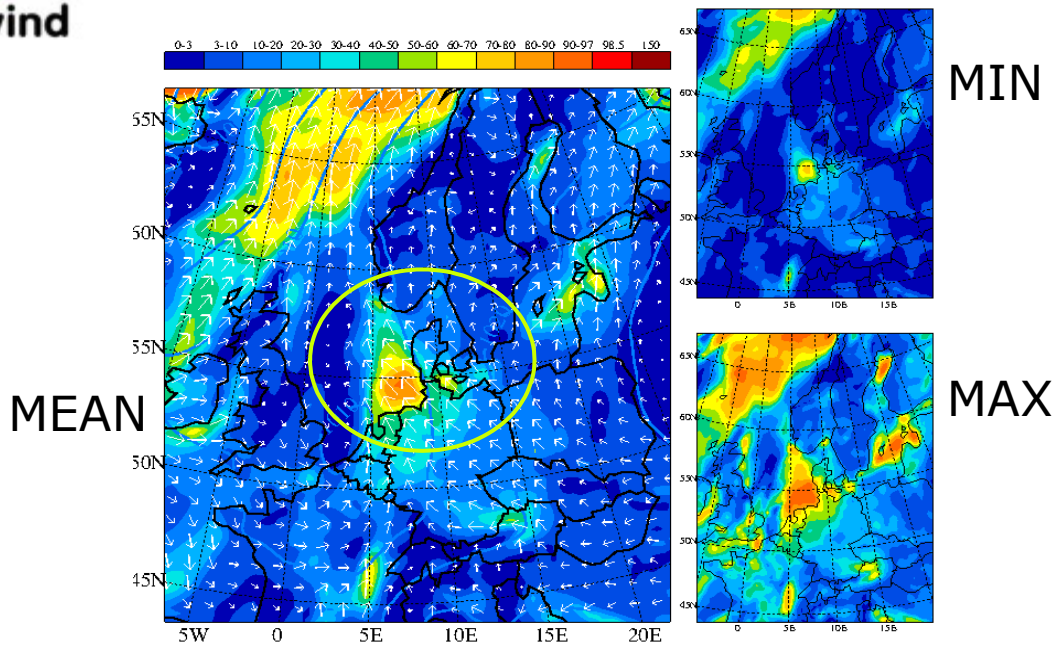
Renewables have a free resource, but also need maintenance!

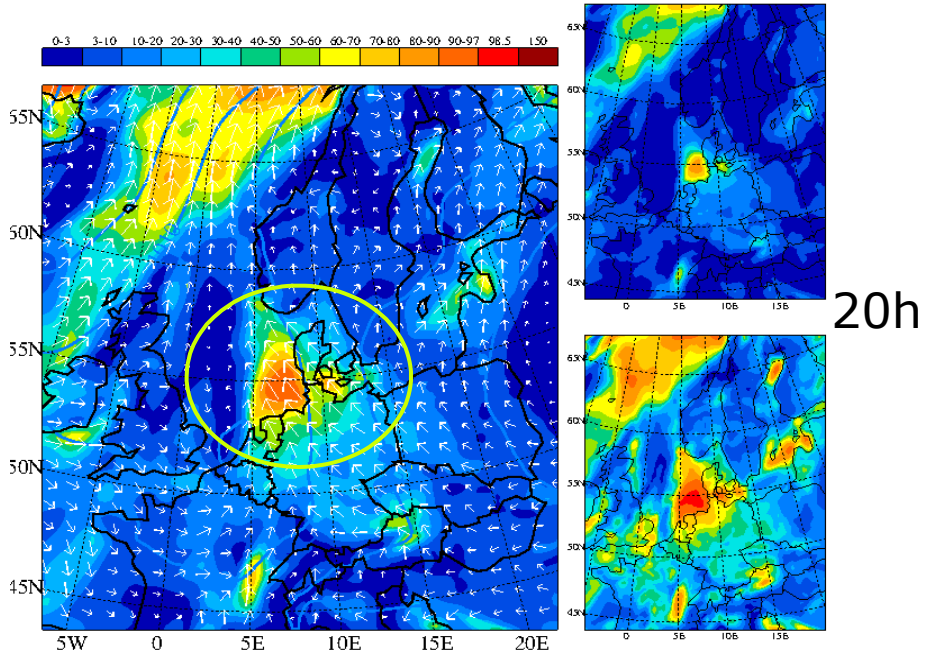
avoid negative prices in high-penetration situations

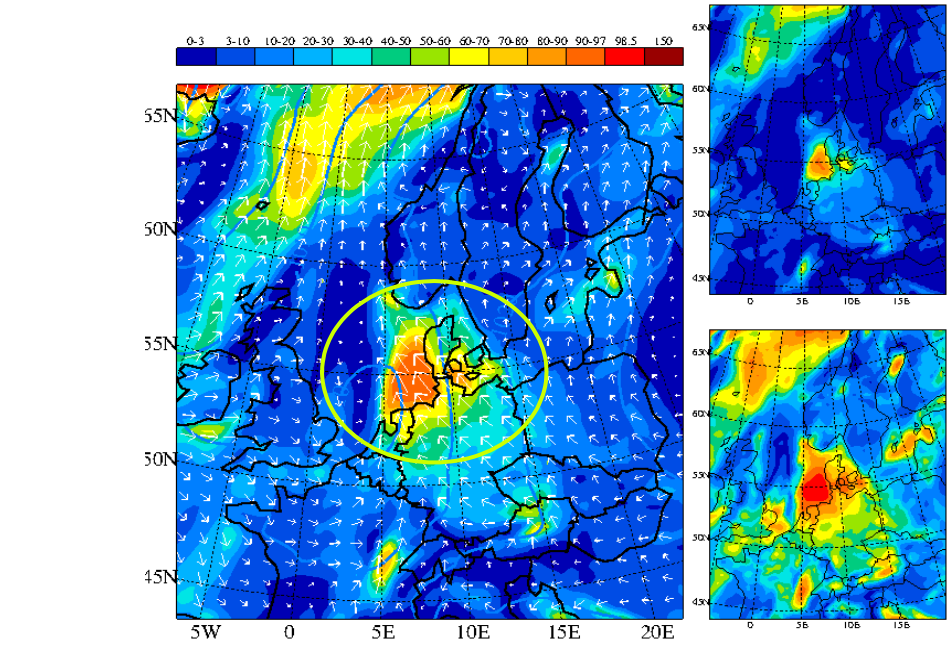
in case of expected shortage to level out higher intra-day prices

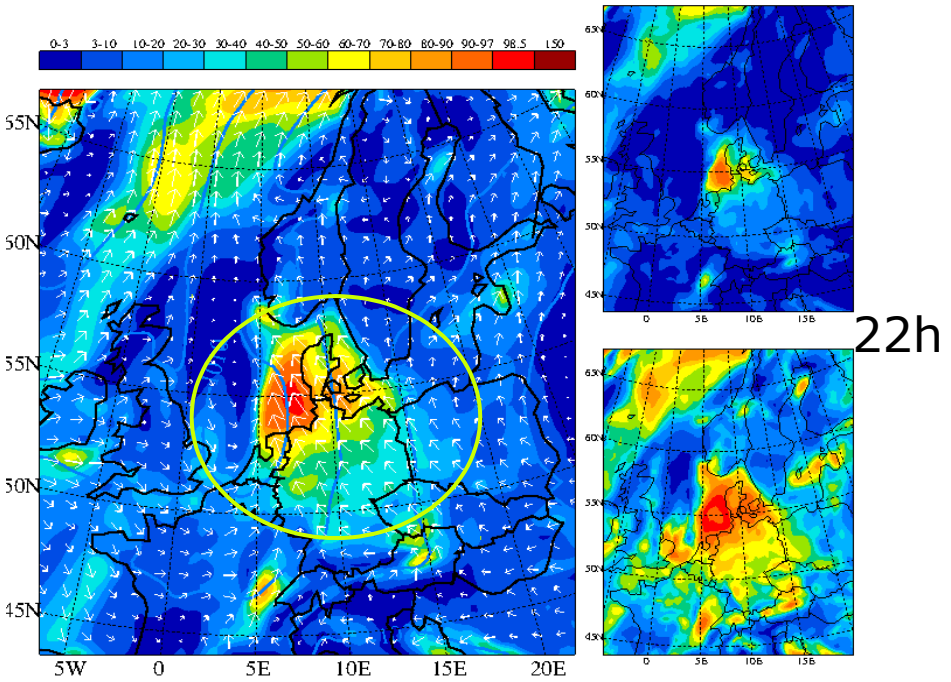
in case of expected surplus to be able to sell lower at intra-day

How to become a price maker : an example

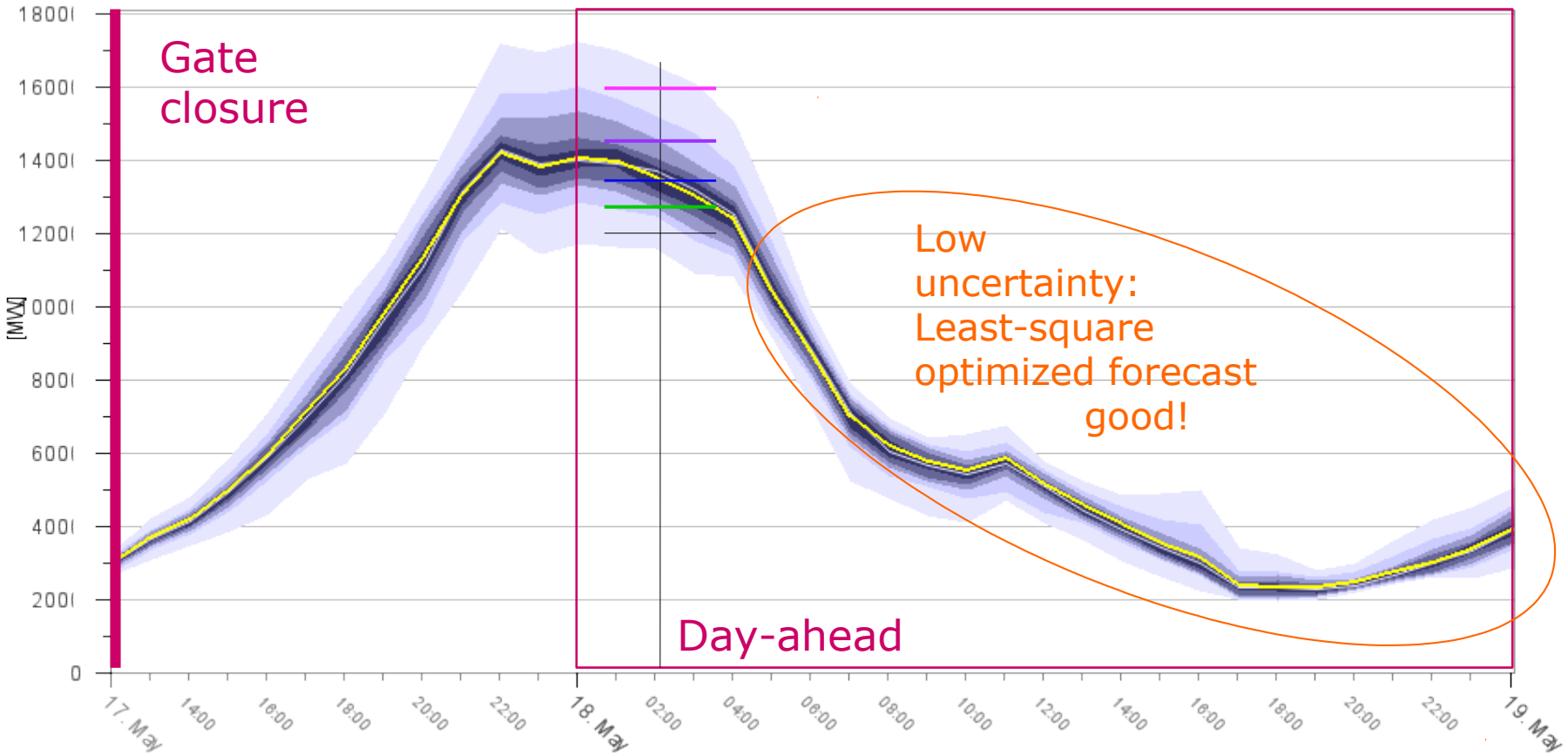








How to become a price maker in the market



Example of how to generate a price bid

Problem: risk for shortage or negative prices!

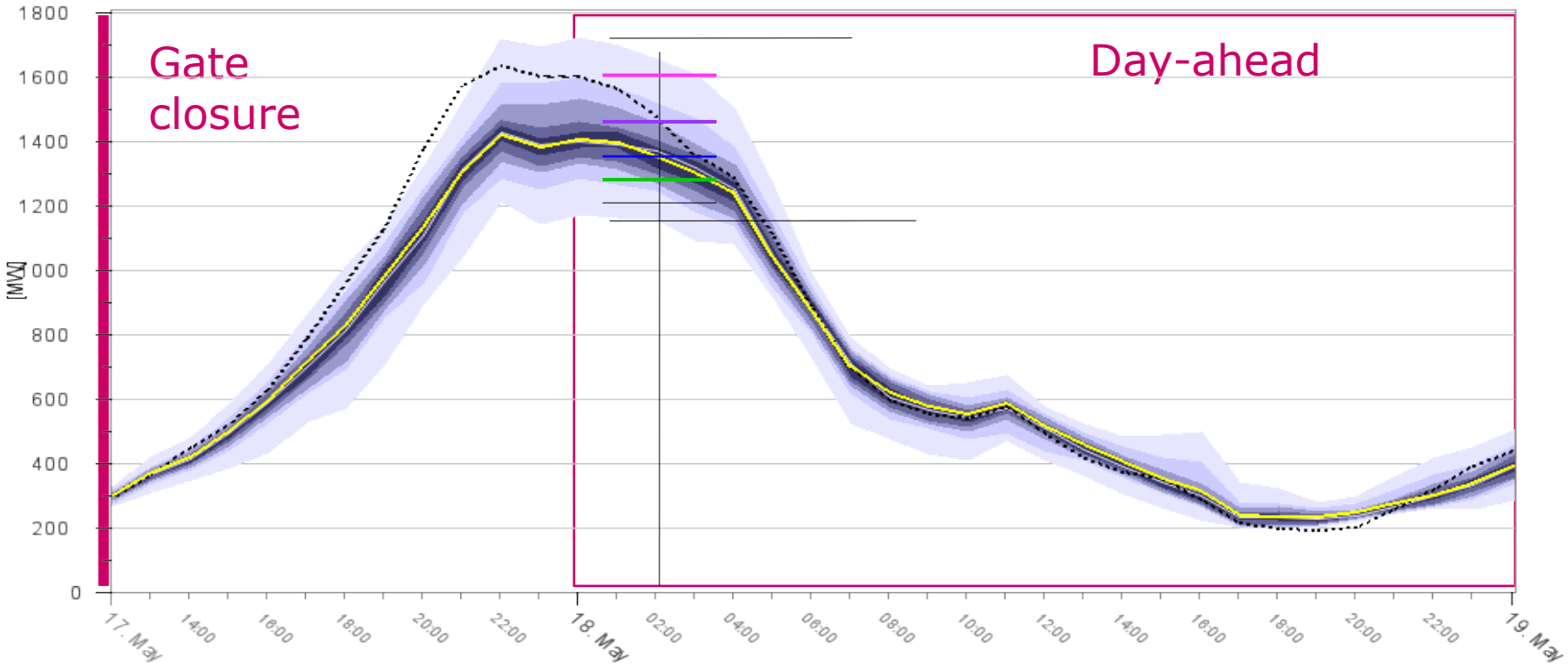
- My pool: 200 MW controllable power
- uncertainty (MAX-MIN): 450MW
- LS-optimised FC: 1200MW

=> strategy: bid safe and add some small risk volume for profit and balance

Example at hour 1:

Bid unlimited	1200MW
Bid price 1 (=0)	80MW
Bid price 2 (>0)	60MW
Bid price 3 (>>0)	40MW
Bid price 4 (>>>0)	20MW

How to become a price maker in the market



Example at hour 1:

Bid unlimited 1200MW → market price

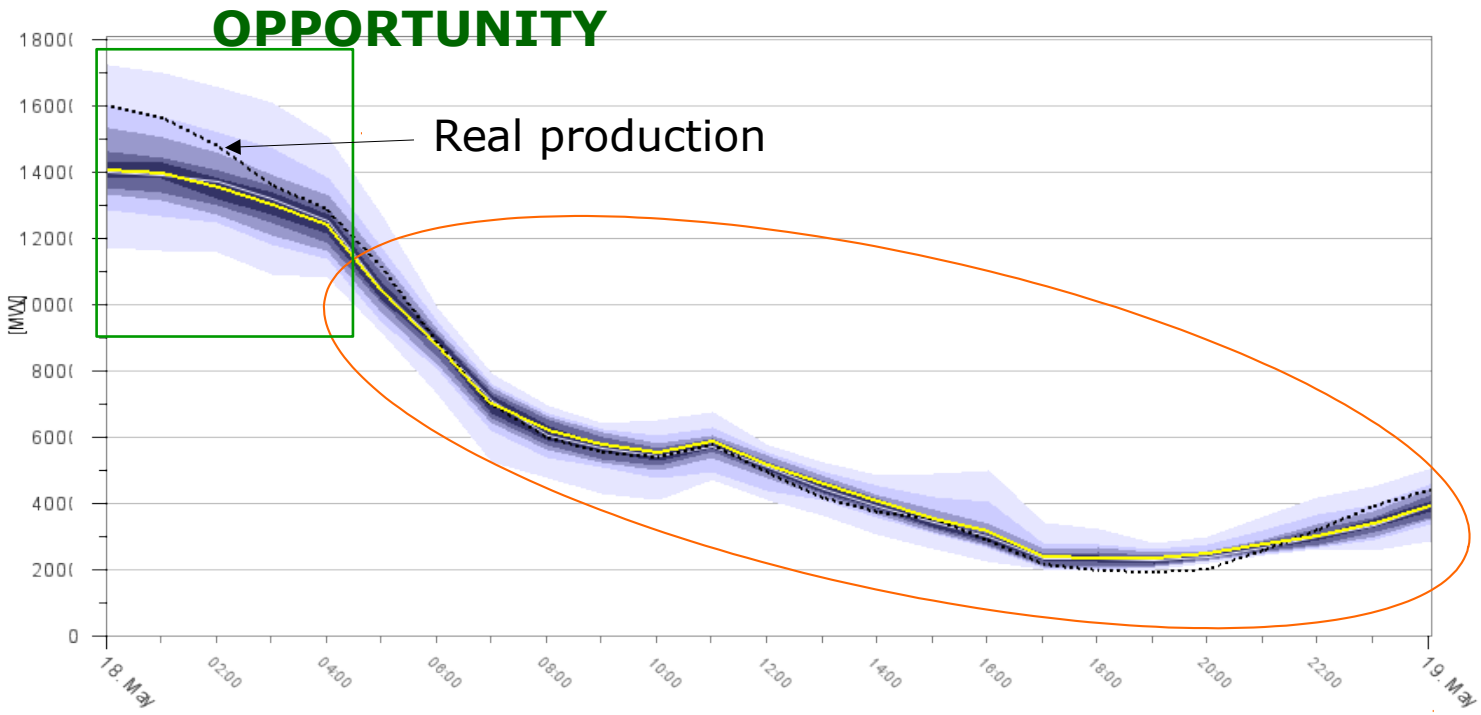
Bid price 1 (=0) 80MW → has to prevent negative prices

Bid price 2 (>0) 60MW → has helped increase the market price

Bid price 3 (>>0) 40MW → ...

Bid price 4 (>>>0) 20MW → did not get a contract || need to balance in intraday

How to become a price maker in the market



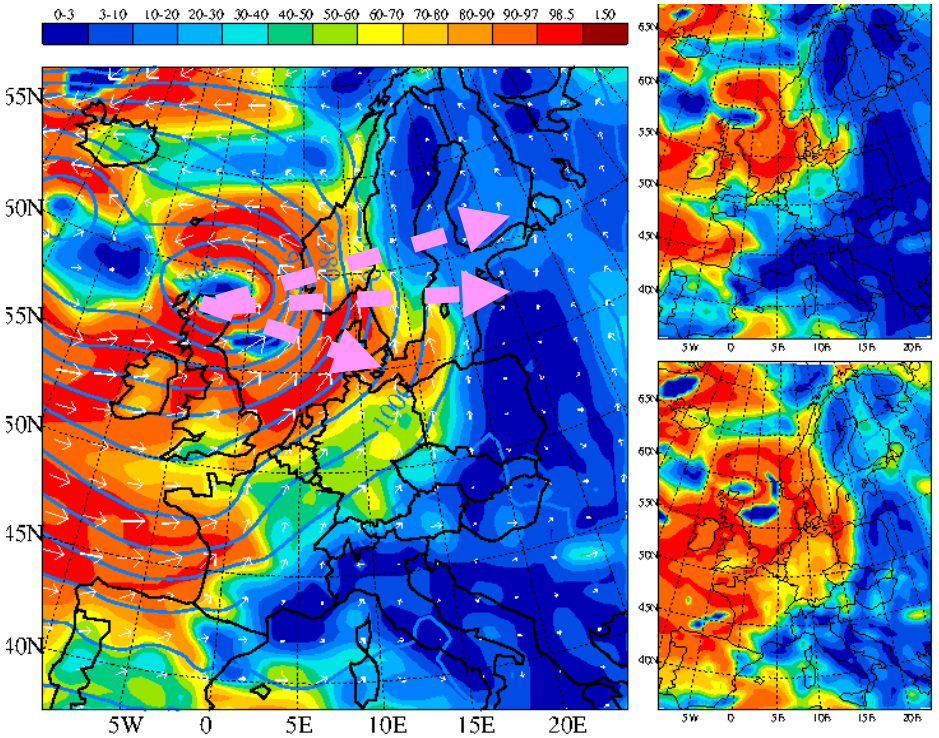
Low uncertainty:
Least-square optimized or
MEAN forecast good!

High uncertainty:
Opportunity to

- reduce imbalance costs
- increase income
- avoid negative prices

Date Hour	18. May 00:00	18. May 01:00	18. May 02:00	18. May 03:00	18. May 04:00	18. May 05:00	18. May 06:00	18. May 07:00	18. May 08:00	18. May 09:00	18. May 10:00	18. May 11:00	18. May 12:00
Min [MW]	1167	1158	1154	1086	1079	911	726	523	475	427	406	470	405
p10 [MW]	1281	1262	1245	1178	1137	948	802	617	538	506	472	495	435
p20 [MW]	1330	1310	1271	1205	1160	975	817	639	561	521	498	538	476
p30 [MW]	1350	1334	1295	1245	1184	1002	843	657	572	532	514	553	489
p40 [MW]	1376	1378	1316	1269	1211	1014	868	671	586	552	525	565	497
p50 [MW]	1398	1390	1367	1317	1248	1040	**881**	**707**	**604**	**564**	**540**	**571**	**508**
p60 [MW]	1426	1427	1379	1334	1270	1058	896	721	629	573	555	580	513
p70 [MW]	**1459**	**1442**	**1403**	**1354**	**1286**	**1086**	903	732	648	596	565	592	522
p80 [MW]	1531	1503	1457	1389	1324	1126	918	743	659	612	578	604	540
p90 [MW]	1598	1562	1517	1470	1379	1164	939	756	671	622	603	625	549
Max [MW]	1721	1699	1657	1607	1502	1267	985	788	691	640	651	672	576
DA-FC [MW]	1403	1391	1350	1296	1238	1039	873	699	618	574	552	581	513
Measurement	1596	1558	1473	1355	1284	1113	886	691	591	548	537	573	488

Thumb rules for Trading in DK-NO-SE and DE-AT



Meteorologically insignificant small differences in path of low pressure system **impact market price!**

Key factors to consider in any strategy:
- system imbalance
- negative prices
- curtailment

North of Denmark: too much wind → **risk of negative prices**

South Sweden: no production → **high imbalance (cost)**

Baltics: congestion from high northsea offshore production
→ system imbalance high (reserve costs) & **risk of curtailment**