Trading of Pumped Hydro Storages in ID Markets

Continuous Optimization – ID Price Forecasts – Market Insights

Strommarkttreffen
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Introduction

- Education
  - Studied Industrial Engineering at KIT (Karlsruhe/Germany)
  - Project Management at NTNU (Trondheim/Norway)
  - Ph.D. *Hydro Power Storage Optimization and Trading Considering Short-Term Electricity Markets* at TUM (Munich/Germany)
- Work experience
  - ICIS Senior Analyst – Power Markets (Karlsruhe/Germany)
  - EnBW Trading and Asset Optimization (Karlsruhe/Germany)
  - EnBW Risk Management of RES (Istanbul/Turkey)
  - DLR on Concentrated Solar Power (Almeria/Spain)
- Free Time
  - Ski touring
  - Running

Structure Presentation Strommarkttreffen

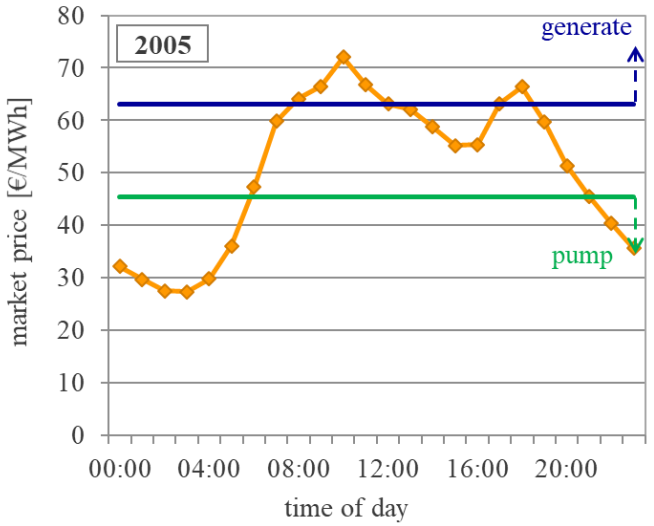
- Motivation to revise the pumped hydro power scheduling problem
- Challenges of continuously traded intraday markets
- Approach for pump storage optimization in intraday markets
- Continuous ID price forecast
- Trading strategies to exploit the spreads between ID high and low

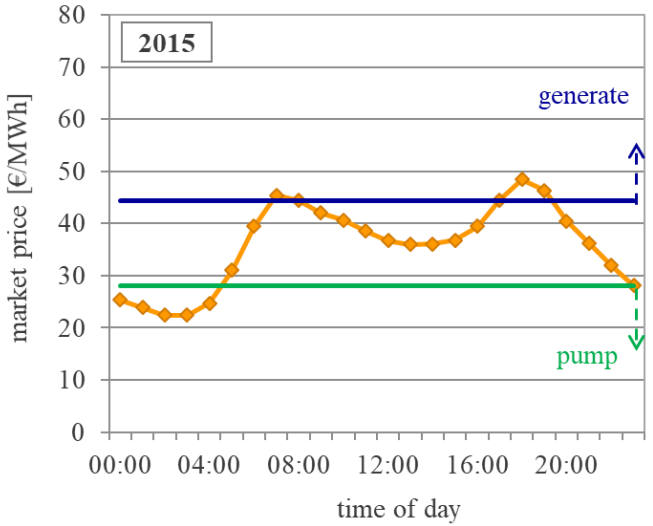
Lünersee

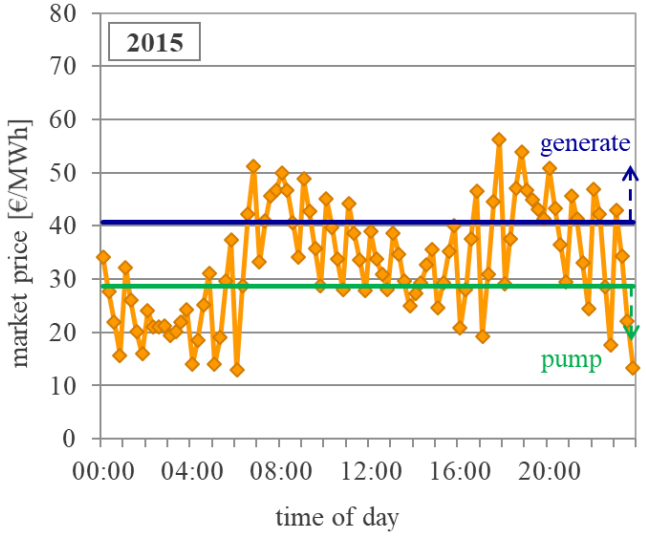
Latschau reservoir

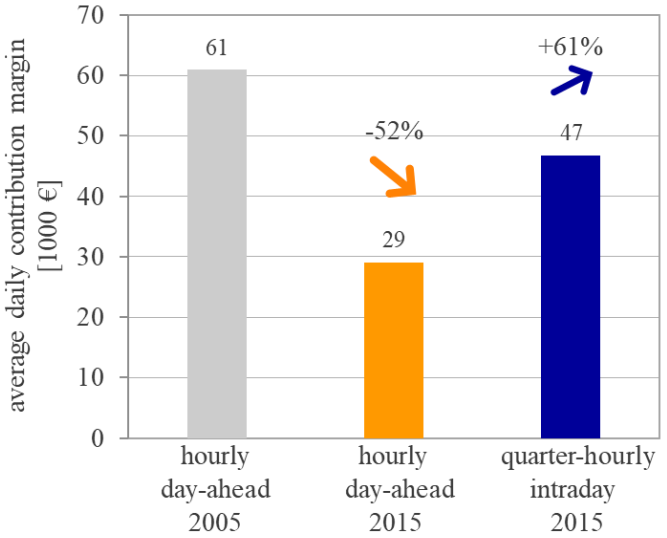
Lünersee machine

Motivation for Flexibilization of Pumped Storages









Comparison of the average hourly day-head auction price from Monday to Friday in 2005 with 2015 and the average quarter-hourly intraday price from Monday to Friday in 2015, data derived from EPEX Spot (2017)

Example: 500MW pumped hydro storage with efficiency of 80% and grid charges of 4€/MWh,

2005 on average:
- spread: 32.21 EUR
- pumping: 9 hours
- generating: 7 hours

2015 on average:
- spread: 21.34 EUR
- pumping: 6 hours
- generating: 5 hours

2015 (qh) on average:
- spread: 21.34 EUR
- pumping: 9 hours
- generating: 7 hours

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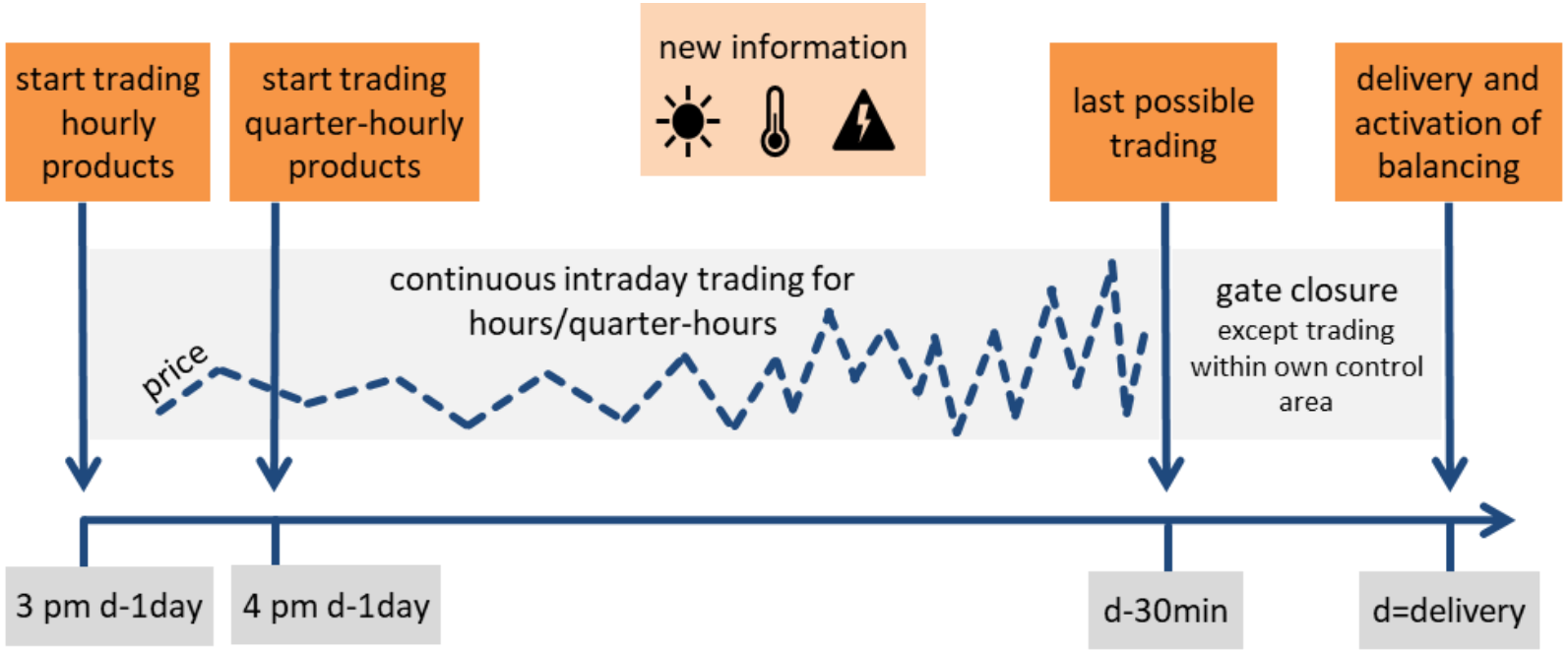
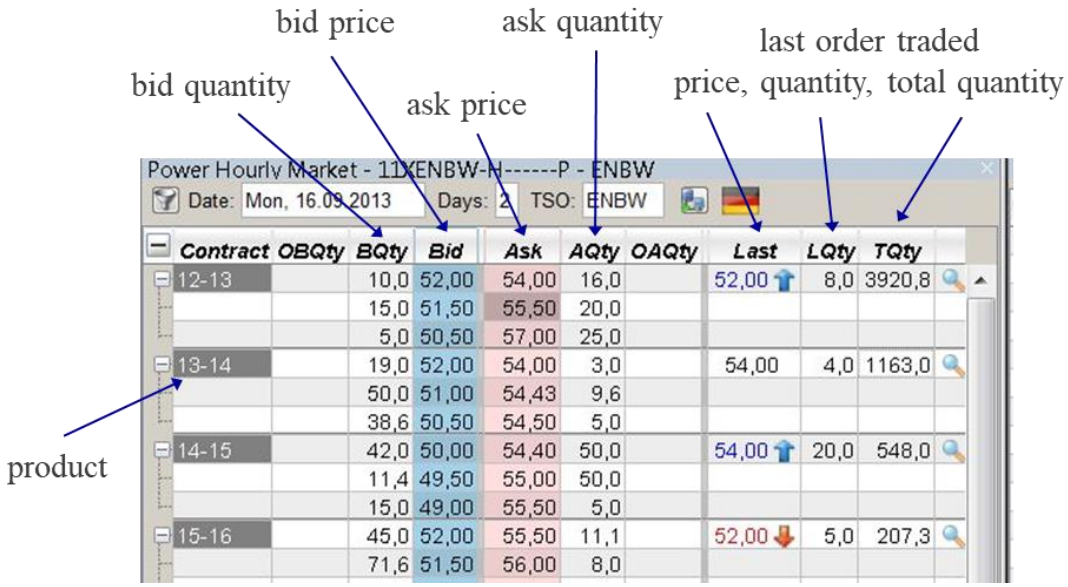
Intraday Trading



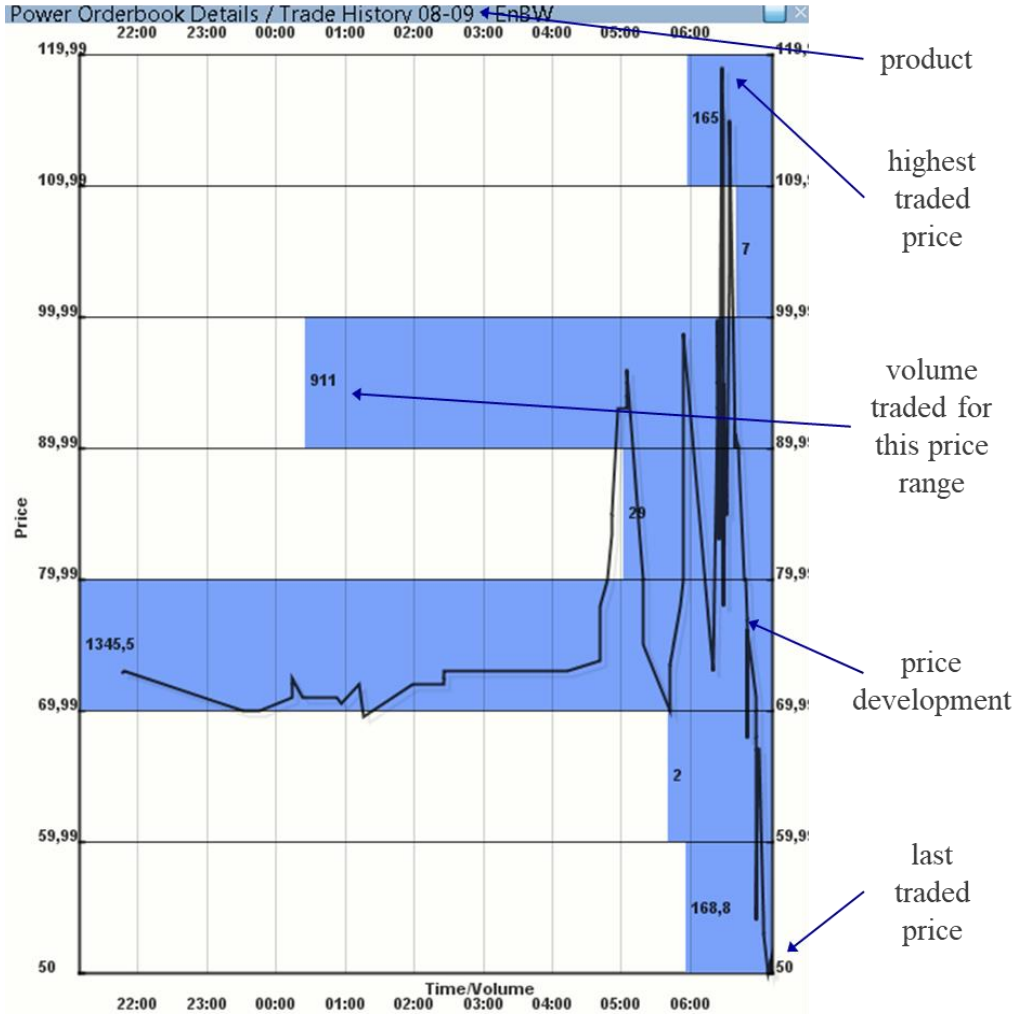
Source: Dissertation Sebastian Braun

Intraday Screen



Contract	OBQty	BQty	Bid	Ask	AQty	OAQty	Last	LQty	TQty
12-13		10,0	52,00	54,00	16,0		52,00	8,0	3920,8
		15,0	51,50	55,50	20,0				
		5,0	50,50	57,00	25,0				
13-14		19,0	52,00	54,00	3,0		54,00	4,0	1163,0
		50,0	51,00	54,43	9,6				
		38,6	50,50	54,50	5,0				
14-15		42,0	50,00	54,40	50,0		54,00	20,0	548,0
		11,4	49,50	55,00	50,0				
		15,0	49,00	55,50	5,0				
15-16		45,0	52,00	55,50	11,1		52,00	5,0	207,3
		71,6	51,50	56,00	8,0				

Screenshot of an exemplary intraday orderbook from September 16th, 2013 at 11 am including some explanations



Screenshot of the price development for one product on the continuous intraday market from September 16th, 2013 at 7 am including some explanations

General Optimization Problem

- Minimize the costs for a specific period of time

$$\min_x \sum_{u,t} c_{u,t}(x_{u,t})$$

- The load need to be covered at all time

s.t. $\sum_u x_{u,t} = l_t \quad \forall t$

- Reservoir balancing equation

$$SQ_{s,t} = SQ_{s,t-1} + SQinflow_{s,t} - SV_{s,t} - x_u + x_u \quad u \in turbines/pump, \forall t, s$$

- Ramp-up and -down gradient

$$|x_{u,t} - x_{u,t-1}| \leq gmax_{u,t} \quad \forall u, t$$

- Min and max production power

$$pmin_{u,t} \leq x_{u,t} \leq pmax_{u,t} \quad \forall u, t$$

- Max storage filling level

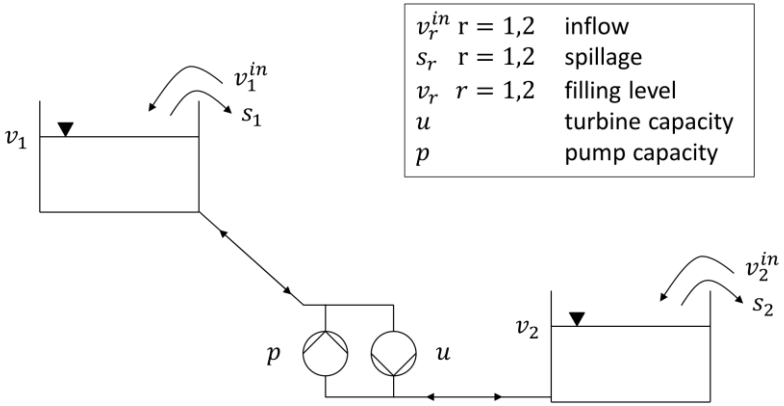
$$0 \leq SQ_{s,t} \leq SQmax_s \quad \forall t, s$$

- Start and End filling levels

$$SQ_{s.t=0} = SQstart_s \quad \forall t, s$$

$$SQ_{s,t=T} = SQend_s \quad \forall s$$

Wehr Oberbecken

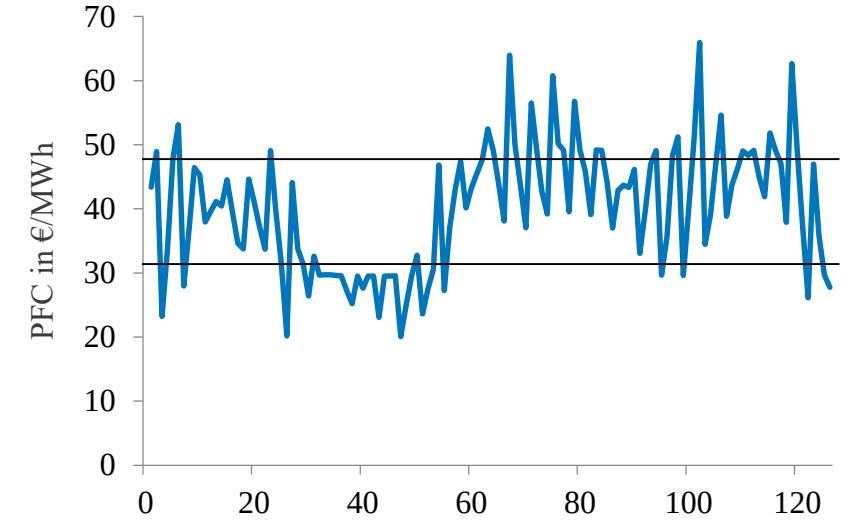


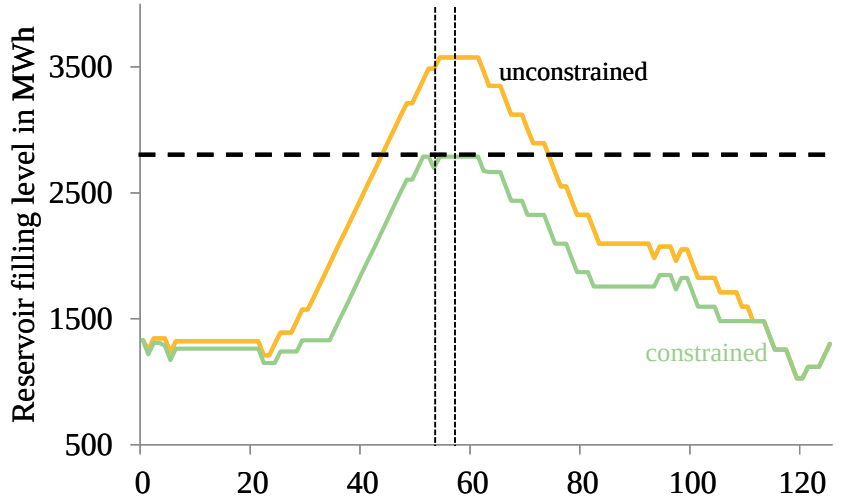
Wehr Unterbecken

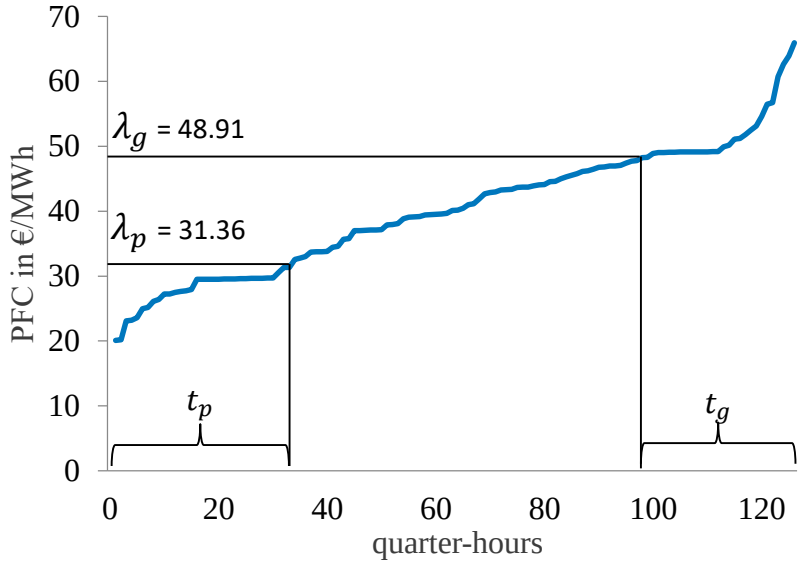
Challenges

- Optimization not quick enough for ID
- Shadow price steering difficult for daily pumped hydro storages
- Connection between **dual variable** – **water value** – **shadow price** not always clear
- How much water should be released at the level of the shadow price?
- How to consider order book data?

Intraday Algorithm for Pumped Hydro Power Storages





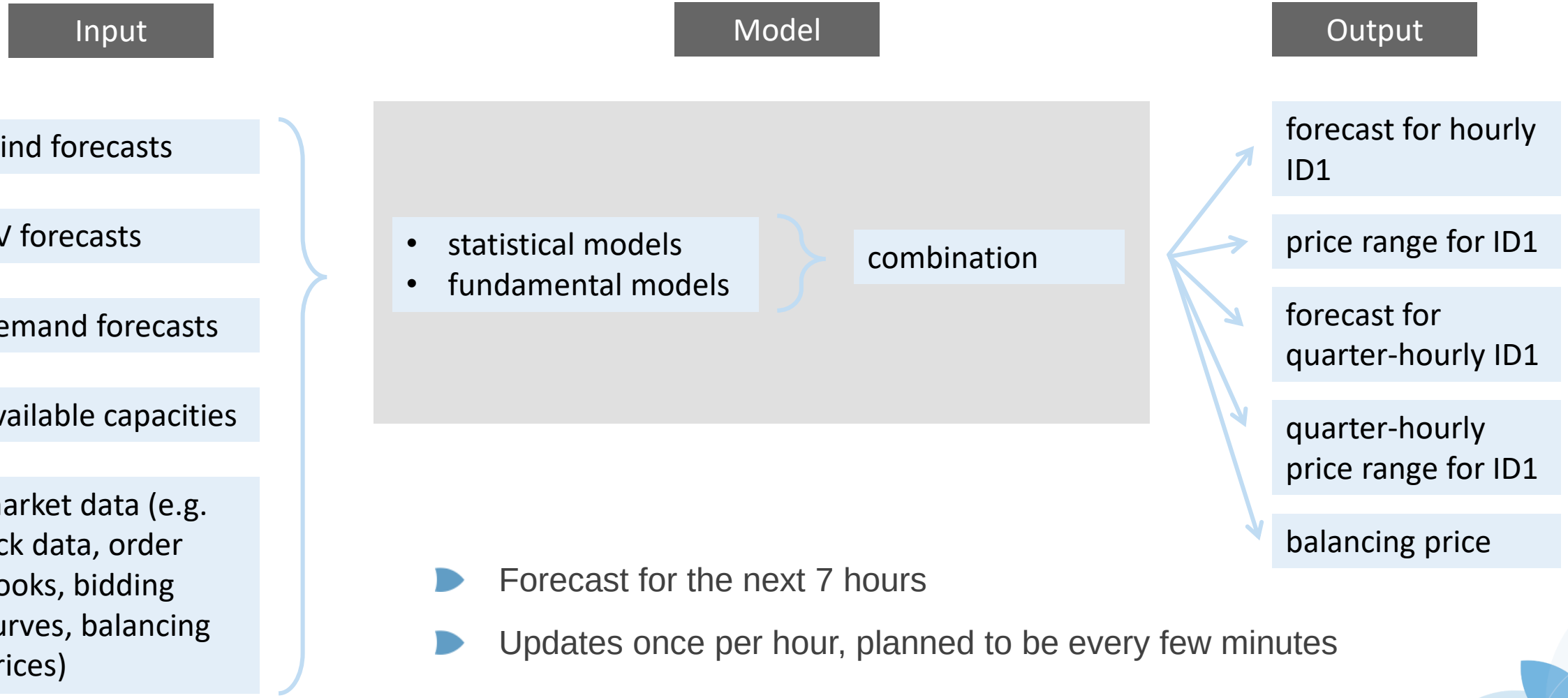


Time in quarter-hours	**Pumping** Marginal Cost in €/MWh	**Generating** Marginal Cost in €/MWh
[0-52]	29.56	47.82
[53-55]	27.26	46.82
[56-126]	29.68	49.13

How to get a price forecast for the intraday market

- Which price fits for the optimization?
  - VWAP (Volume Weighted Intraday Average Price)
  - Last trade for each product
  - Average of the first orders in the order book (two prices for bid and ask side?)
  - Price forecast
- At that time we calculated the VWAP of the last trades for each our in the future. In case there were no deals we used the results of the Intraday Auction

ICIS Continuous Intraday Forecast

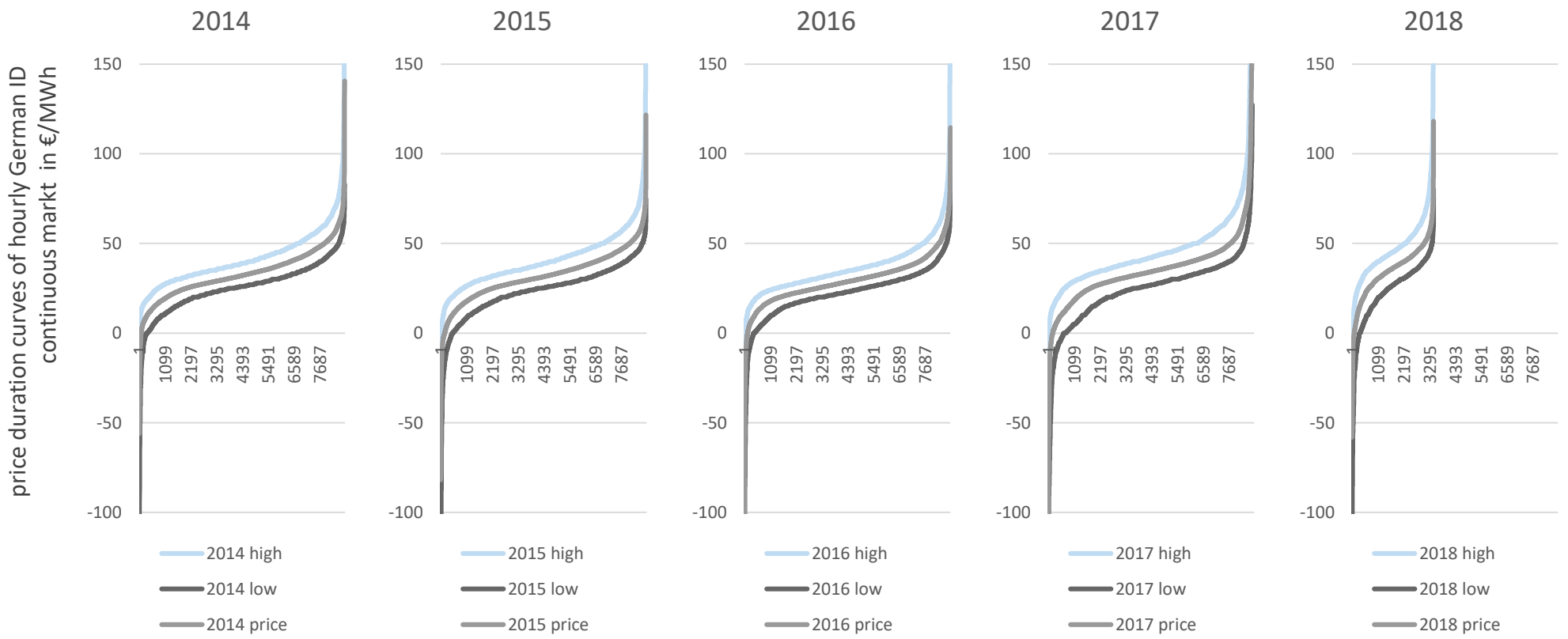


- Forecast for the next 7 hours
- Updates once per hour, planned to be every few minutes

Intraday Forecast

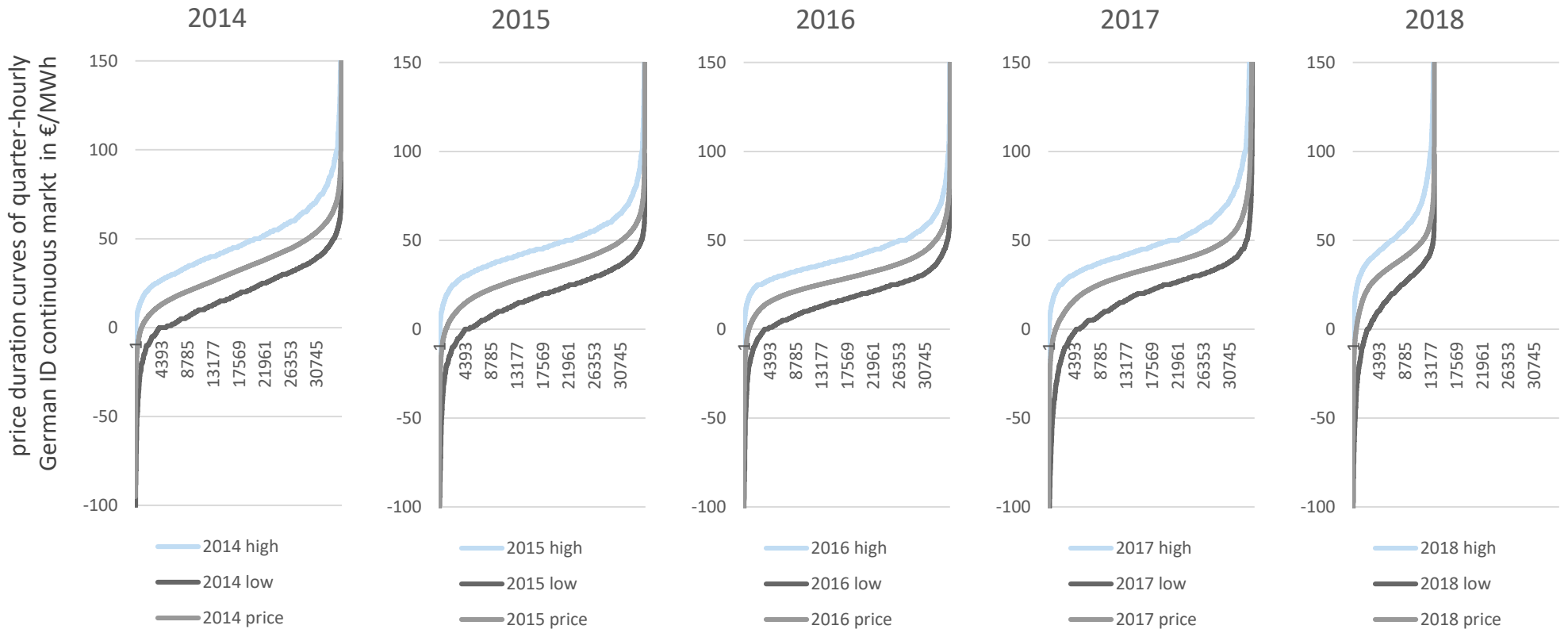
Intraday Forecast

Hourly ID Price Distribution



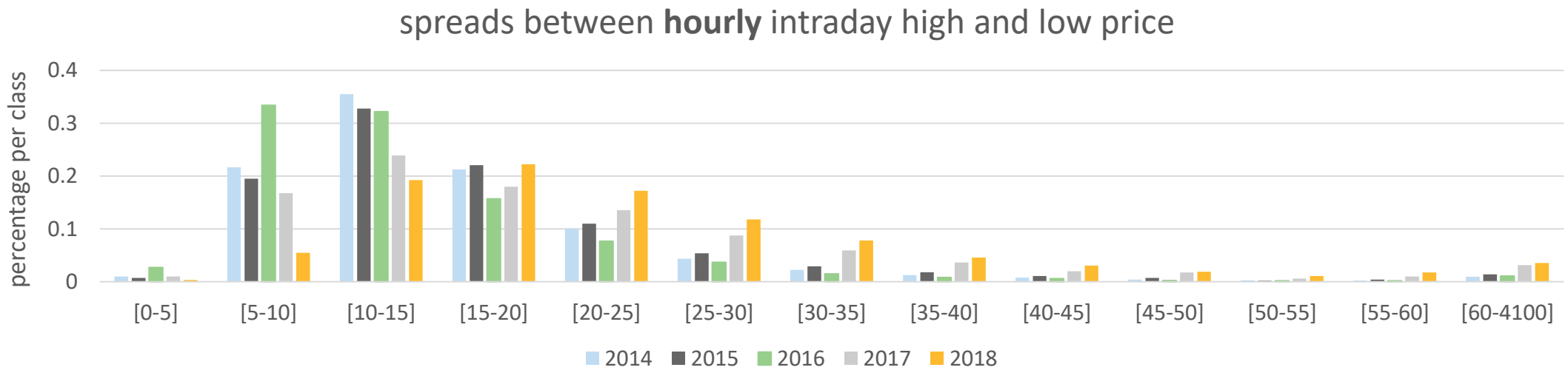
Average spread between ID high and low in €/MWh	16.41	17.95	14.93	22.79	25.25

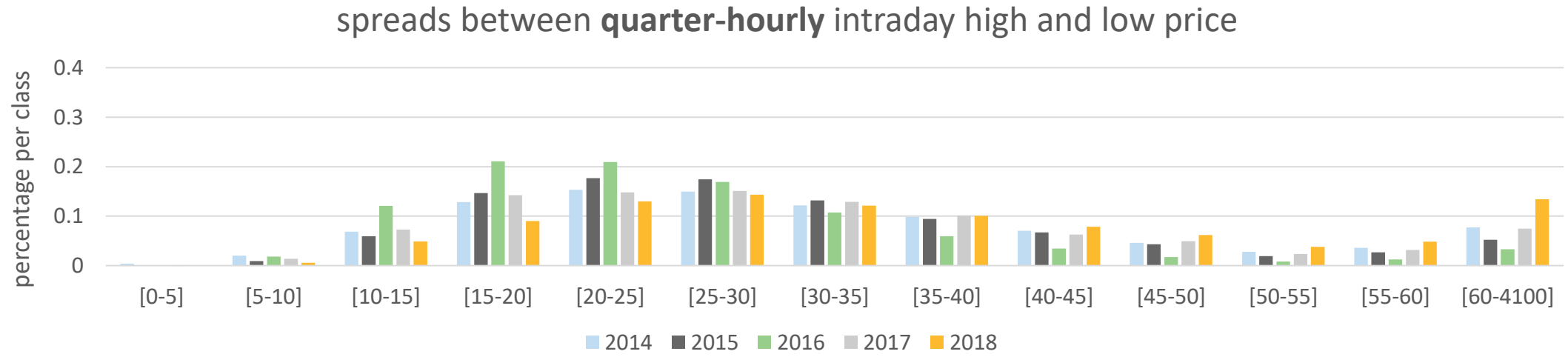
Quarter-Hourly ID Price Distribution



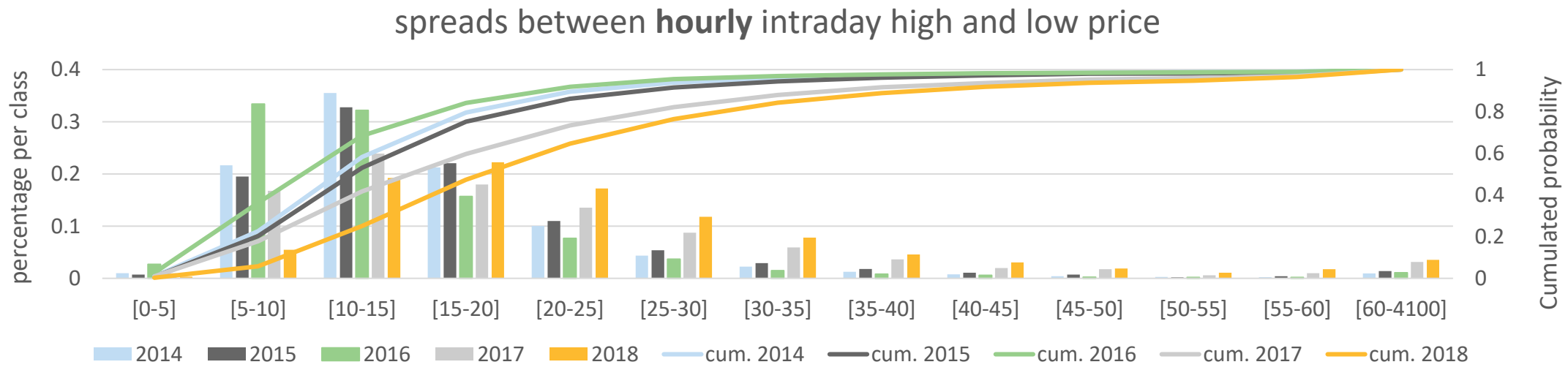
Average spread between ID high and low in €/MWh	30.67	31.05	26.91	35.61	41.05

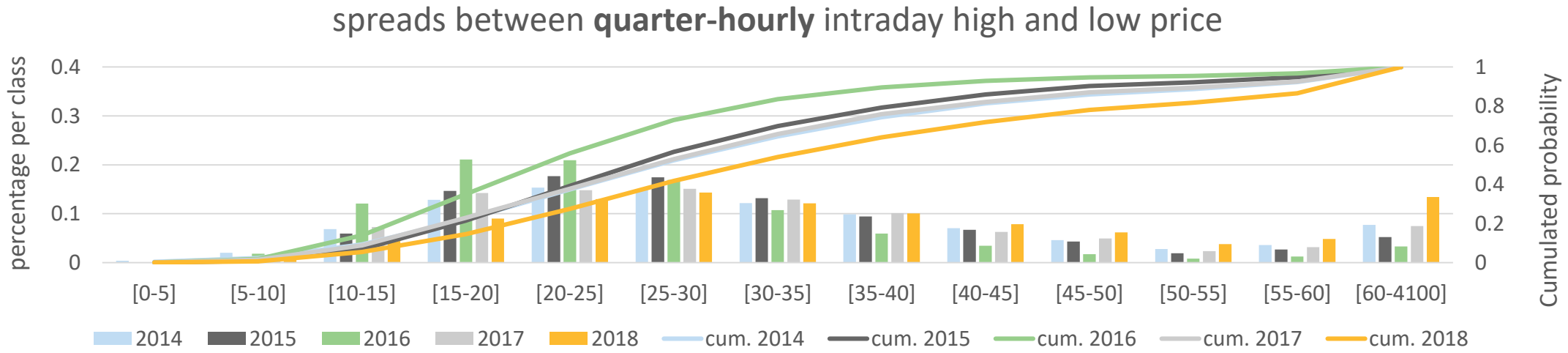
Development of ID Price Spreads



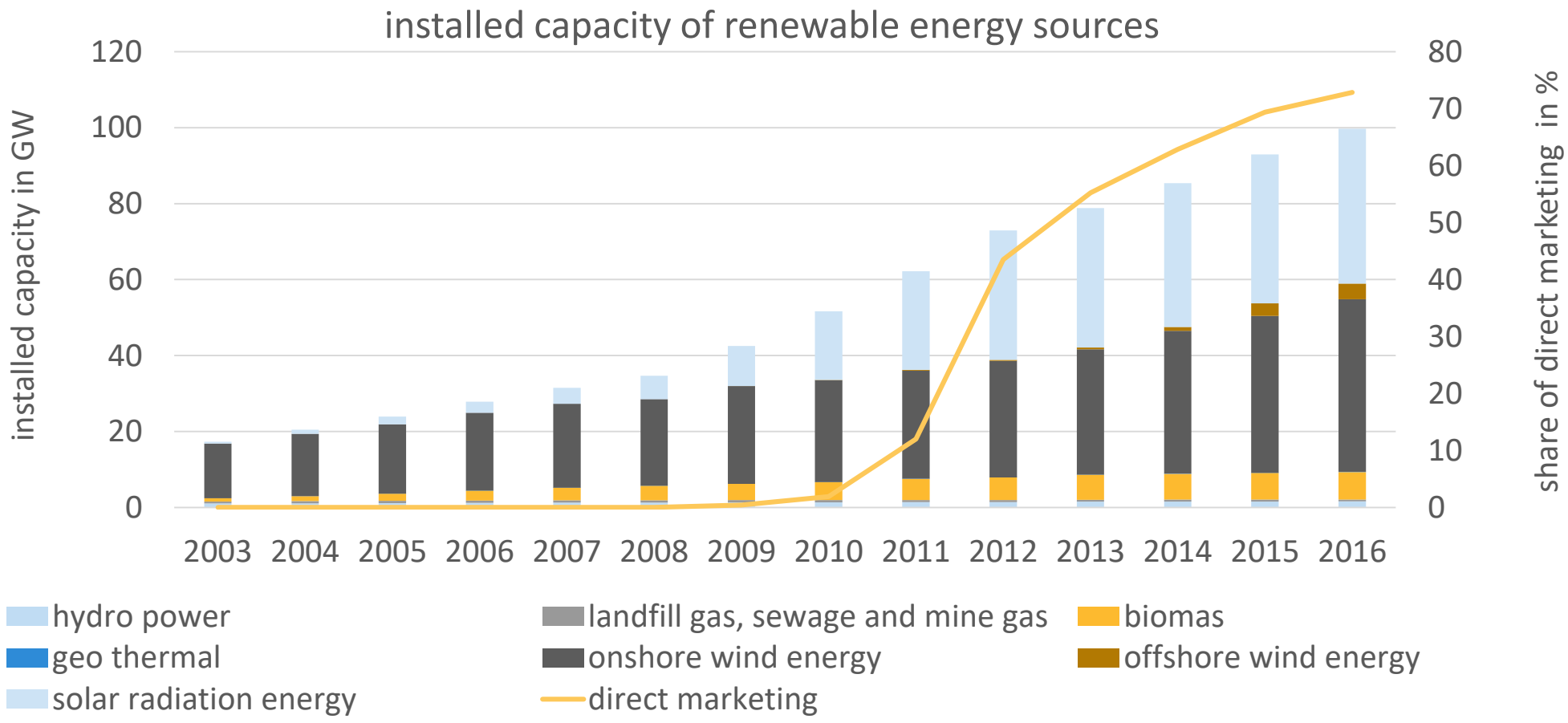


Development of ID Price Spreads

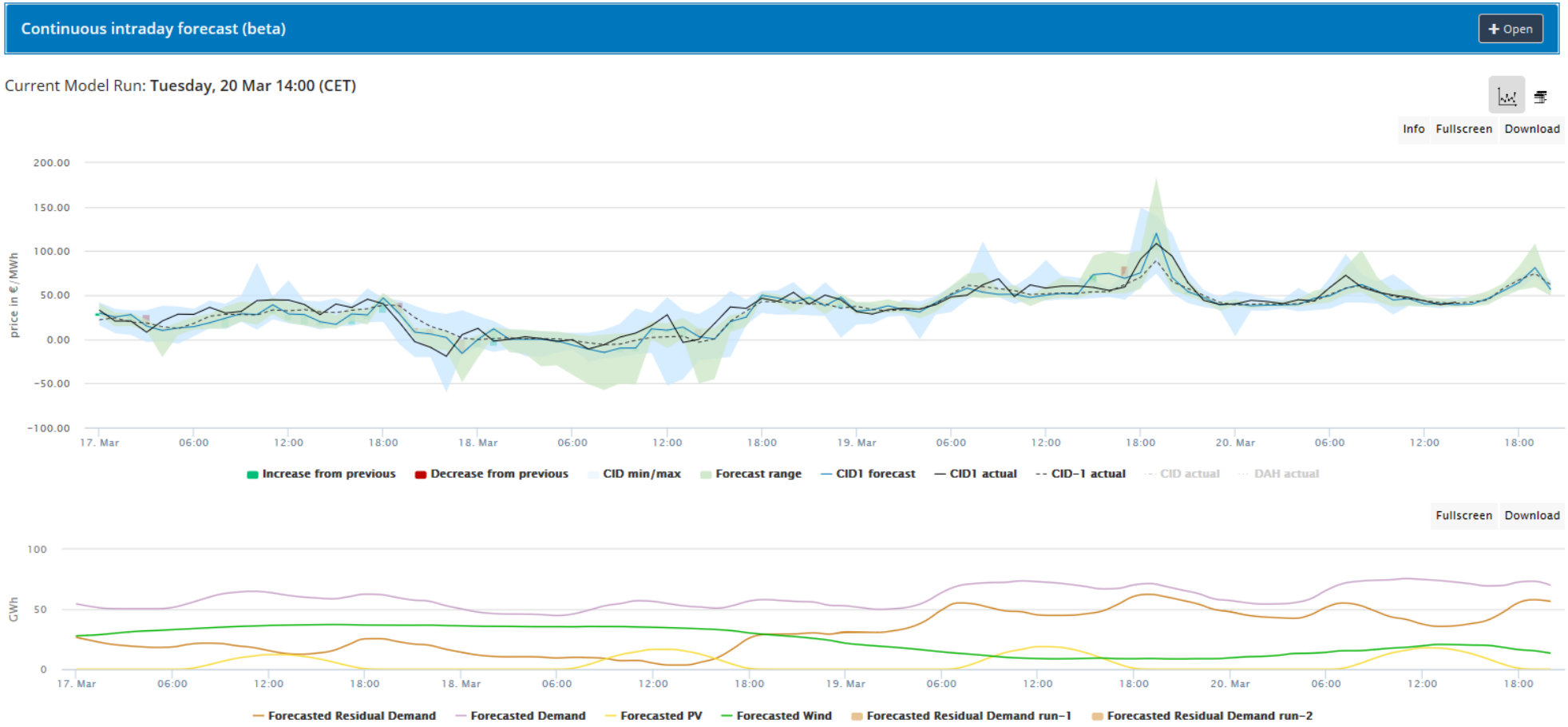




Growth of RES Production and Trading



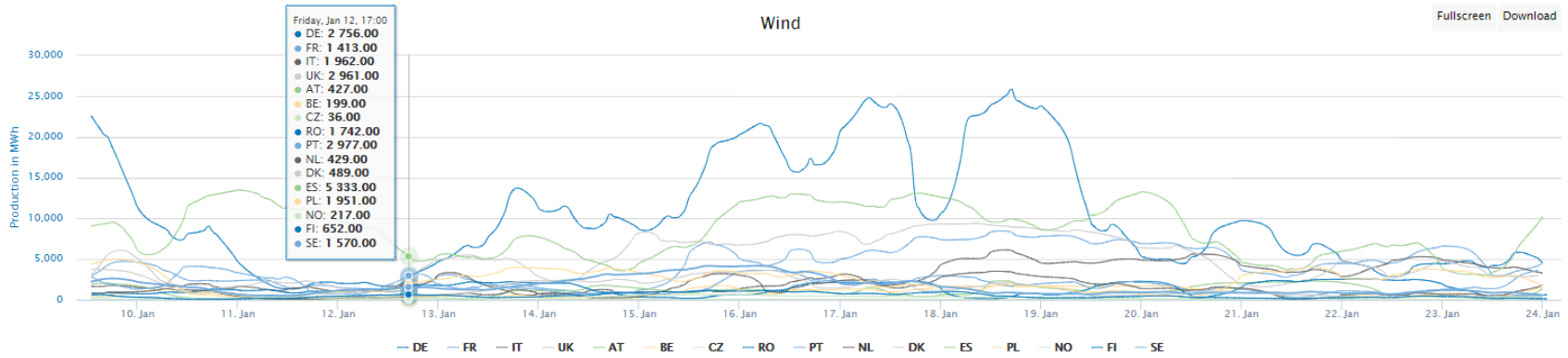
Intraday Forecast

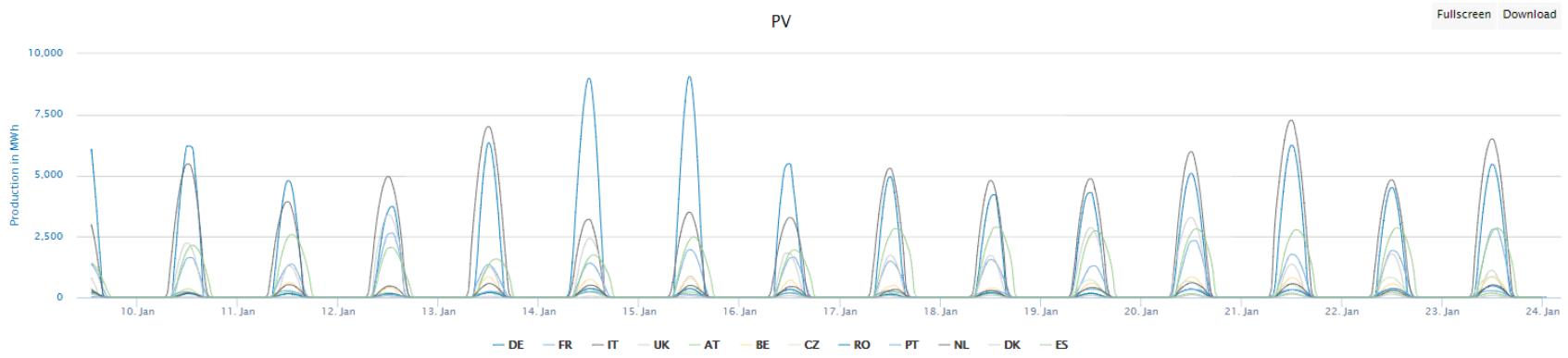


Renewable Production

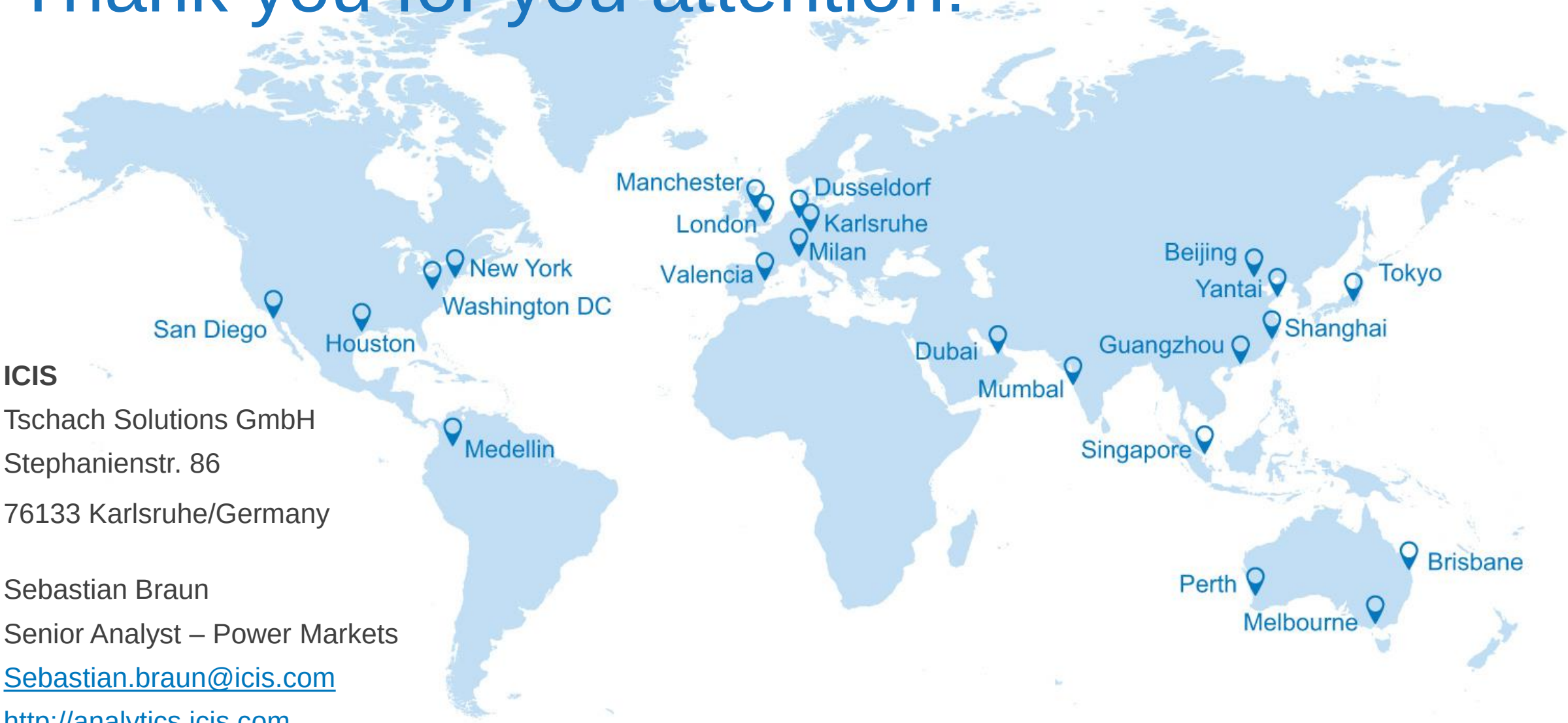
As part of our daily model runs, we are estimating the **expected wind and solar power feed-in** into Europe's power markets over the next days.
Shown results are updated four times a day. By default, latest complete modelrun displayed. Select currently calculated run in dropdown.

Modelrun 2018-01-09 00:00:00 ▼ Update





Thank you for you attention!



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