

Working to create a world powered by renewable energy

Bridging The Gap

**Validation of pre-construction wind farm
modelling against operational data**

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We offer our clients services across the full lifecycle of **renewable energy** projects.

We advise on, plan, engineer, analyse and manage their assets and the environment.

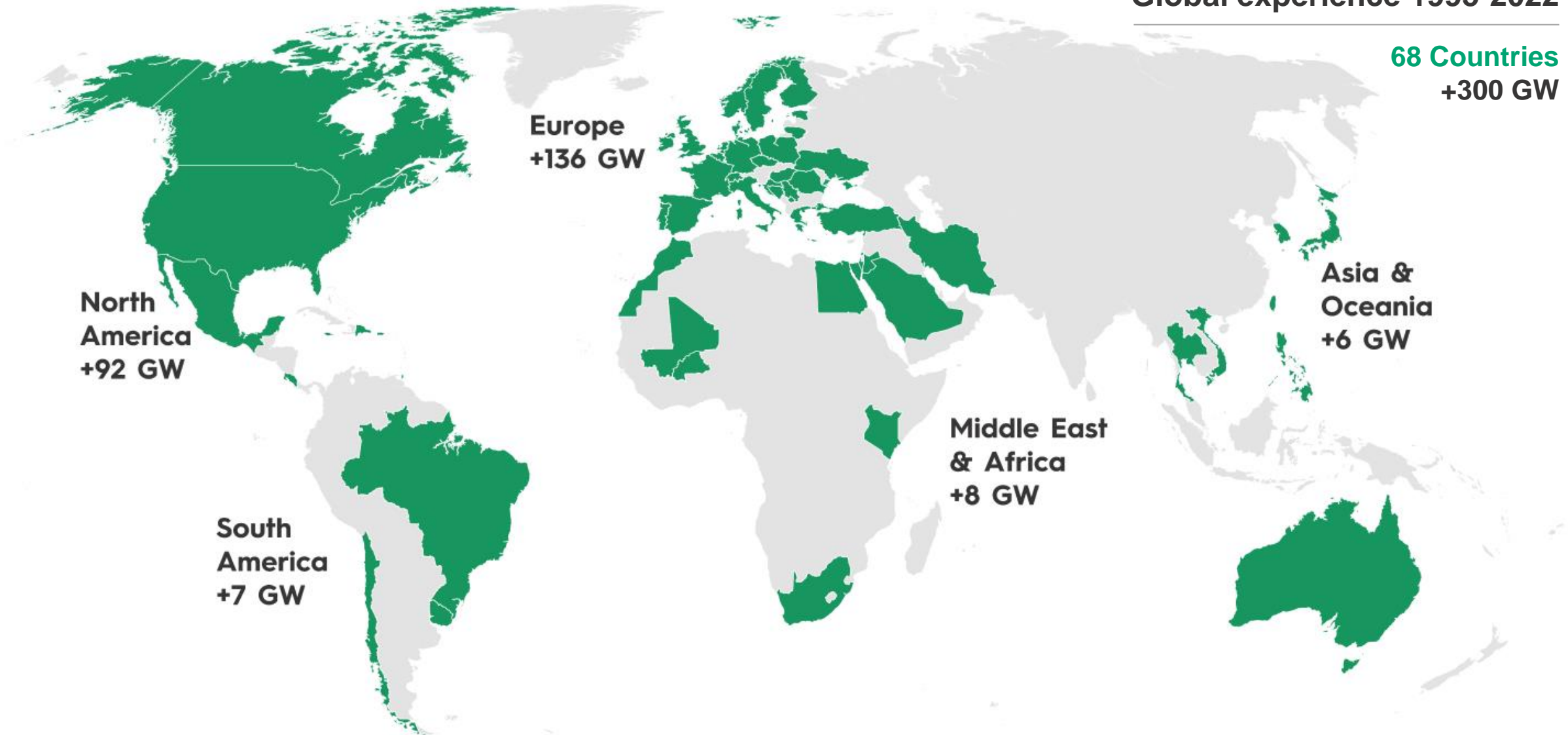


Global reach, local expertise



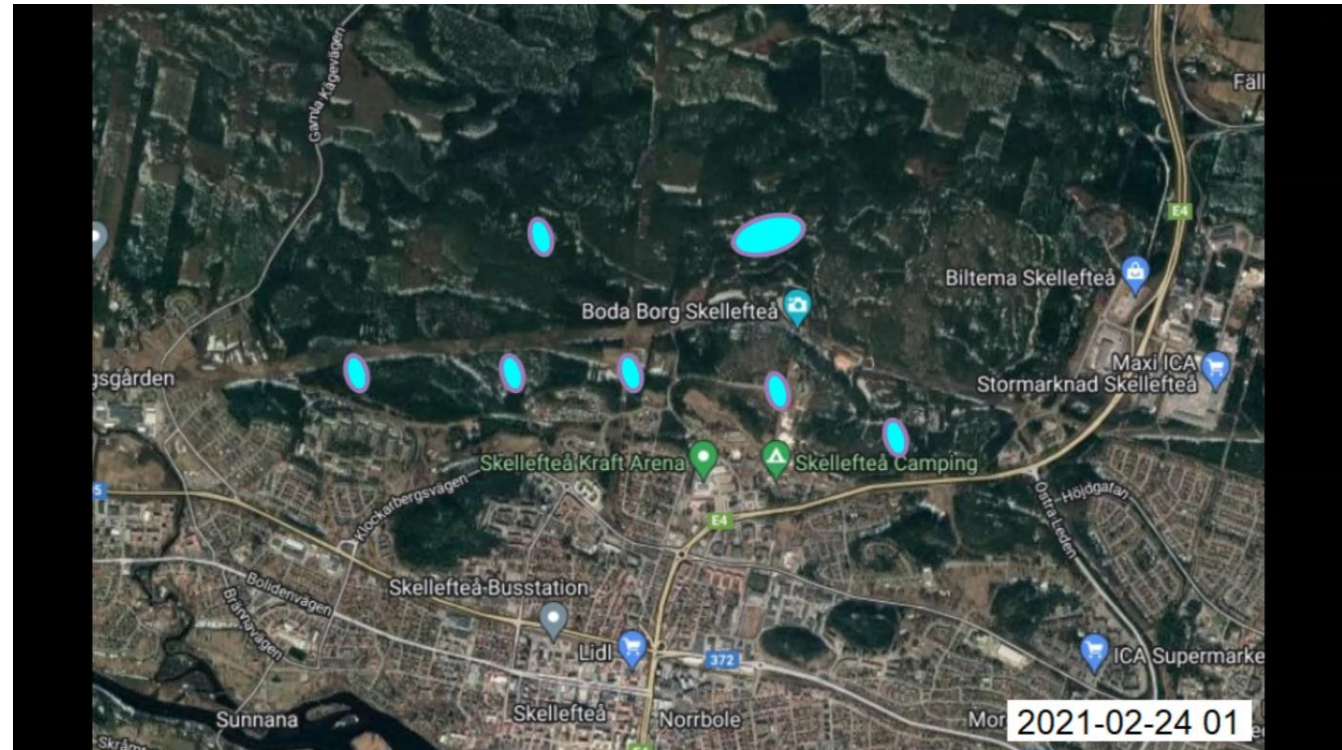
Global experience 1995-2022

68 Countries
+300 GW



From frequency to real time

WS/WD	0	30	60	90	120	150	180	210	240	270	300	330
1	2	2	2	3	2	2	1	1	2	1	1	1
2	22	15	22	32	26	16	13	19	21	14	14	20
3	65	57	62	76	67	46	40	58	55	50	39	46
4	84	74	108	117	104	66	62	86	68	67	58	82
5	106	102	146	146	122	102	88	106	82	77	75	112
6	140	120	144	150	129	129	115	113	89	88	107	132
7	154	152	153	126	104	119	118	112	91	105	139	164
8	163	146	131	117	98	108	107	103	93	116	164	178
19	128	128	96	94	92	107	102	109	104	136	161	140
10	75	96	71	71	97	101	97	104	129	137	116	65
11	35	63	39	38	84	89	92	89	119	92	64	28
12	15	26	17	19	46	59	79	55	89	62	35	17
13	6	12	4	6	18	31	49	28	38	30	14	8
14	3	5	1	2	6	14	27	11	15	15	8	4
15	2	1	2	1	4	7	7	3	5	5	4	2



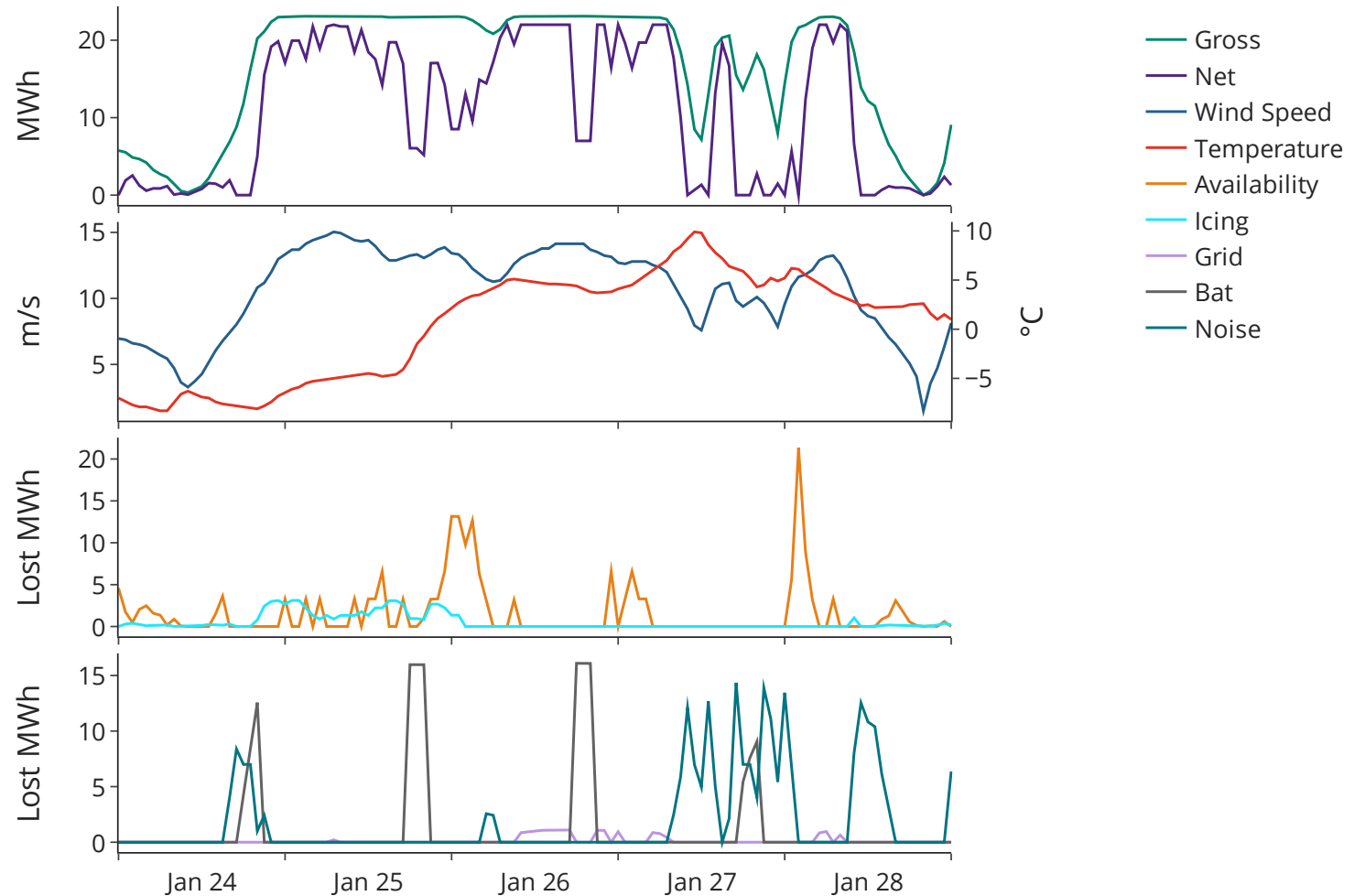
From frequency to real time

Why we do it

- Capture of “averaged out” effects
- Loss interaction
- Dynamic Curtailments
- Atmospheric Stability
- Valuable input to financial modelling

It better reflects the complexity of real wind farms

Sample Production Profile

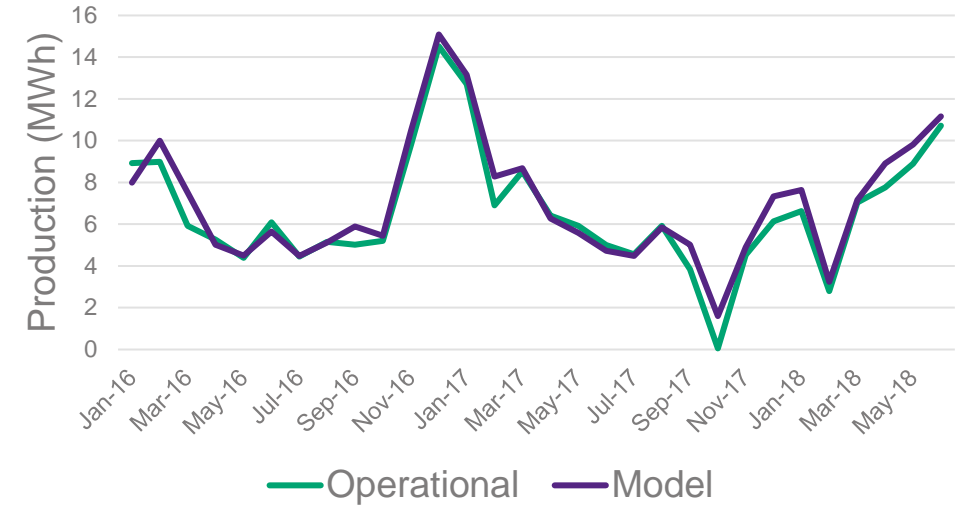


Validation against real data

- Start with PCYA of operational wind farm
- Create pre-construction model
- Run timeseries EYA during operational period
- Compare the post and pre-construction productions

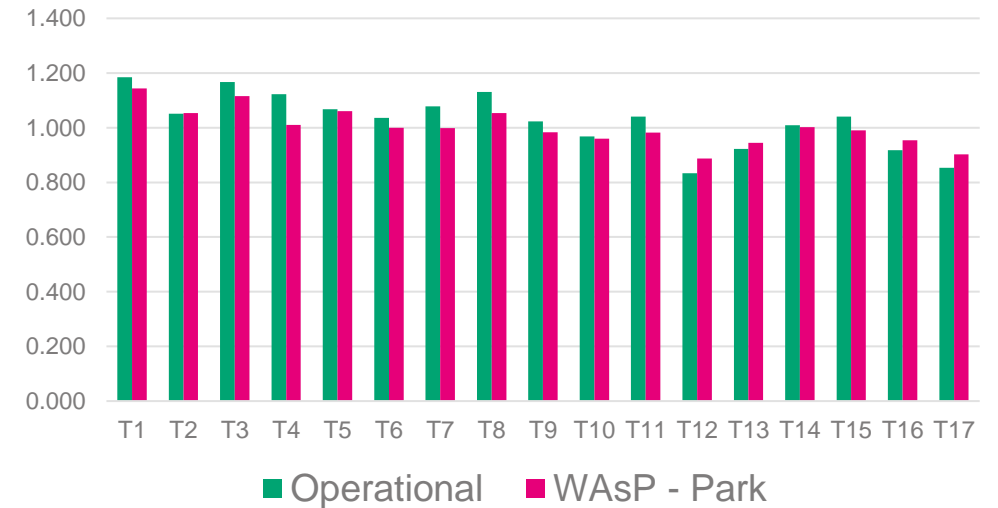
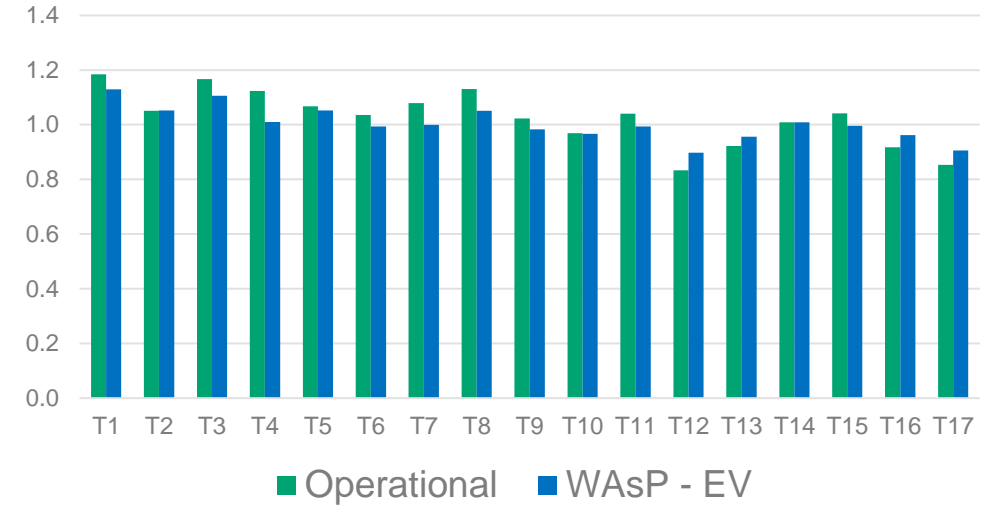
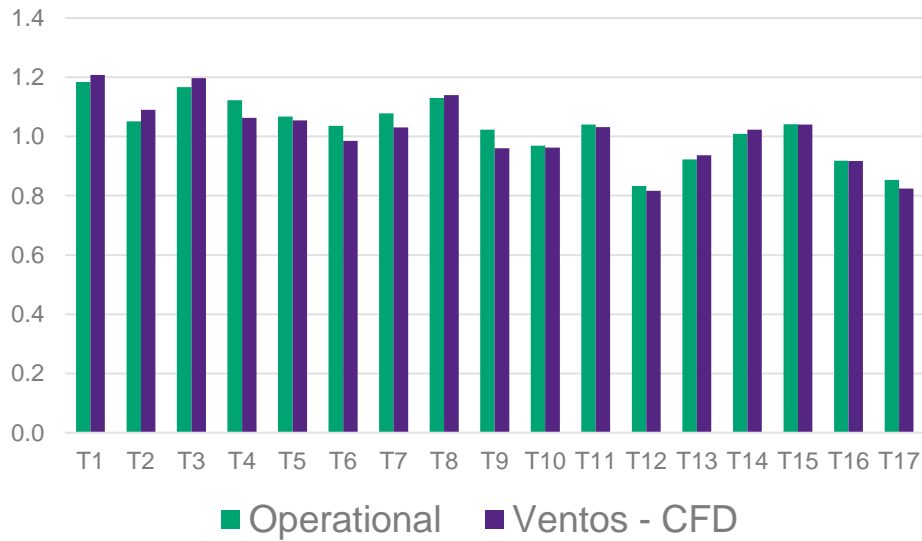
Reconciliation of gap

- Turbine performance
- Spatial or wake modelling challenges



Modelling chain testing

Patterns of production from different spatial and wake models compared to operational data



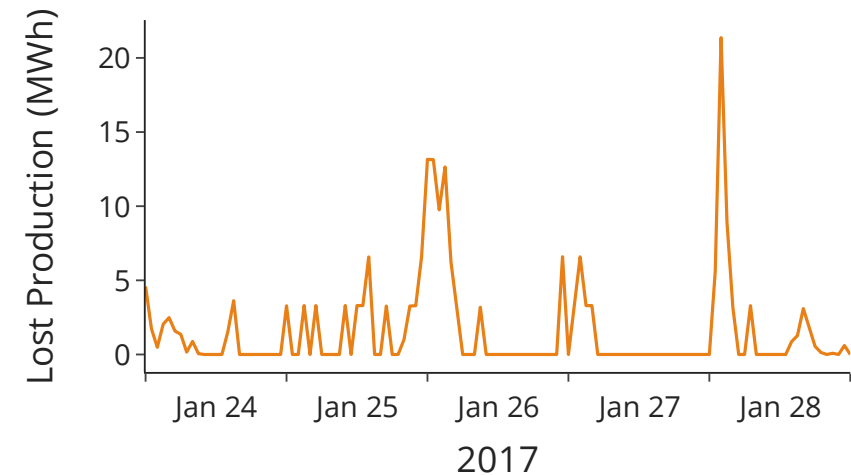
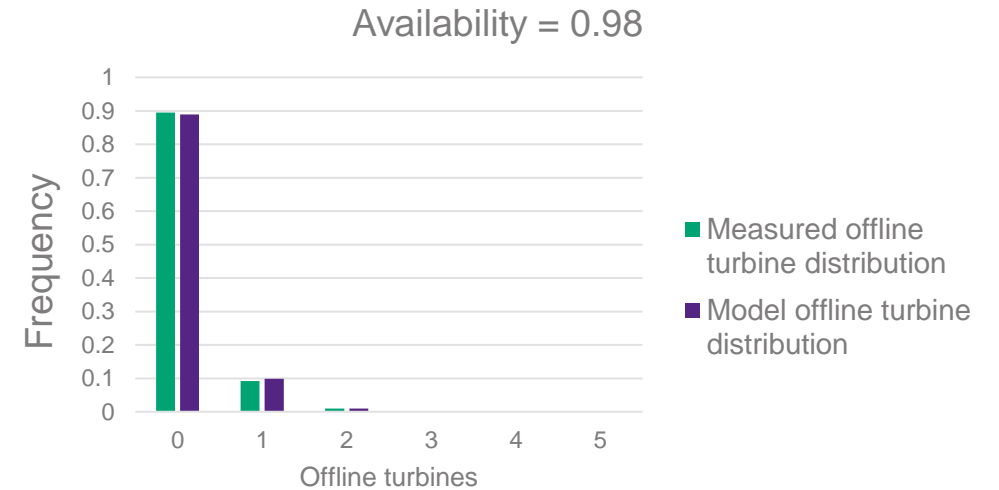
Stochastic Availability

Markov Chain Modelling

Method

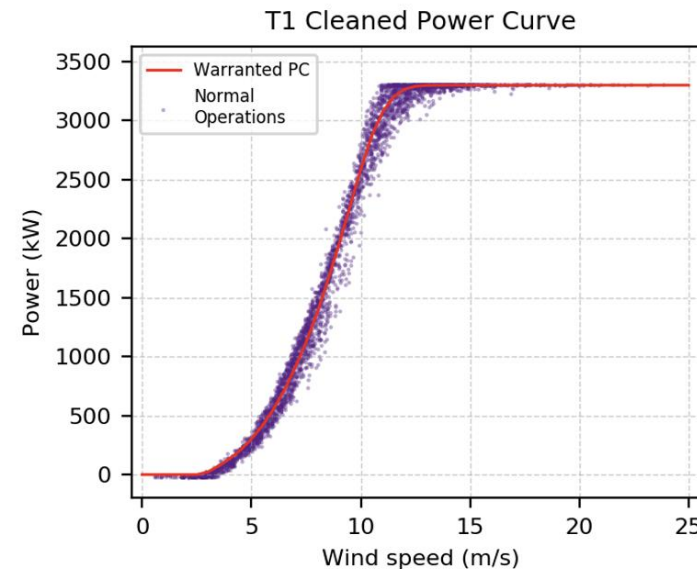
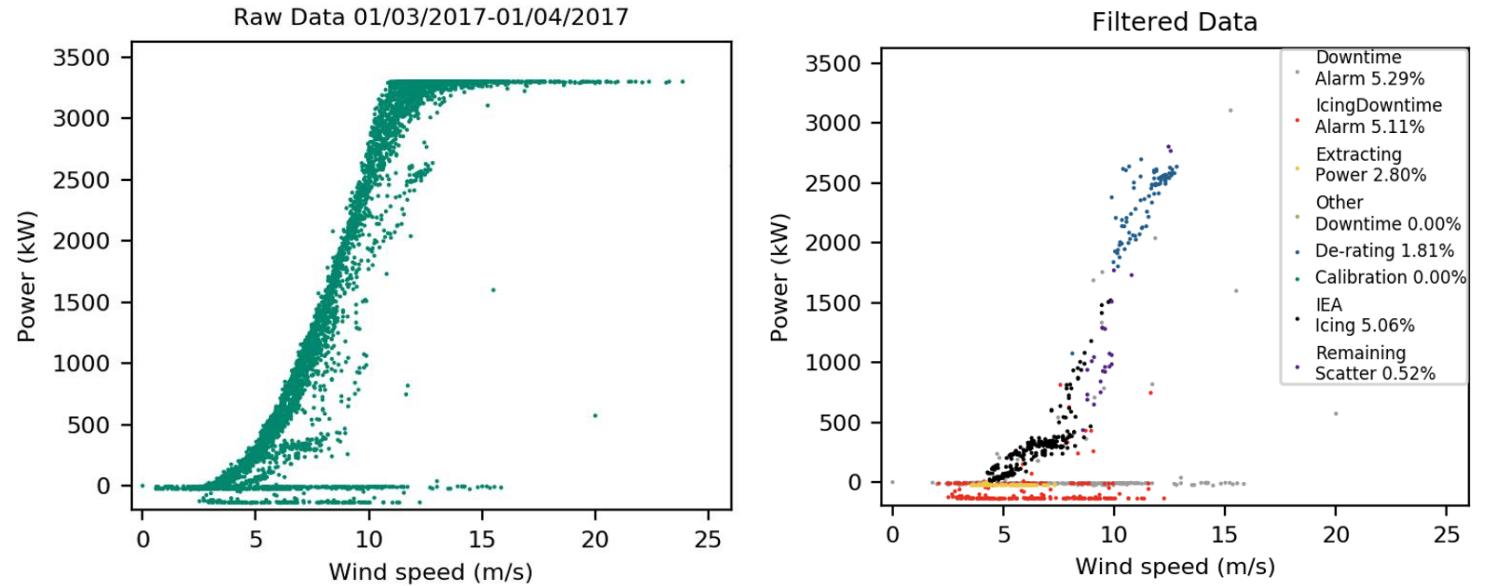
- Simulate distribution of offline turbines
- Markov chain estimation
- Stochastic timeseries of number of offline turbines
- Downtime allocation

Realistic production variations on a timeseries basis



Icing Operational data filtering

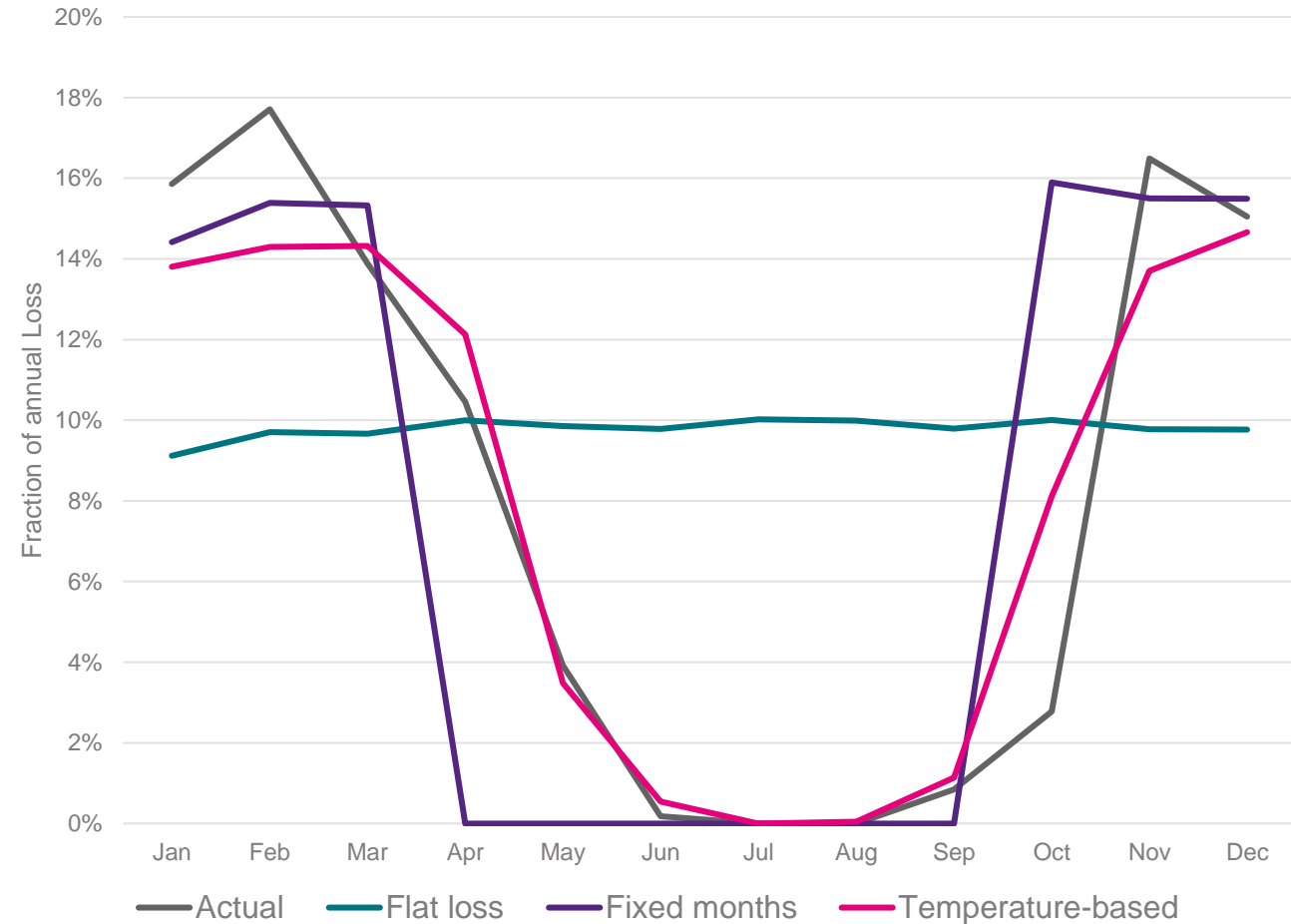
- Parse raw SCADA data
- Categorise performance scatter
- Icing filtering based on IEA19
- Cleaned power curve represents “normal operations”

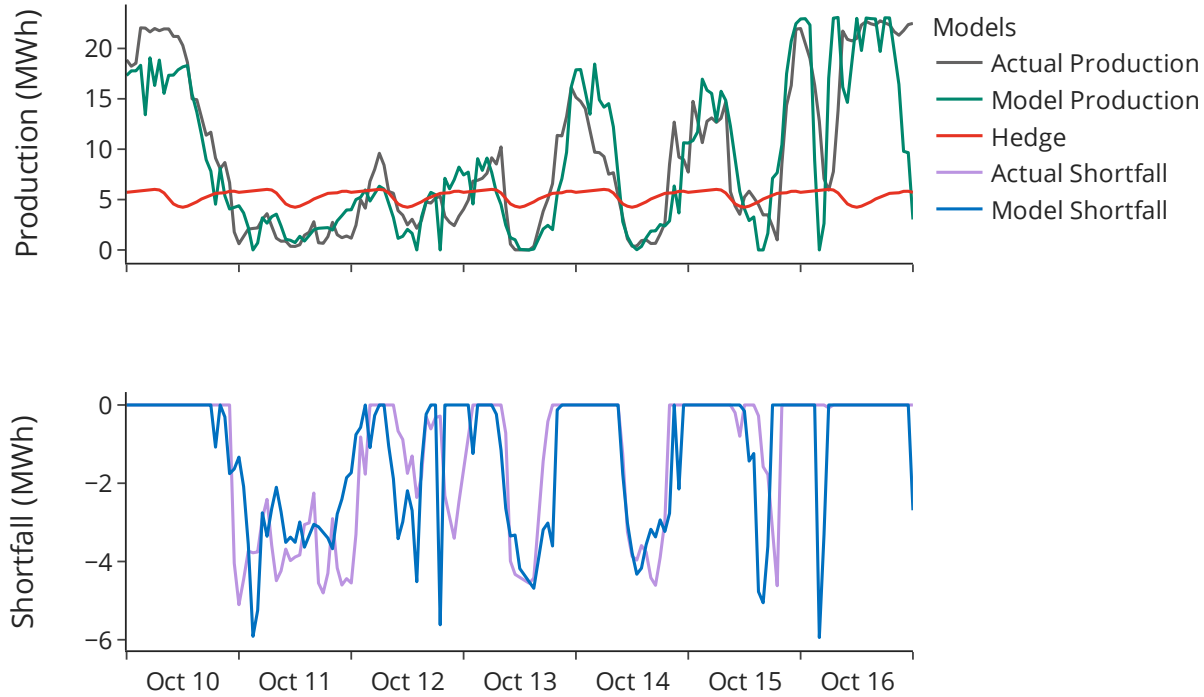


Icing Loss models

- Actual Data (IEA Task19)
- Flat icing Loss
- Flat loss in winter months
- Temperature-dependent loss

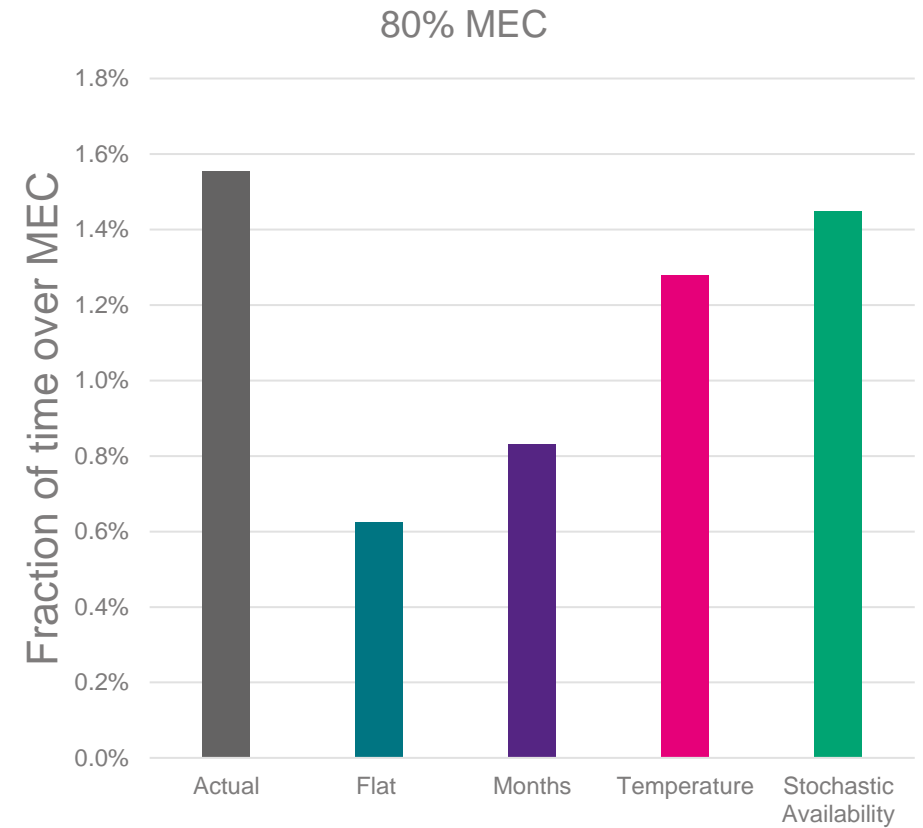
Can be based on third-party study and other climate data



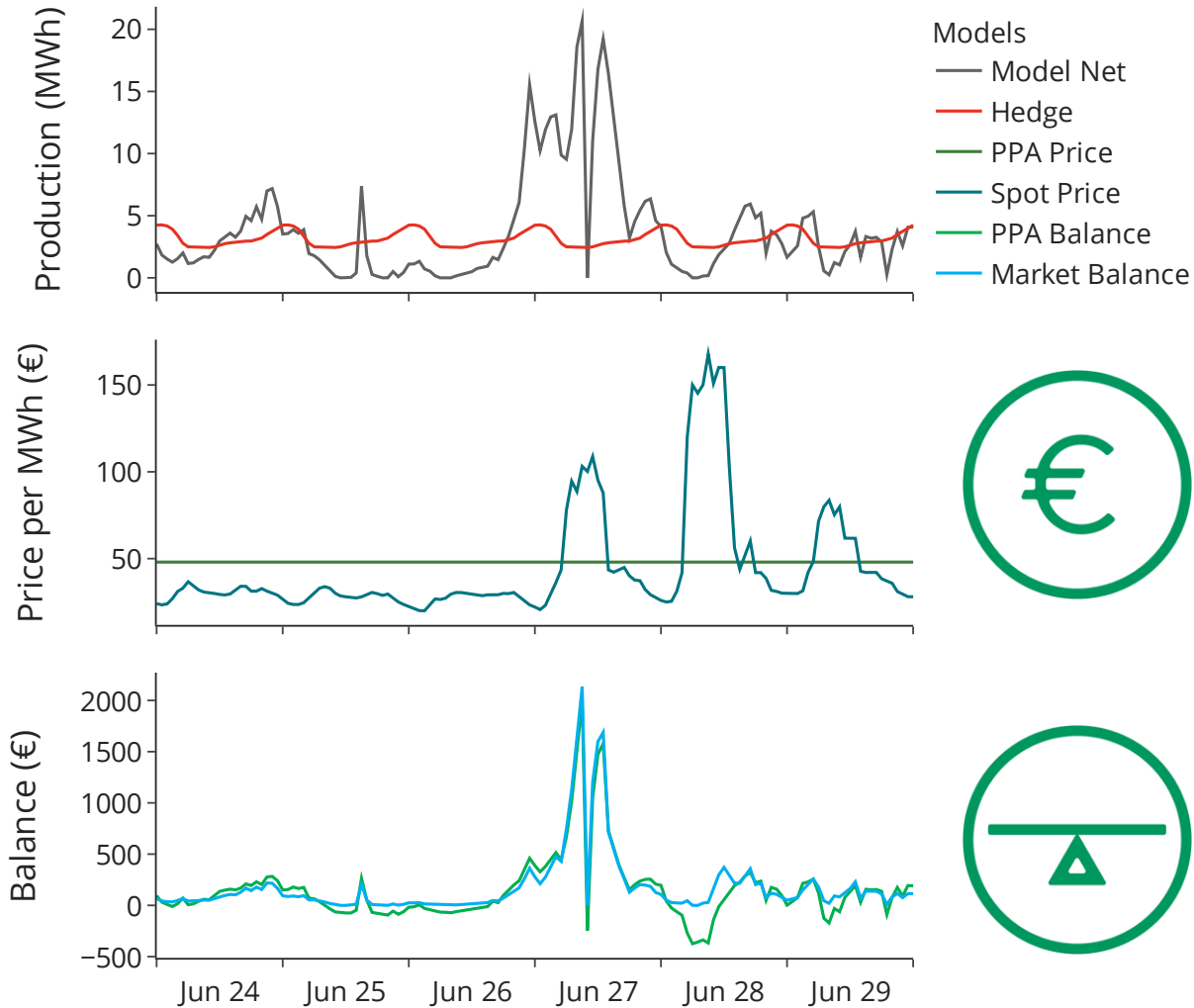


Production Shortfall

Maximum Export



PPA modelling



○ N = Wind Farm Net Power

○ H = Hedge

○ S = Spot Price

○ P = PPA Fixed Price



Balance formula:

$$\begin{cases} HP + S(N - H) & \text{if } N > H \\ NP + S(N - H) & \text{if } N < H \end{cases}$$

The (PPA) Price Is Right

Compare the overall balance of PPA vs Market

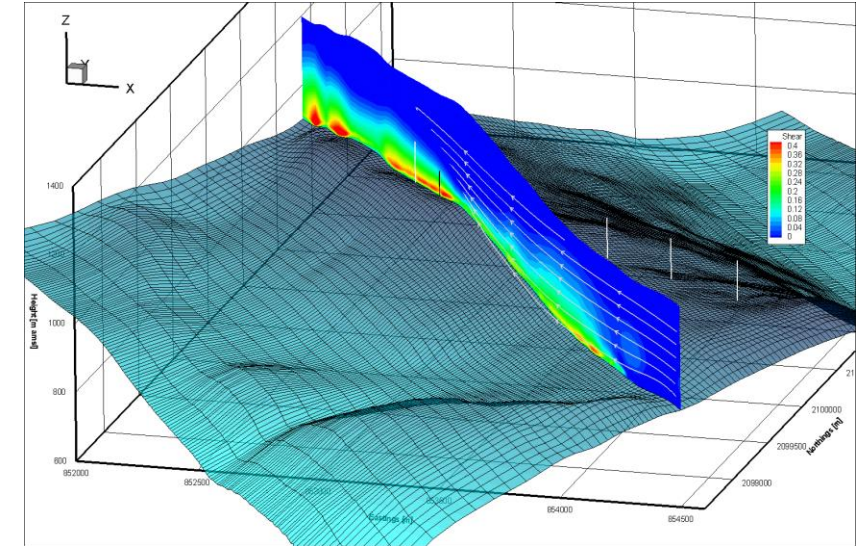
- Set fixed PPA € per MWh
- Run PPA balance timeseries
- Run Market balance timeseries
- Compare overall balance
- Adjust price until PPA matches Market balance

Compare crossover PPA price with operational case

Dataset	Crossover (€)
Model	46
Operational	48

Ongoing development

- Natural Power validation study (Q2 release)
- Stochastic availability white paper (Q2 release)
- Hybrid projects (storage, hydrogen, solar,...)
- In-built wake and spatial modelling, including incorporating time-resolved VENTOS®/M CFD mesoscale-coupled spatial model





Thank you.

