Blade equipped with Wicetec technology

AEP losses - less than half of the truth of the economic icing losses

Case example Finland

Winterwind 28.3.2023


Neighbouring turbine without heating

Wicetec – The Leader in Blade Heating

- Sells and develops carbon fiber –based blade heating technology
  - New installations with wind turbine OEMs
  - 45 retrofit installations in Quebec, Canada
- Founded in 2014 as a spin off from Technical Research Centre of Finland (VTT)
- Company with most experience on wind turbine icing worldwide!
  - Key persons have 10 – 25 years of experience
- Strong engineering force: Composite, electrical and lightning protection, mechanical, control, software, and cyber security

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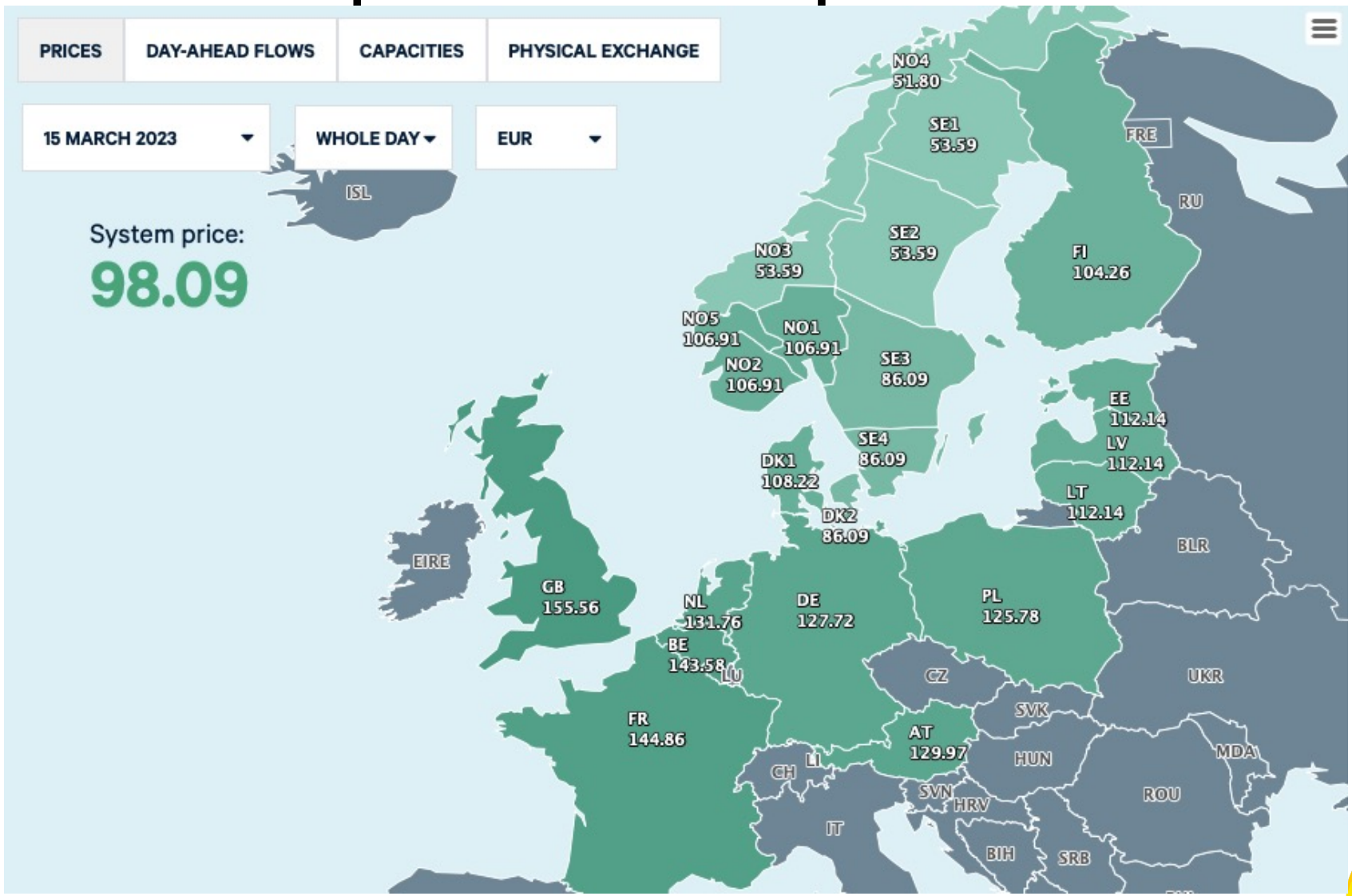
Finland - as part of Nordpool market



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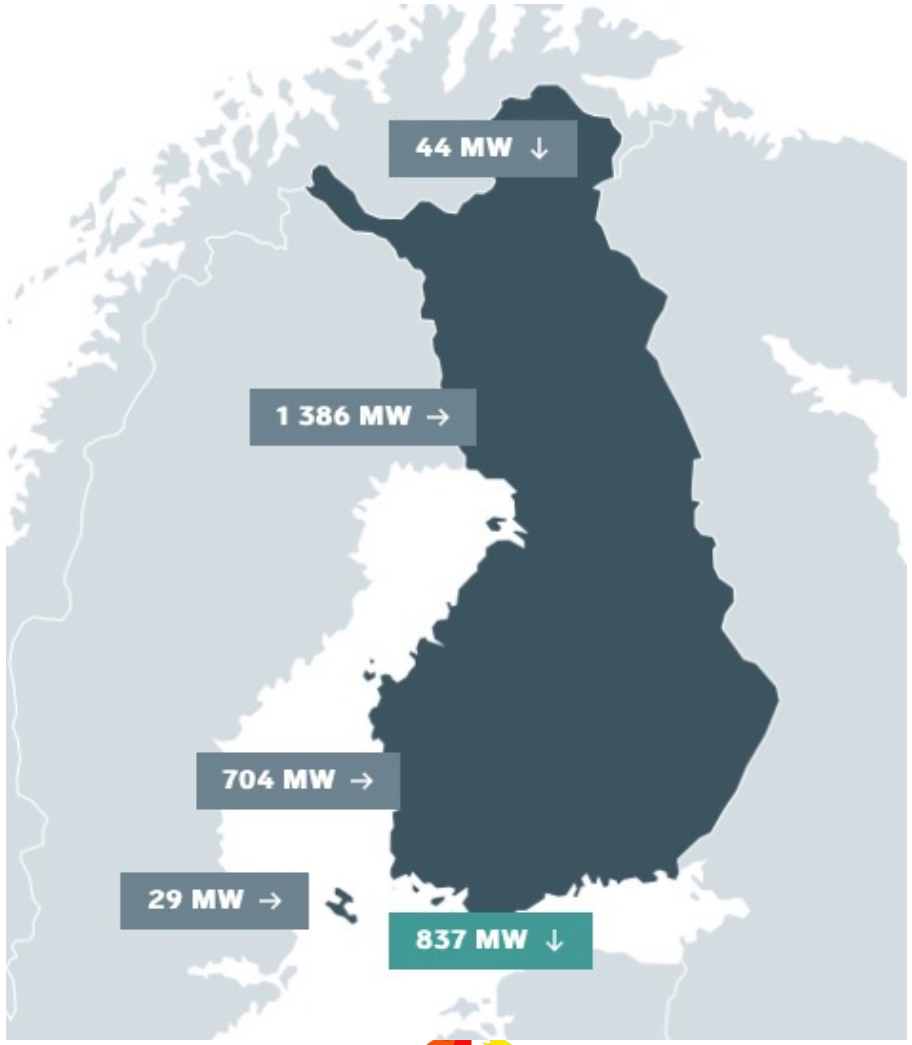
Characteristics of Finnish Price Area

- 10 GW average electricity consumption
- Finland in the past has been relying on electricity imports
  - Situation changing due quick increase in renewables and 1,6 GW Olkiluoto 3 nuclear plant
- Import 1 GW from Russia ended 2022
- Import capacity from Northern Sweden typically “sold out” on day ahead markets due cheaper price
  - No possibility to get balancing power from Sweden



Picture source: https://www.fingrid.fi/en/electricity-market/power-system/

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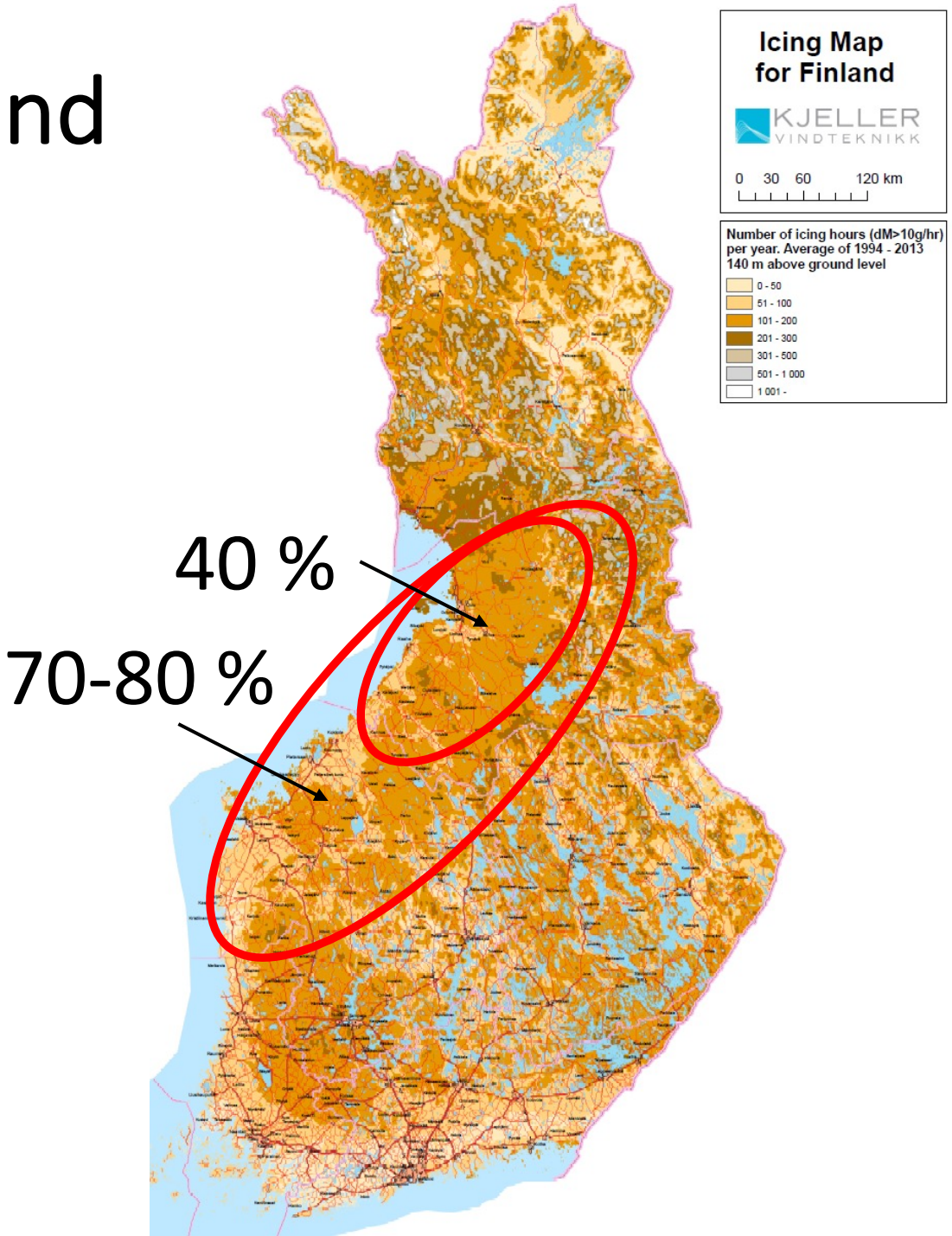
Wind Power Capacity in Finland

- 5 GW wind power at the end of 2022
  - 50% of average consumption
  - Concentrated in small area
- 20 GW wind power 2030



The Factors Increasing The Cost of Icing in Finland

Icing increasing factors

- Many of the wind parks are built to inland instead of coastal proximity
- New turbines reach higher
- Modern big turbines are more sensitive for icing

Operative Factors

- Forecasting the starting time of icing is difficult
- Forecasting the ending time of icing is even more difficult
- The icing affects most on low and medium winds, cut-in speed increases, i.e., to 7-8 m/s level

Electricity market factors

- Cheap balancing power not available anymore
- On new balancing power contracts the cost of icing is on wind power producer
- The cost of balancing power is high during the icing events due high demand
- The spot price is high on low winds

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The Factors Increasing The Cost of Icing in Finland

Icing increasing factors

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The overall economic losses due icing will increase!

(With turbines without ice prevention)

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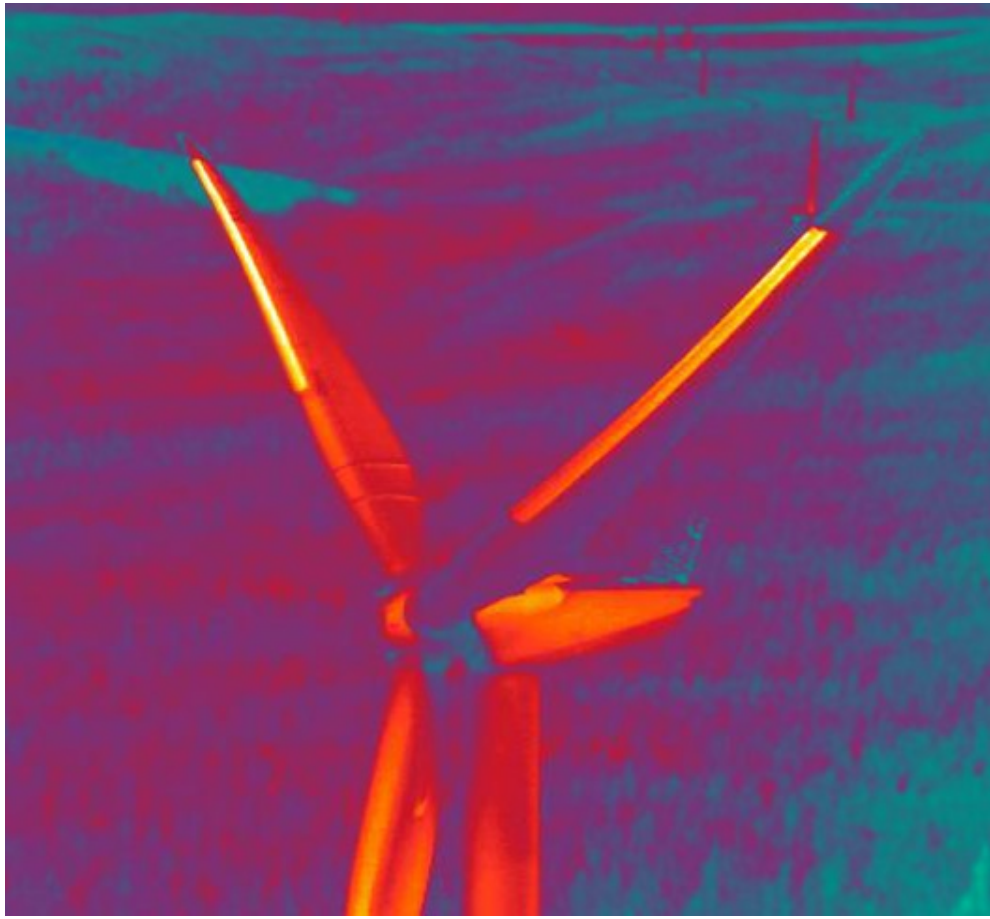
Typical Ice Loss Evaluation is Outdated in Dynamic Markets

- Losses typically evaluated as percentage of annual energy production (AEP) with average electricity price
- The operating environment has changed due to quick increase of wind power

- Method does not include dynamics of electricity market:
  - Cost of sourcing the missing production
    - Intraday trade (Nordpool) and balancing power (Fingrid)
  - Value of production on low winds
  - Uncertainties: Any big production facility down at the same time. Is it weekday or weekend, night or day?



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Proposal to estimate icing losses

			Example % / AEP
		Production loss	3 %
		+	
Economic icing loss	=	**Cost of sourcing missing production**	3 %
		+	
		Cost of lost more valuable production	3 %

The total loss for site with expected 3% of AEP can be in real life 10%!

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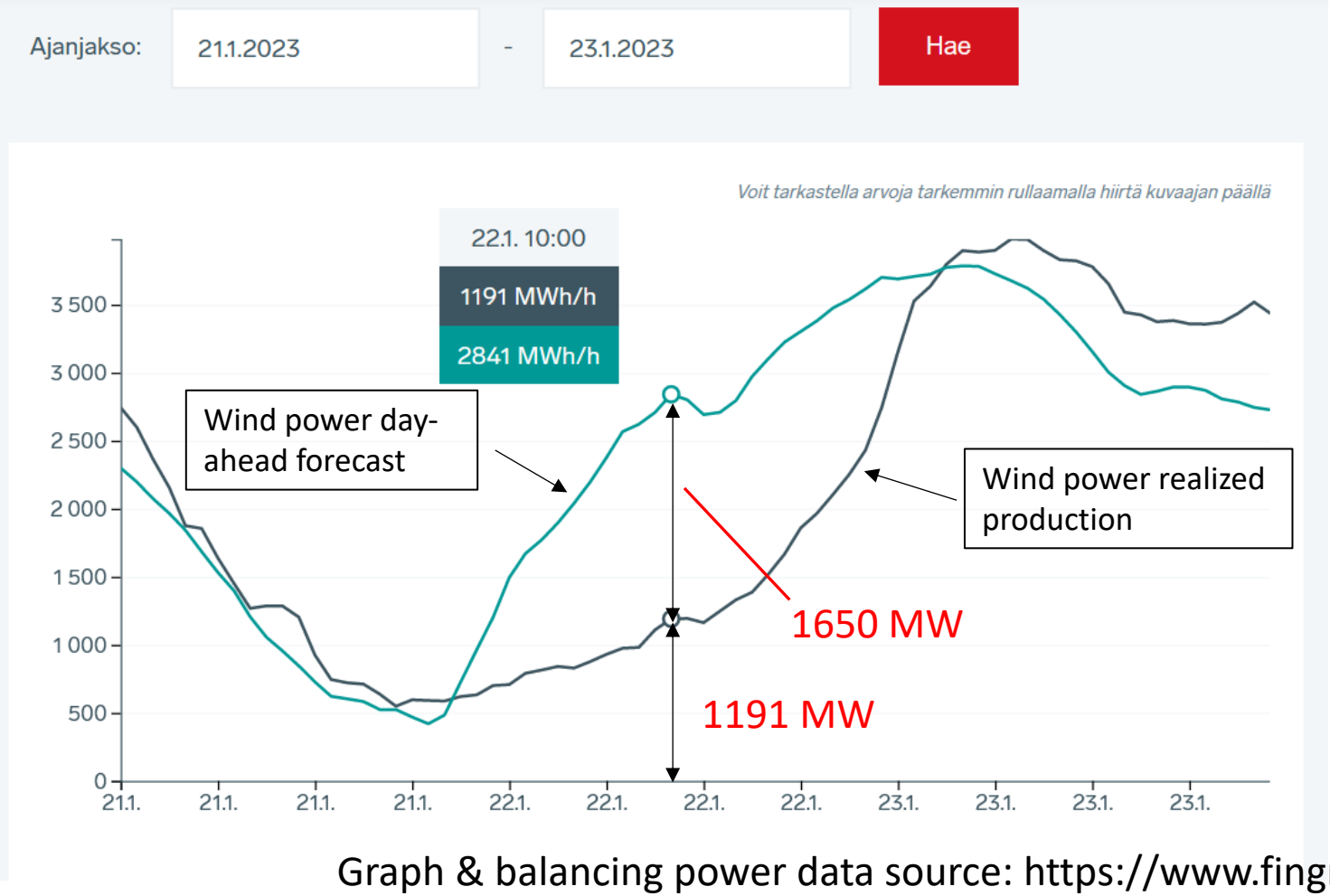
Example: Sunday 22.1.2023 in Finland



Wind power total capacity	5300 MW
Capacity with blade heating	~800 MW
Production loss (33,6 GWh)	2,28 Meur
Intraday and balancing cost	2,37 Meur
Total cost	**4,7 Meur**

Graph & balancing power data source: https://www.fingrid.fi/
Intraday data source: https://www.nordpoolgroup.com/

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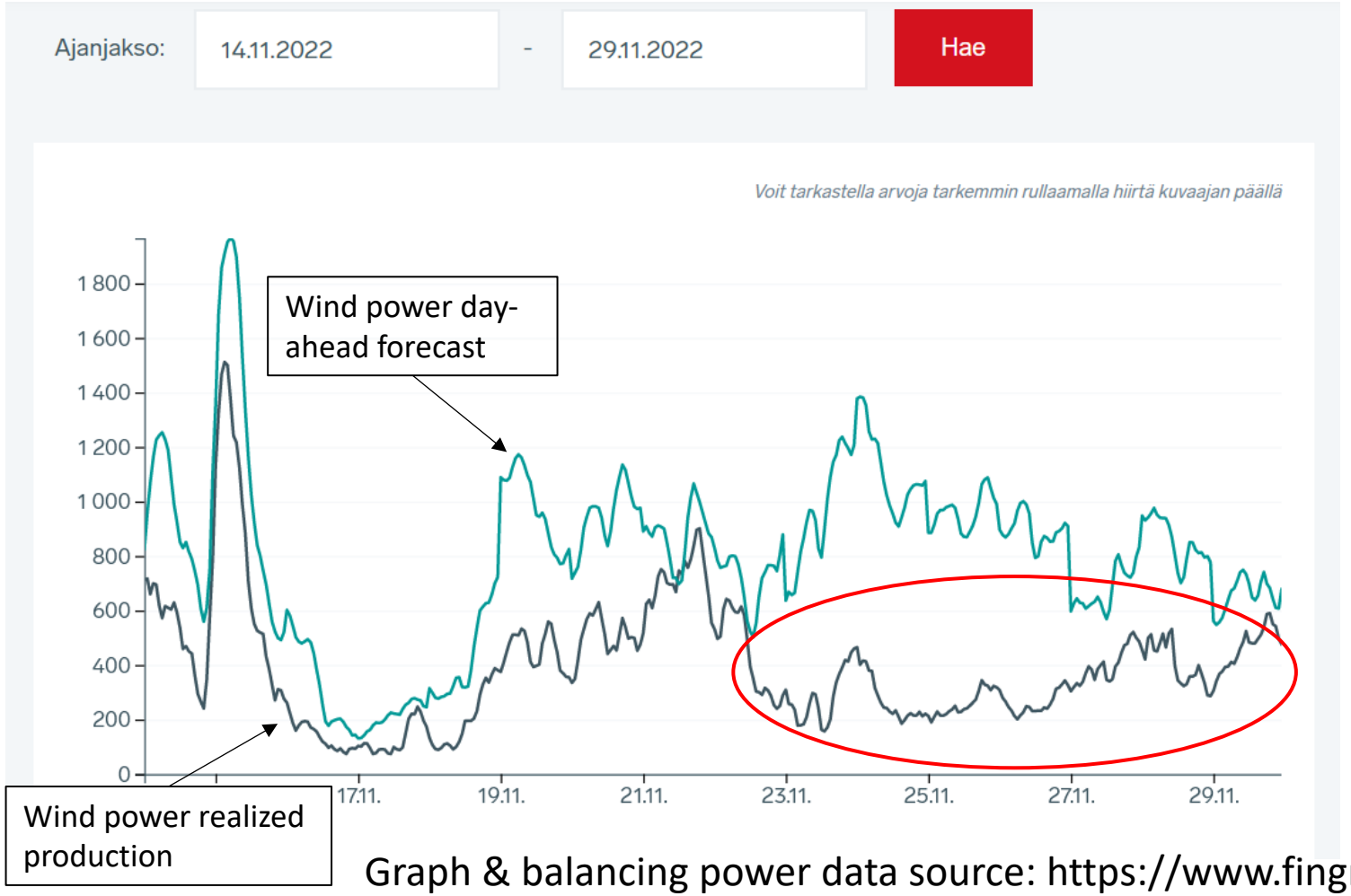
Example: November 14.-29.11.2022 in Finland



Wind power total capacity	4800 MW
Capacity with blade heating	~700 MW
Production loss (155 GWh)	38,5 Meur
Intraday and balancing cost	29,7 Meur
Total cost	**68,2 Meur**

Blade heating payback time for 6 – 7 MW turbine two weeks!

Graph & balancing power data source: https://www.fingrid.fi/
Intraday data source: https://www.nordpoolgroup.com/

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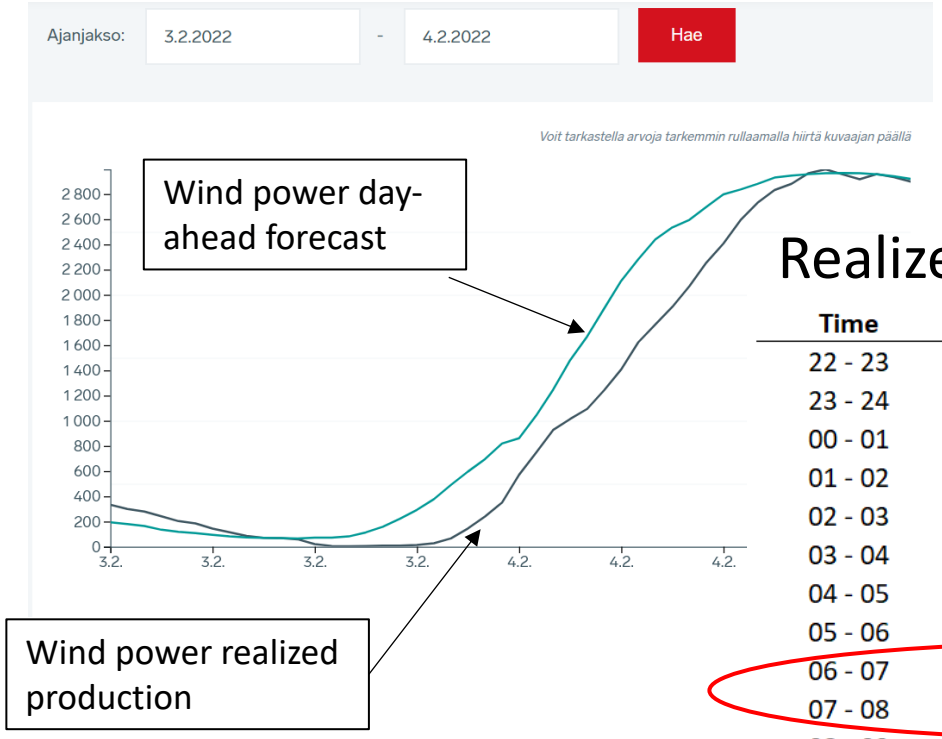
Example: Friday 4.2.2022 in Finland



Realized balancing power

Time	Price	Volyme	total price / hour
22 - 23	245 €	118	28 910 €
23 - 24	234 €	337	78 858 €
00 - 01	180 €	179	32 220 €
01 - 02	170 €	184	31 280 €
02 - 03	105 €	22	2 310 €
03 - 04	170 €	178	30 260 €
04 - 05	200 €	440	88 000 €
05 - 06	191 €	393	75 063 €
06 - 07	3 500 €	322	1 127 000 €
07 - 08	3 500 €	396	1 386 000 €
08 - 09	409 €	274	112 066 €
09 - 10	140 €	20	2 800 €
10 - 11	140 €	65	9 100 €
		Total price	**3 003 867 €**

Wind power total capacity	3400 MW
Capacity with blade heating	~430 MW
Production loss (33,6 GWh)	0,9 Meur
Intraday and balancing cost	3,9 Meur
Total cost	**4,8 Meur**

Graph & balancing power data source: https://www.fingrid.fi/
Intraday data source: https://www.nordpoolgroup.com/

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Final words

Economical icing losses are greatly underestimated!

The market factors are difficult to predict.

But, you can disregard these by choosing a turbine with efficient anti-icing solution.