Electricity-based technologies for flexible heat production and their role in mixed heat systems

Andreas Zourellis - FENAGY

FENAGY
FUTURE ENERGY SOLUTIONS

FENAGY

Manufacturer of heat pumps and chillers with natural refrigerants only

- Part of Beijer Ref
- Founded 2020
- 4,400 m^2 office and production in Aarhus
- 100 dedicated employees
- 114 projects sold

- 75 projects handed over
- 400 MW sold
- 231 heat pumps
- Revenue:
  2023: 30 M€, 2024: 41 M€
  2025: 44 M€, 2026: 60 M€

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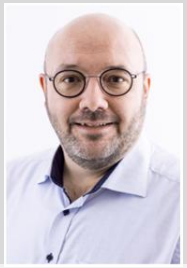
Founders team (CO_2 pioneers since 2005)

KIM G. CHRISTENSEN
CEO



KLAUS NØRGAARD
CFO

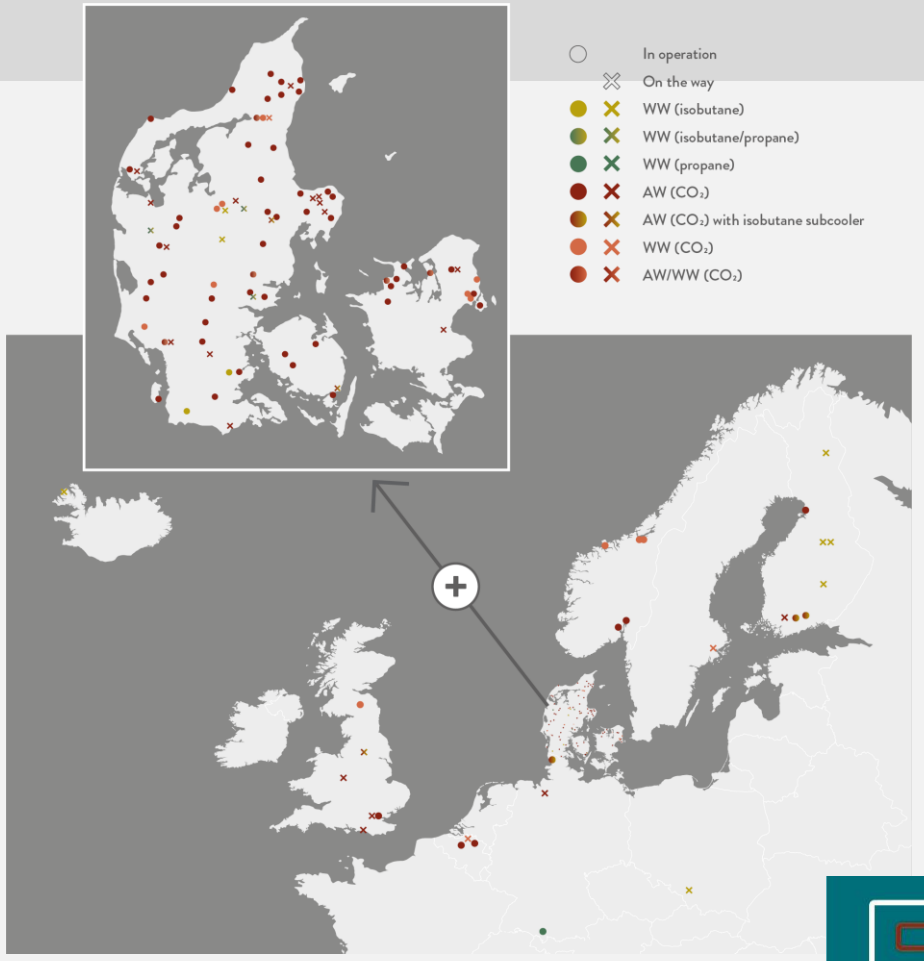
JACOB NIELSEN
CTO Mechanical

MADS H. NIELSEN
CTO Electrical

History

- Fenagy was founded in 2020 - during corona lockdown
- Focus on heat pumps with CO_2 as refrigerant, later also hydrocarbons
- Started in a garage at Bautavej, Aarhus
- Priority on development, proof of concept, testing heat pump at DTI, defining products
- First real project (field test) delivered late 2020

  - 2021: 9 heat pumps, capacity 7 MW
  - 2022: 46 heat pumps, capacity 63 MW
  - 2023: 48 heat pumps, capacity 103 MW
  - 2024: 45 heat pumps, capacity 80 MW
  - 2025: 38 heat pumps, capacity 57 MW
  - 2026: 45 heat pumps, capacity 91 MW (YTD medio April)



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The way we work

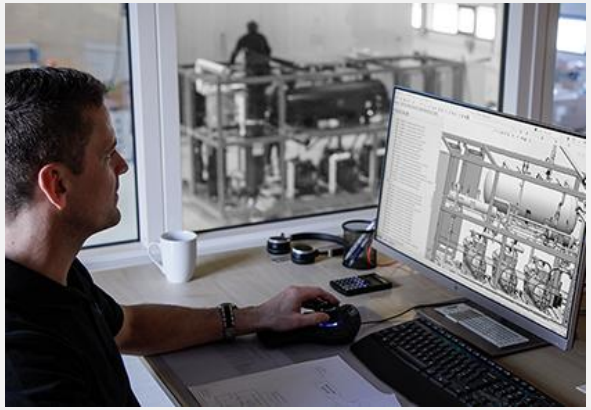
ADVICE

PROJECT MANAGEMENT & DESIGN

START UP & COMMISSIONING

REMOTE MONITORING

SUPPORT



PRODUCT DESIGN ++

PRODUCTION +++

INSTALLATION -

COMMISSIONING ++

SERVICE ++

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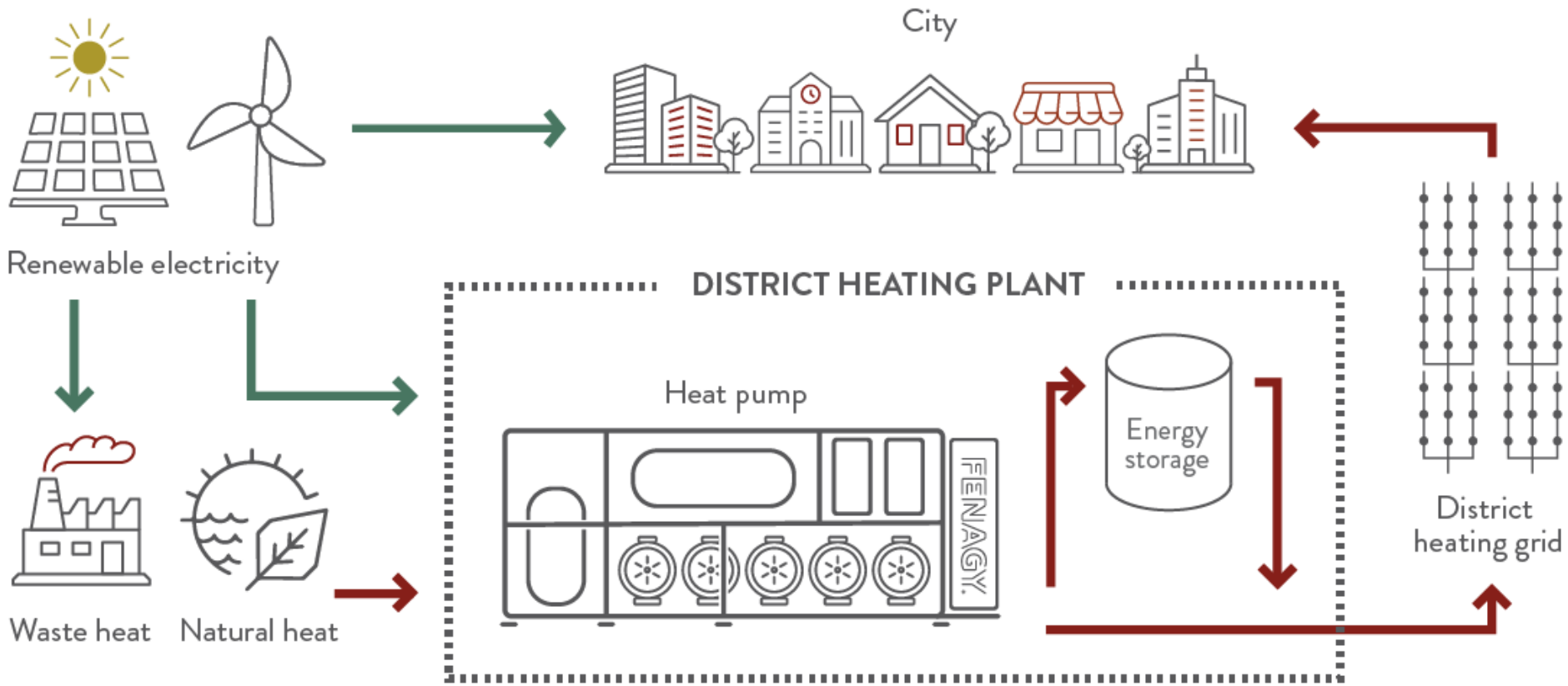
Heat pumps and CHC · District heating and industry



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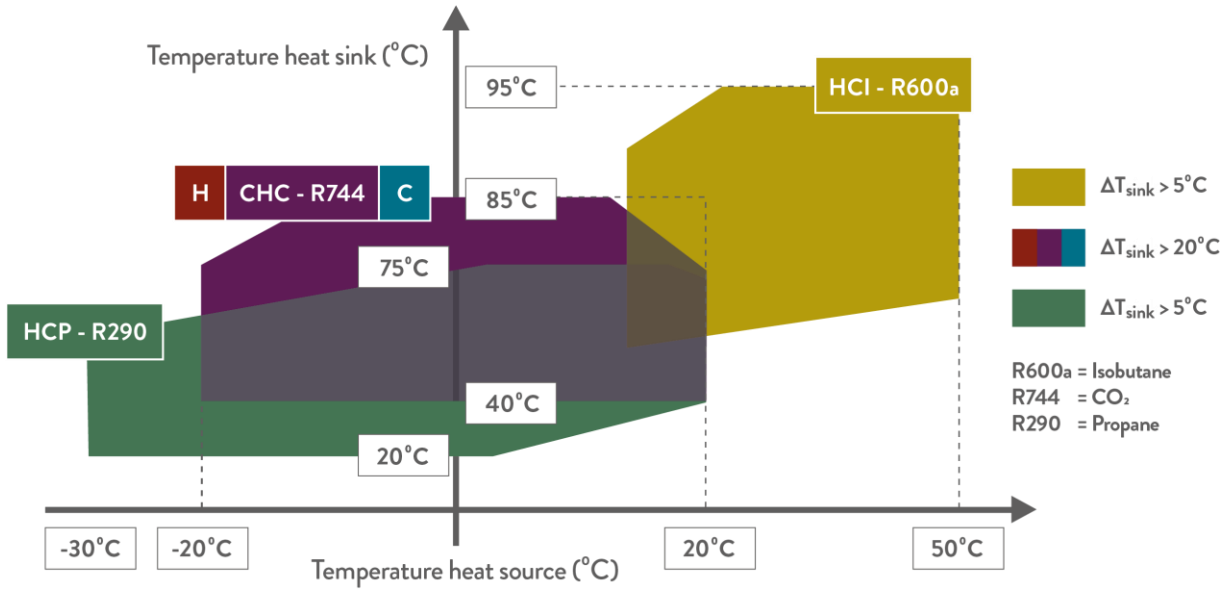
Product range

- Only natural refrigerants (CO_2, Isobutane, Propane)
- Full range of temperatures
- Both water and air-sourced
- Factory built and customised
- Selling Projects – not Products
- Selling all the services around the product (consultancy, commissioning, service and after-sales)



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DANISH DISTRICT HEATING

BACKUP HEATING

CHP – BALANCING ELECTRICAL GRID

SOLAR PANELS + PV AND WINDMILLS

HUGE STORAGES

ELECTRICAL BOILERS AND HP´s

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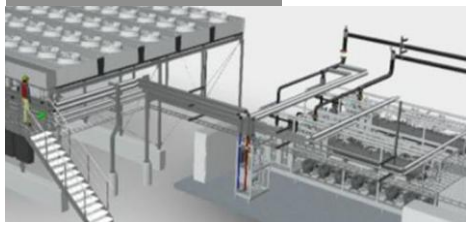
Typical scope for CO_2 air-to-water heat pumps

Accumulation

Evaporators

Control and SCADA

Machine room



Heat pump rack

Defrosting module and pumps

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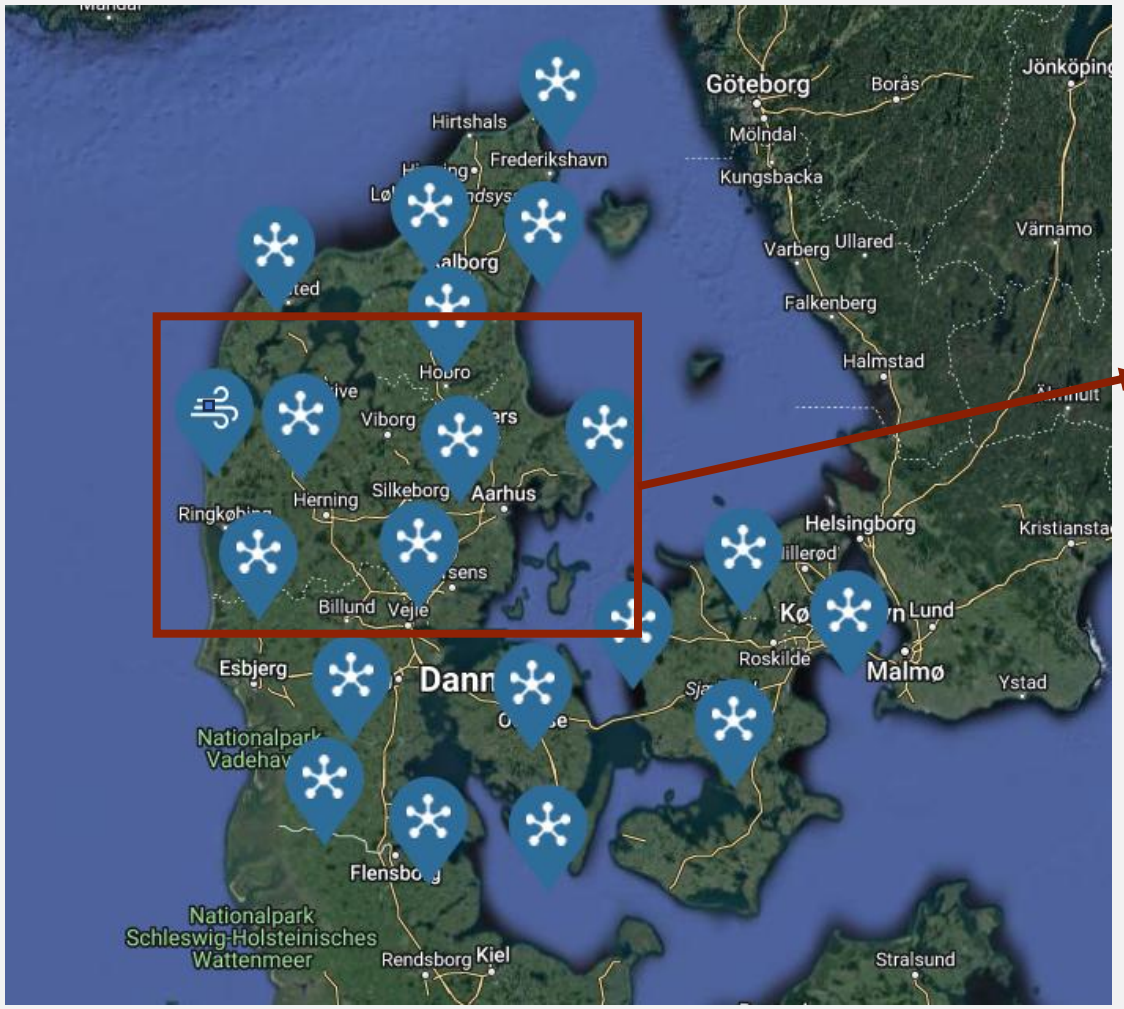
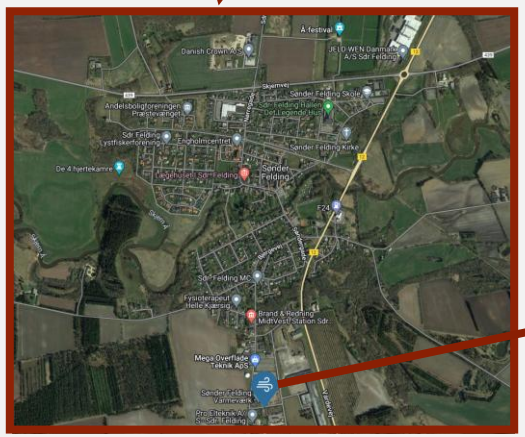
WWW.VARMEPUMPEDATA.DK (ON-LINE DATA FOR SOME HEAT PUMPS)





SDR FELDNING CASE

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Very visionary district heating system

12
days storage
in summer

750
households
4.5 m3/house

16
GWh/Y
200 m3/GWh

85%
HP in 2024

15%
E-boiler in 2024

40
hours storage
in winter

30%
more capacity
70 to 80°C

- Runs on renewable electricity when prices are low
- Large tank and large heat pump decouple the heat demand from fluctuating electrical prices
- Fast start and stop
(less than 5 minutes)
- 3.5 MW air-to-water heat pump
- Large energy storage tank

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Air-to-water heat pump · Sound attenuated

- YEAR: **2023**
- MODEL: **2 x H-1800**
- APPLICATION: **Air-to-water HP**
- CAPACITY (HEAT): **4 MW (5°C ambient, 38/70°C hot water)**
- HEAT SOURCE: **Air**
- COP: **3.1**
- DEFROST METHOD: **Glycol**

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The largest CO2 Air/Water Heat Pumps to date

Billund 16 MW (0°C) ≈ 20 MW (7°C)

Haderslev 11 MW (-1°C)

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Hanstholm · Only 6 months from order to delivery

Delivered
in FENhouse

- ✓ Fast execution
- ✓ No bureaucracy
- ✓ Plug-and-play delivery

- YEAR: **2024**
- MODEL: **2 x H-2600 AW**
- APPLICATION:
  Air-to-water heat pump
- CAPACITY (HEAT): **5.2 MW**
  (5°C ambient, 42/75°C hot water)
- COP: **3.0**
- DEFROST METHOD: **Glycol**
- HOT WATER STORAGE: **10,000 m³**
- aFRR operation (5 minutes start/stop)

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Fårevejle · Combined air and water source (sewage)

- YEAR: **2023**
- MODEL: **2 x H-1800 (4x8CTE + 2x6DTE per heat pump)**
- APPLICATION: **Air-to-water heat pump**
- CAPACITY (HEAT): **4 MW (5°C ambient, 37/75°C hot water)**
- HEAT SOURCE: **Air with 6 evaporators per heat pump**
- REFRIGERANT CHARGE: **1000 l per heat pump**
- COP: **3.1**
- DEFROST METHOD: **Glycol**
- HOT WATER STORAGE: **4,000 m³**

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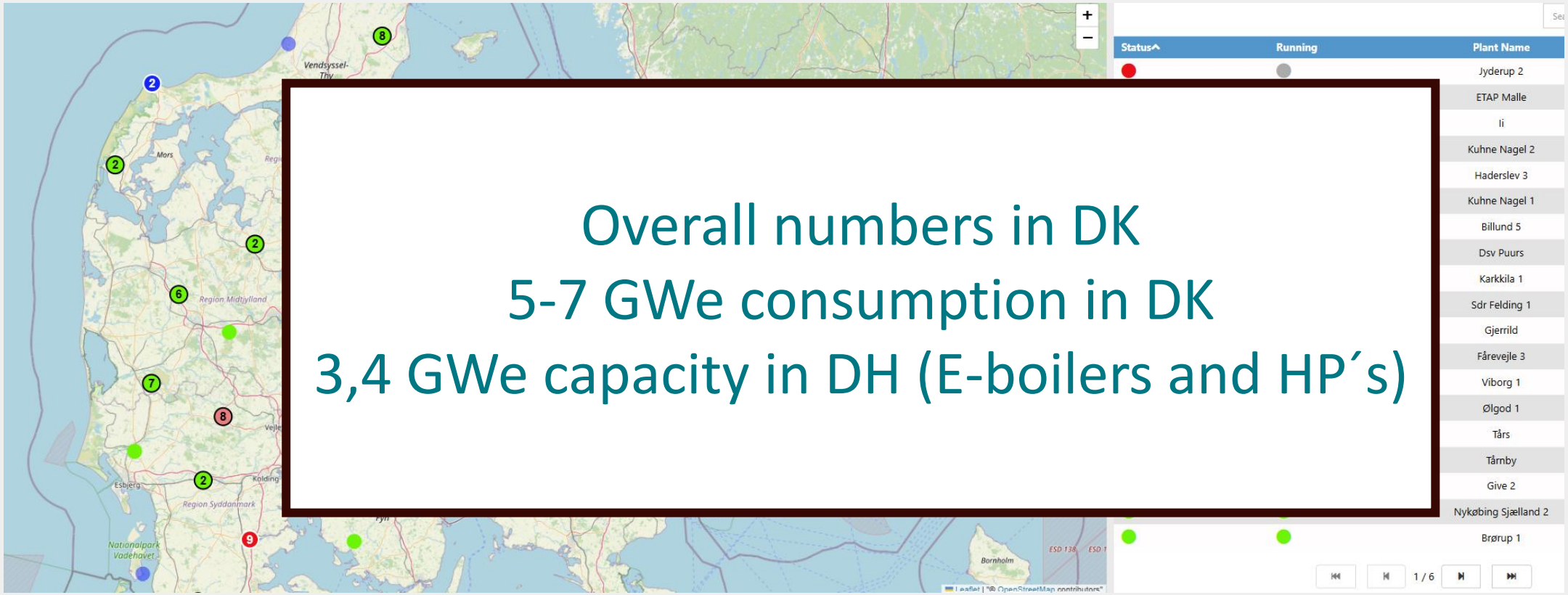
Electrification of district heating in Denmark

- Fenagy offers service and extended warranty of up to 10 Years in Denmark – online monitoring
- Fenagy and our customers are frontrunners in electrification of district heating with heat pumps



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Some differences between Poland and Denmark – HP´s

Topic	Denmark 🇩🇰	Poland 🇵🇱
Temperatures	Return: 30-50°C, Supply 60-90°C Air source HP: -20 → +25°C	Return: 40-60°C, Supply 70-120°C Air source HP: -30 → +30°C

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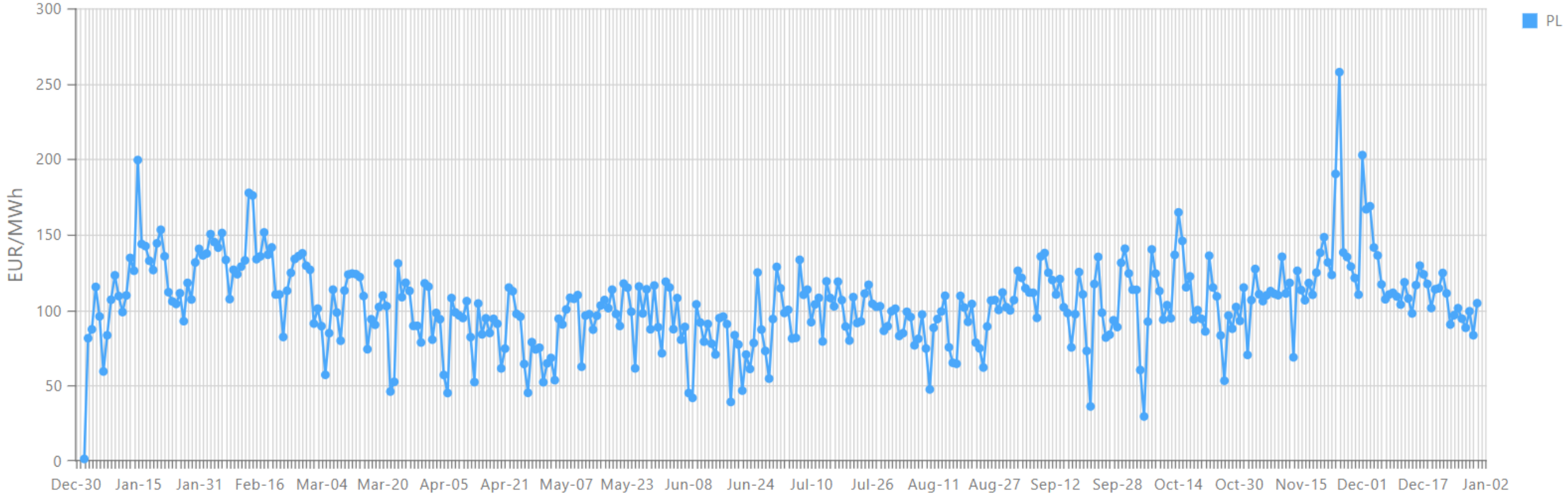
Average Spot Prices PL - 2025



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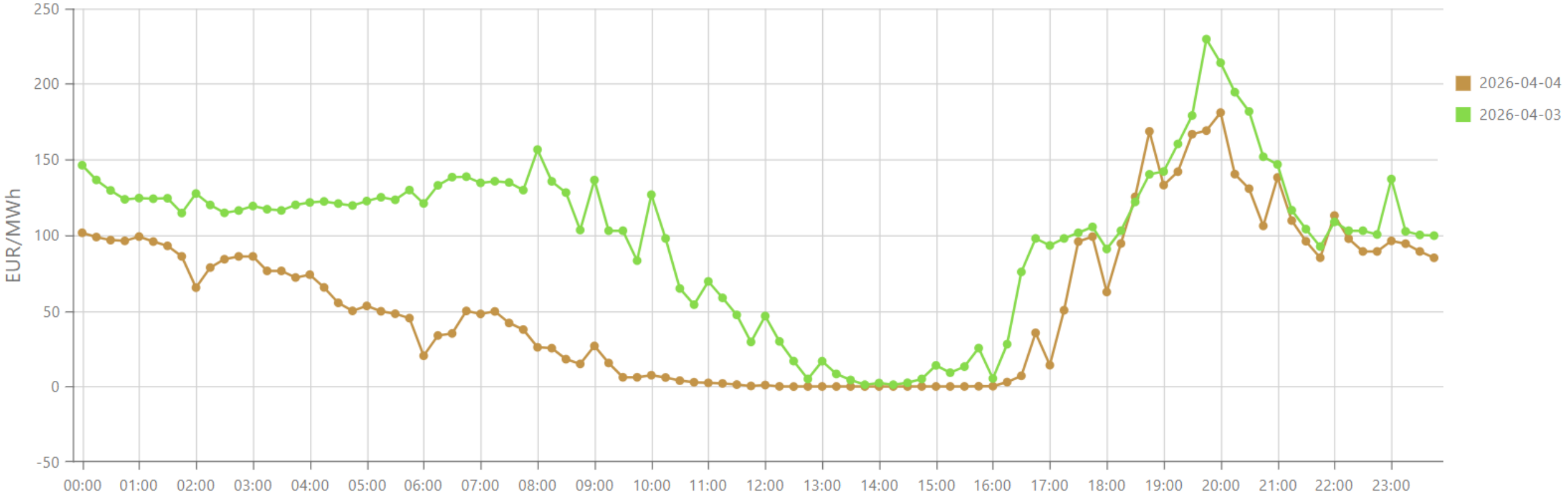
Hourly Prices PL – 3rd & 4th April 2026



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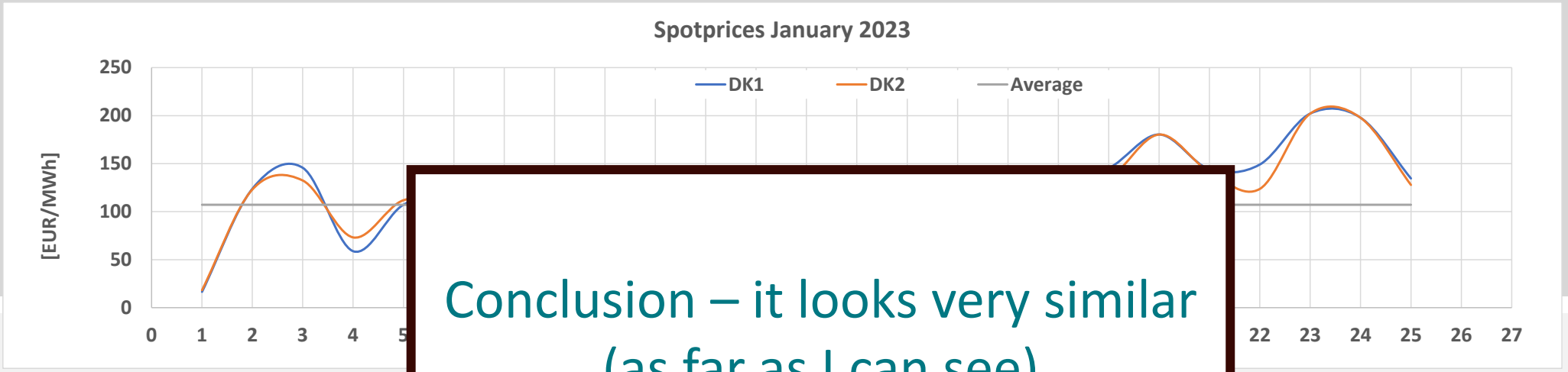
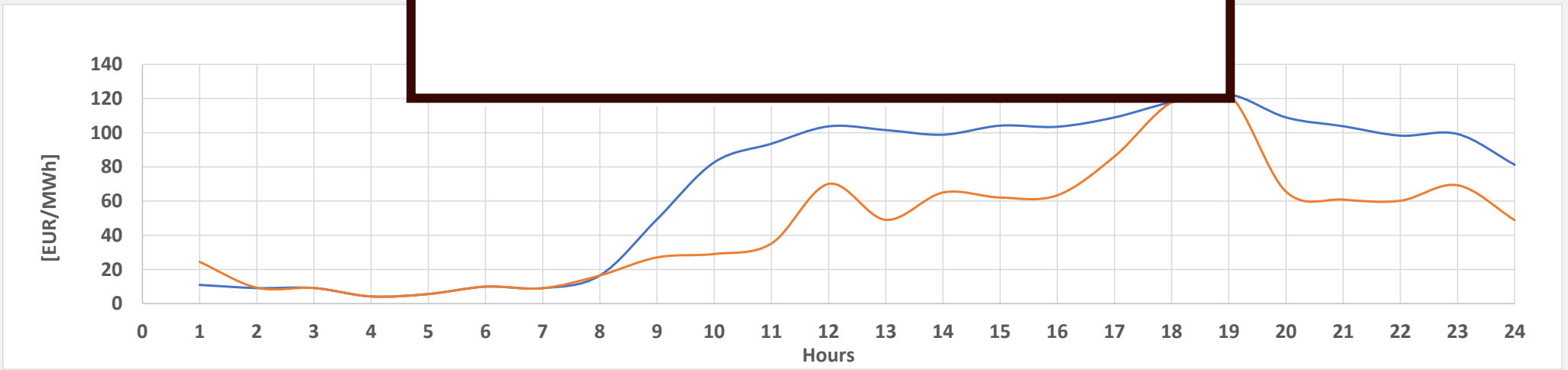
FLUCTUATING ELECTRICITY PRICES – SEEMS TO BE NEW NORMAL



Conclusion – it looks very similar
(as far as I can see)



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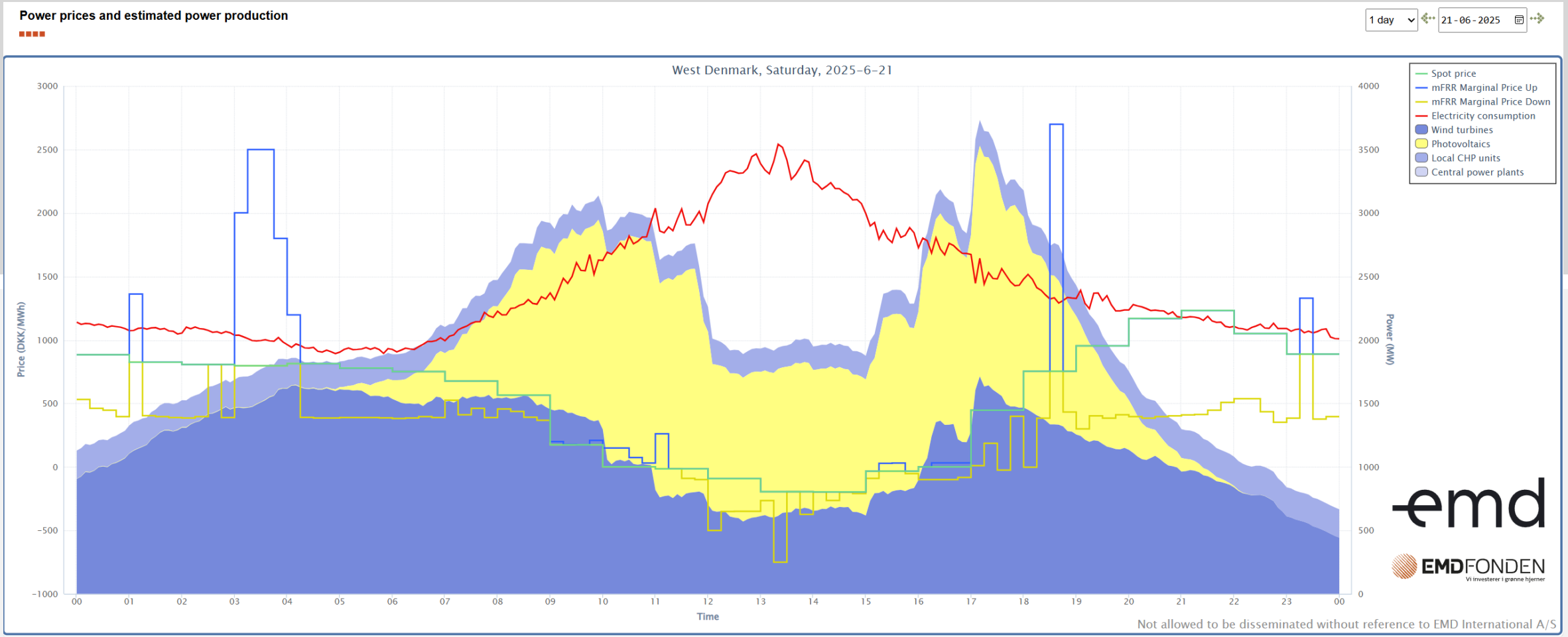
Electrical market in Summer



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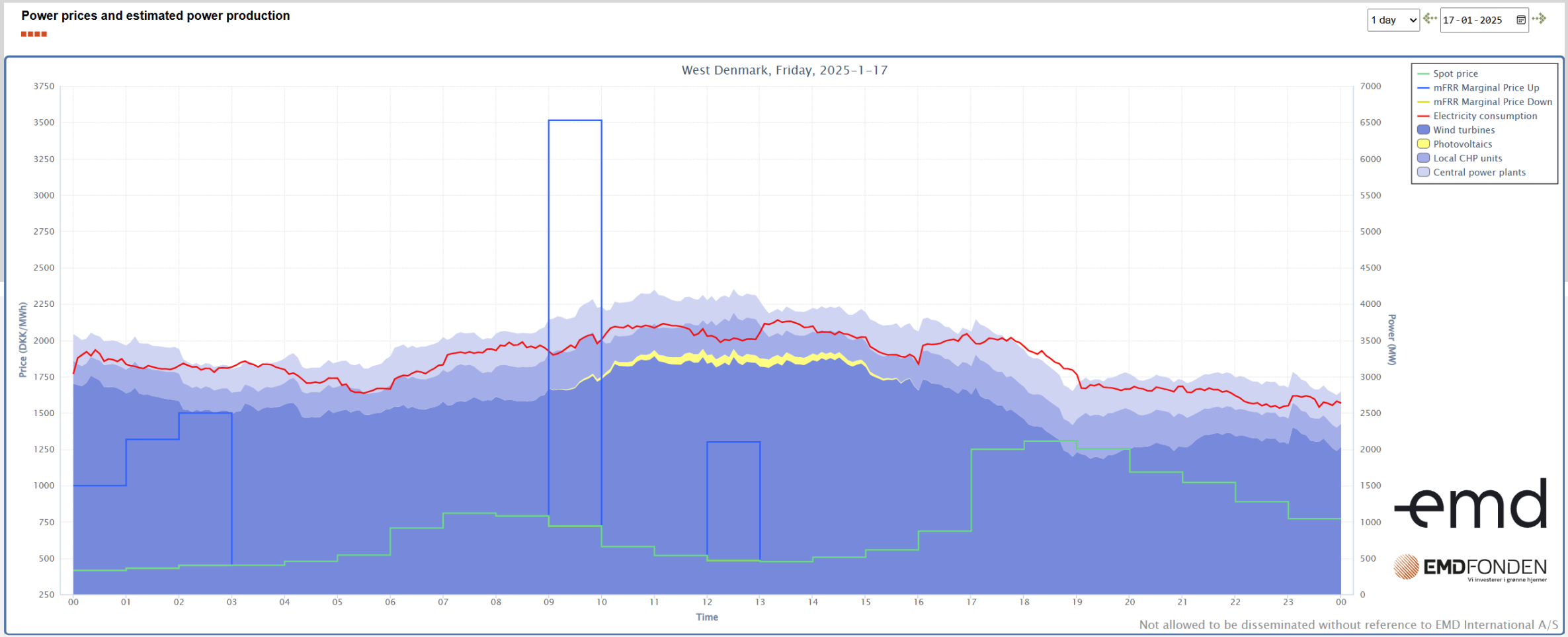
Electrical market in Winter



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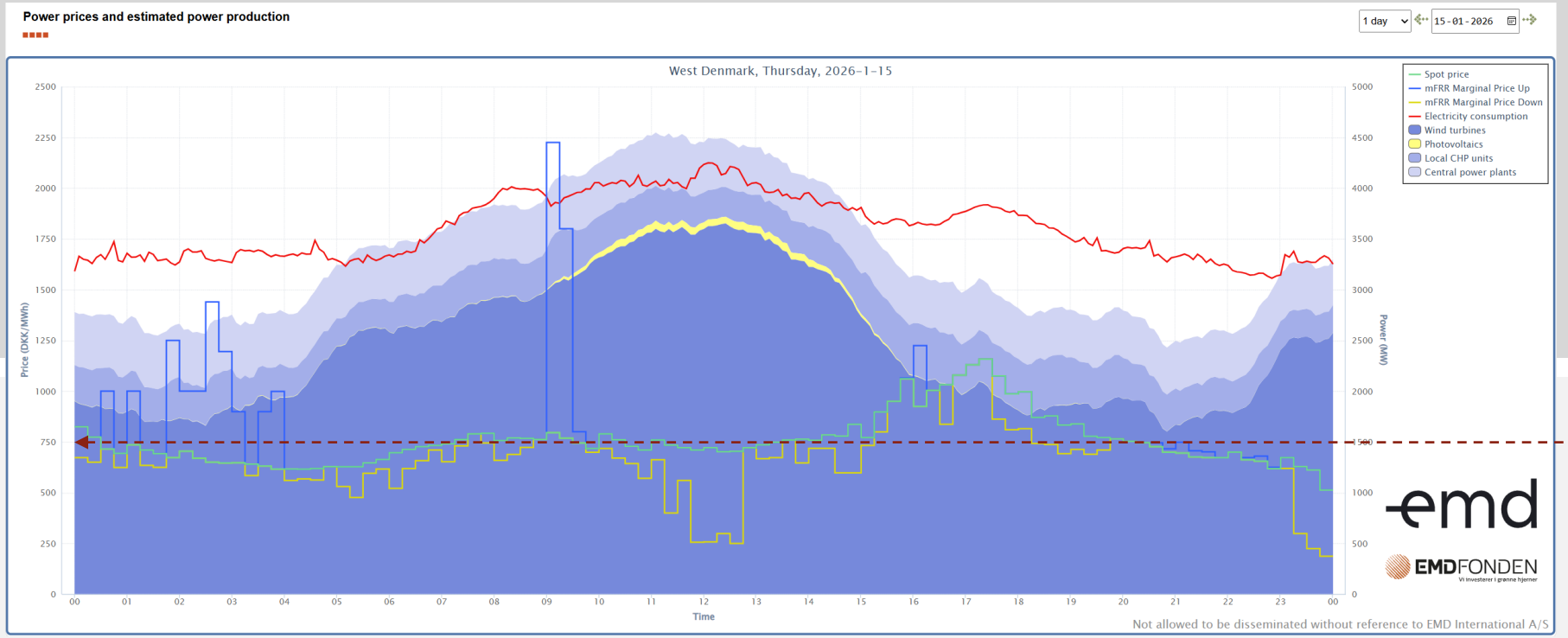
How the commercial part works - example



2 x H-2600 AW

Apparant heat production price
Assumed TSO and DSO tariffs 100 DKR/MWh
Total electrical price is 750 + 100 = 850 DKR/MWh

System COP of the HP that specific day was 2,9.
Price for heat production = 850 / 2,9 = 293 DKR/MWh

Realized heat production price
152 DKR/MWh

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Recommendation for electrifying DH in PL 🇵🇱 and DK 🇩🇰 – storage and flexibility

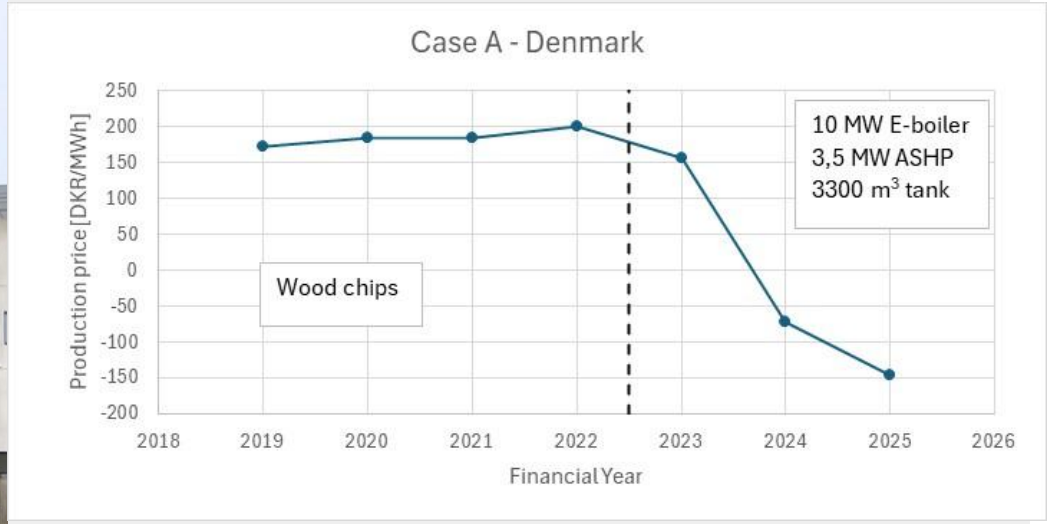

Fig.: Case example for electrification

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Capacity market 2024 og 2025 – (ex. activation market)

Key figures for 2024 in Denmark

Product	No. of purchase hours	Average delivery MW	Average price EUR/MWh	Yearly payment per MW EUR
mFRR up - day (DK1)	8784	355	6	50.904
mFRR up - day (DK2)	8784	200	16	137.343
mFRR down - day (DK1)	1008	19	1	902
mFRR down - day (DK2)	1008	11	1	1.286
mFRR up - day (DK2)	8784	343	18	155.867
aFRR up (DK1)	2175	100	71	153.796
aFRR down (DK1)	2175	100	13	29.188
aFRR up (DK2)	8056	5	31	246.341
aFRR down (DK2)	8056	11	37	295.095
FCR DK1	8784	3	16	143.061
FCR-N DK2	8784	10	48	418.018
FCD-D up DK2	8784	46	10	91.952
FCD-D down DK2	8784	61	27	236.939
FFR up DK2	1505	6	23	35.272
Trading DK1 and DK2	3426	1274	44	150.641

Key figures for 2025 in Denmark

No. of purchase hours	Average delivery MW	Average price EUR/MWh	Yearly payment per MW EUR
8760	378	11	99.150
8760	344	46	407.390
8760	22	1	7.140
8760	21	7	62.432
8760	163	23	214.977
8760	100	36	317.668
8760	100	1	7.130
8760	45	26	222.837
8760	63	9	77.041
8760	7	15	133.266
8760	5	27	235.552
8760	47	6	53.199
8760	70	6	51.870
952	5	17	15.688
3426	1274	44	228.827

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mFRR DK1 – Fenagy standard

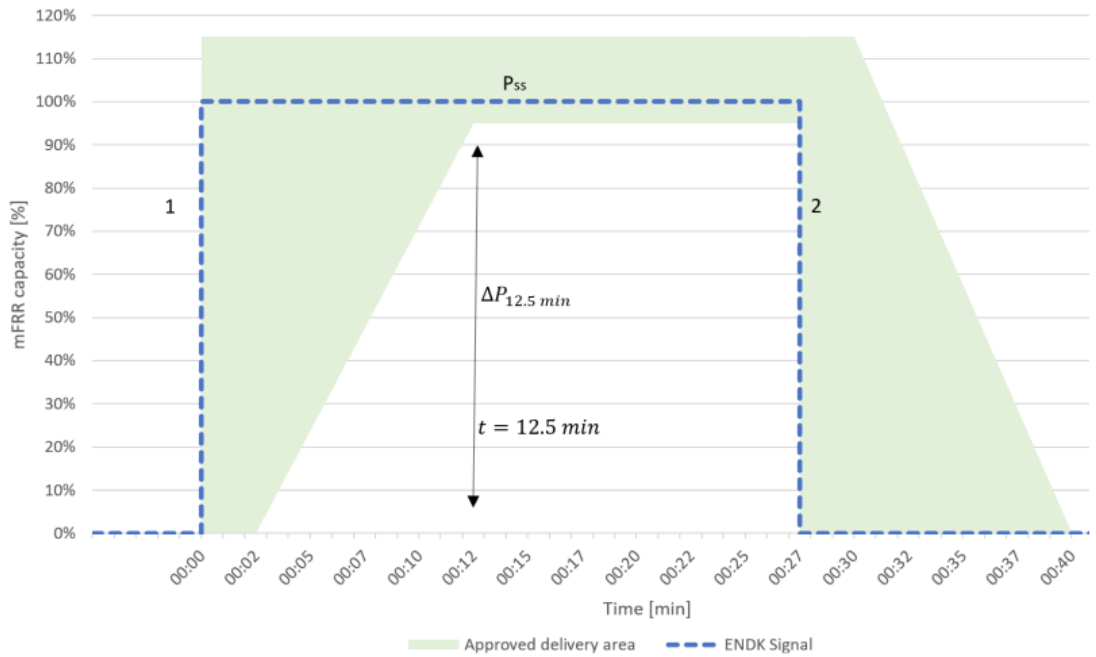

Figure 29 – mFRR upregulation activation response, denoting a full response at 12.5 minutes.

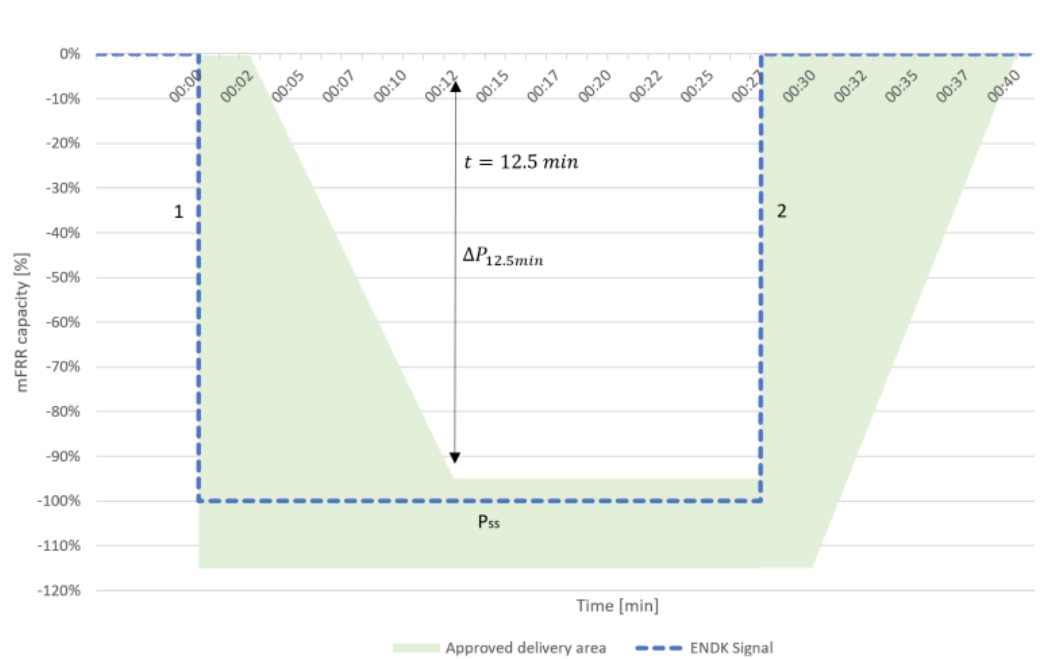

Figure 30 - mFRR downregulation activation, denoting a full response at 12.5 minutes.

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aFRR DK1 and DK2 – New Fenagy standard

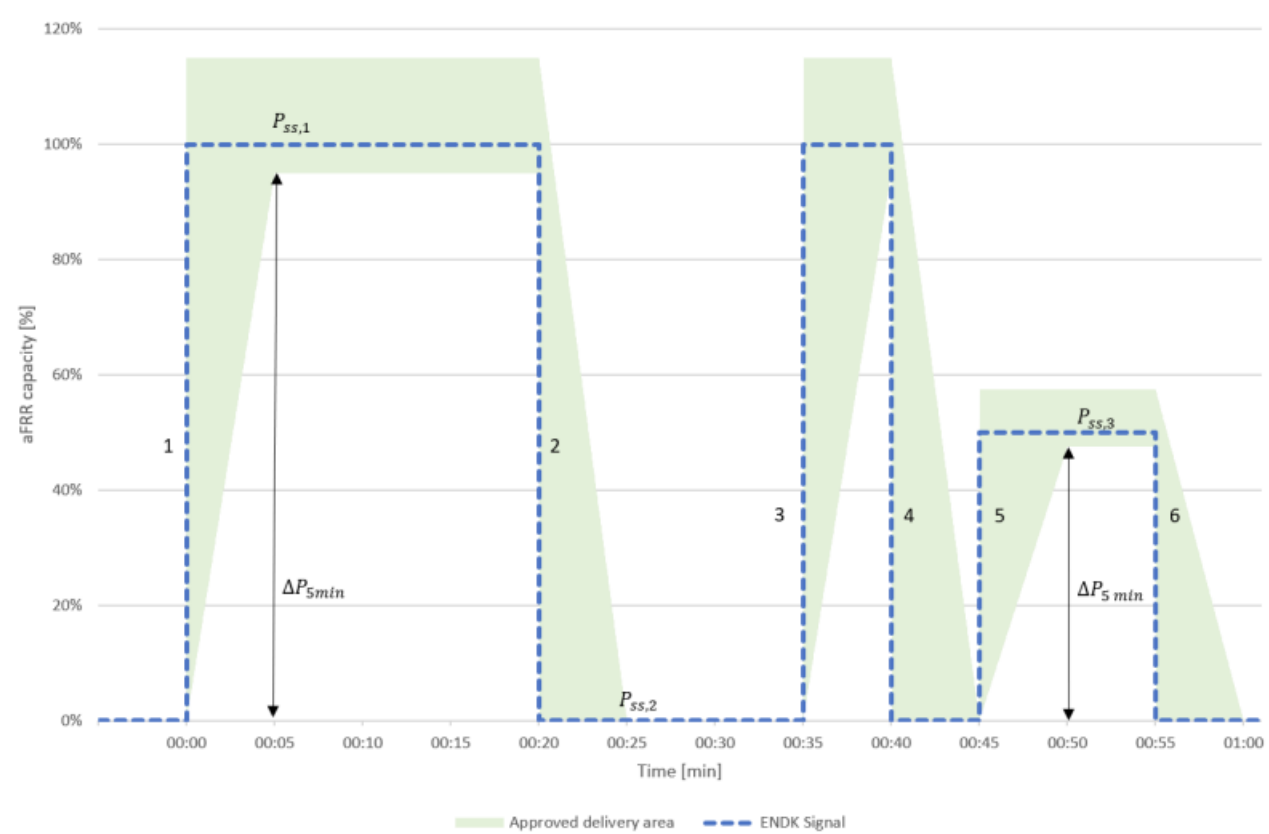

Figure 31 - aFRR functional test response for DK1 and DK2.

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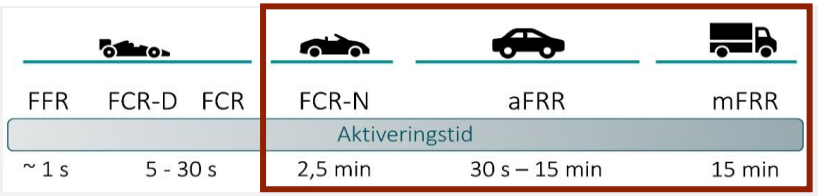
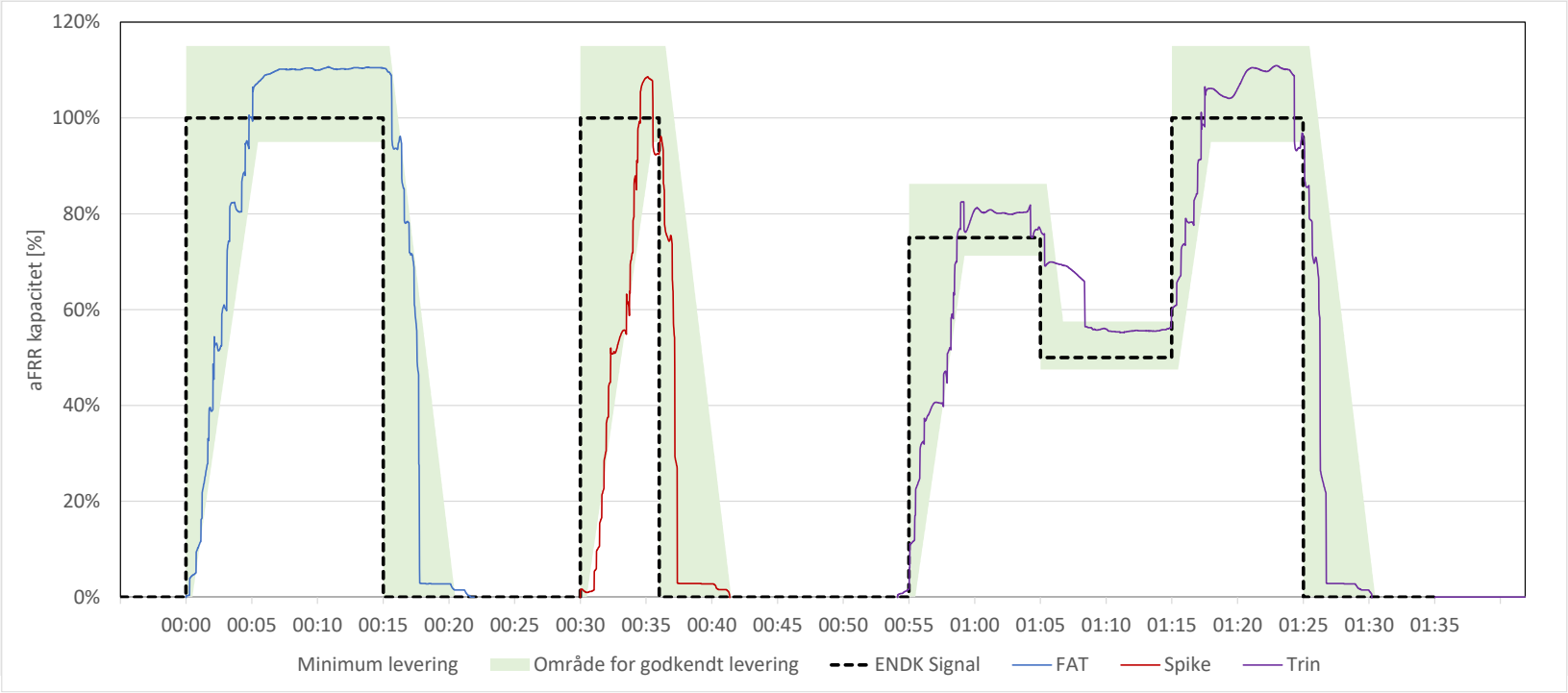
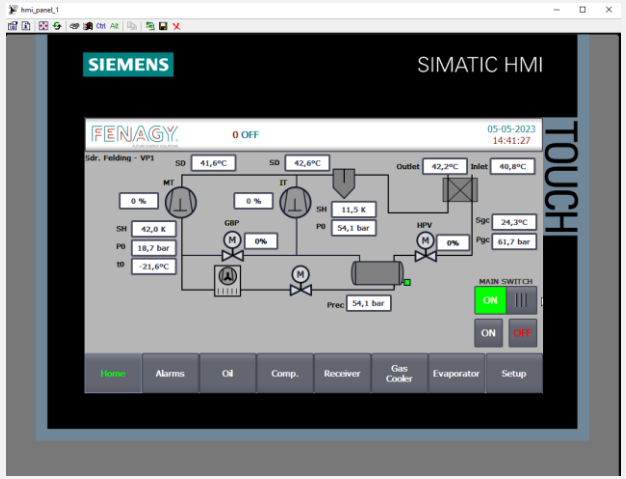
BALANCING ELECTRICAL GRID – TODAY & TOMORROW

- Analysis together with Danish TSO and customer (Energinet)
- aFRR requirements dictate “start” and “stop” within 5 minutes
- We get an automatic signal from the Scada system, so there is no human involvement in activation.
- Conclusion: The machine is the first HP to be approved for aFRR







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Billund DH: New experiences with system services

ENERGINET

BILLUND VARMEVÆRK
Rugmarken 2
7190 Billund

Energinet
Tonne Kjærsvej 65
DK-7000 Fredericia
+45 70 10 22 44
info@energinet.dk
CVR-nr. 28 98 06 71

Dato:
24. februar 2026
Forfatter:
HTH

GODKENDELSE AF LEVERING AF SYSTEMYDELSER I DK1

BILLUND VARMEVÆRK

Hermed et svar på jeres anmodning om godkendelse til levering af systemydelser.

For at et anlæg kan tildeles denne tilladelse, skal der foreligges dokumentation for, anlæggets overensstemmelse jf. "SYSTEMYDELSER TIL LEVERING I DANMARK UDBUDSBETINGELSER" og "Prequalification of aggregated portfolios and units v 2.2.1".

Anlægget har følgende GSRN: **571313134499988832**

Tilladelsen skal vurderes på baggrund af følgende dokumentation som efterviser de tekniske krav i ovennævnte udbudsbetingelse og prækvalifikationstest:

1. Tilsendt dokumentation for kommunikationssetup og testmanual.
2. Tilsendt måledata for prækvalifikationstesten.

På baggrund af ovenstående dokumentation, kan det meddeles at anlægget lever op til krav specificeret, hvorfor anlægget godkendes som leverandør af:

Produkt	Godkendt mængde op	Godkendt mængde ned
aFRR EAM	5.52 MW	5.52 MW
aFRR CM	5.52 MW	5.52 MW
mFRR EAM	5.52 MW	5.52 MW
mFRR CM	5.52 MW	5.52 MW

Nærværende godkendelse er gyldig så længe de tekniske egenskaber er intakte og frem til **24. februar 2031**.

Dette dokument fungerer som en bekræftelse på den maksimale tekniske kapacitet, som et anlæg eller en portefølje kan levere. Det er anlægsejerens ansvar at sikre, at de ikke overbyder deres kapacitet. Er der i det forelagte grundlag, mangler eller fejlagtige oplysninger forbeholder Energinet sig retten til at revurdere afgørelsen.

Eventuel klage over Energinets afgørelse kan rettes til Forsyningstilsynet, Torvegade 10, 3300 Frederikssund.

Med venlig hilsen

Prækvalifikationsteamet
PQ.Audits@energinet.dk
Energinet

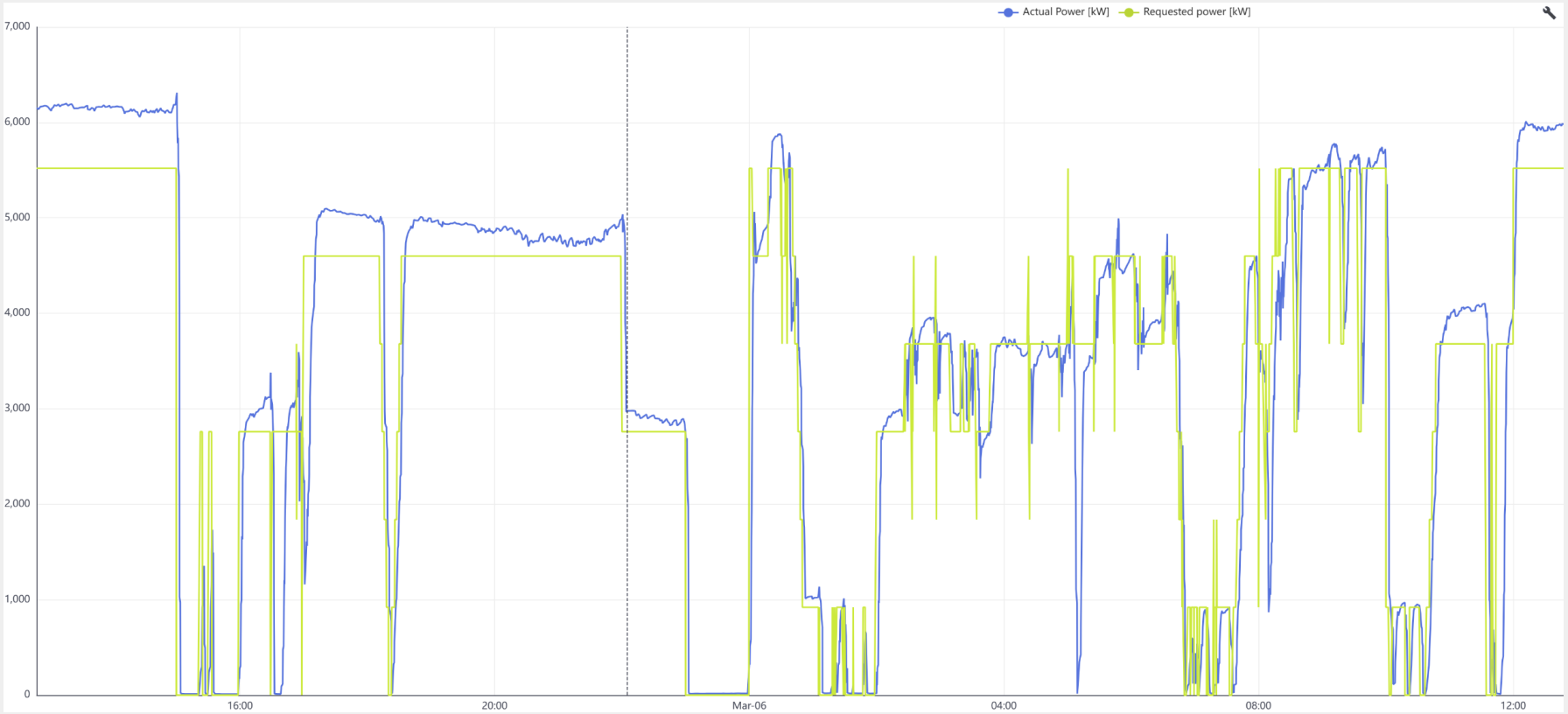

Fig.: Illustration of 24-hour operation of Billund's 6 x H-2600 AW heat pumps on 06/3-2026

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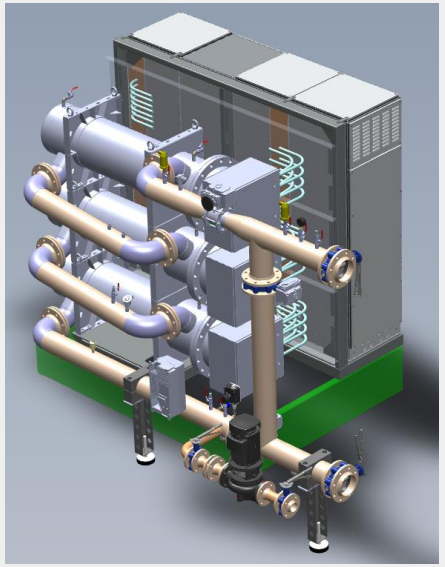
System services
DK probably the only place in the world where HP's are used in **aFRR**

- Fenagy has 4 air-to-water heat pumps in operation which are used in the **aFRR** market
- Exchange of experience with frontrunners: Sdr Felding, Ølgod, Hanstholm and Bramming

FENpower



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Whatever you do please choose a **Natural refrigerant!**

CO2 (R744)	Hydrocarbons (R290, R600a)	Ammonia (R717)
• GWP 1 • A1 Classification • High operating pressures • Low critical point	• GWP <5 • A3 Classification • Flammable	• GWP 0 • B2L Classification • Flammable/toxic
Applications - District heating - Industrial processes - Air & water source	**Applications** - District heating - Industrial processes - Waste heat use - CO_2 subcooler	**Applications** - District heating - Industrial processes - Waste heat use - Mainly water source

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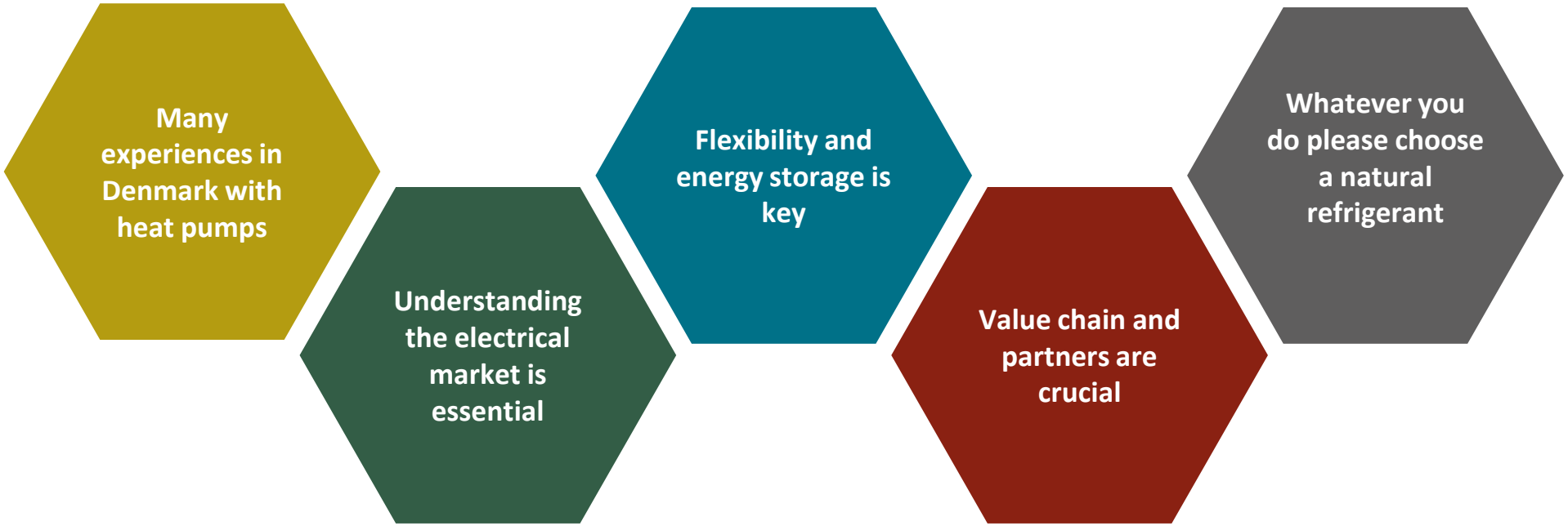
Summary



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Thank you for listening! 😊

Andreas Zourellis

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Benelux and Eastern Europe

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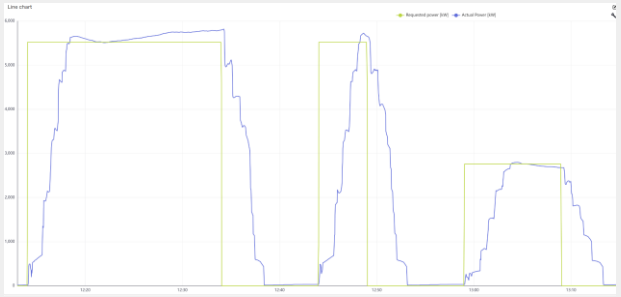
Supportive Slides

FENAGY

Billund nye erfaringer med systemydelser – MAYBE ????

- Prækvalifikation til systemydelser er én ting – praksis er noget andet
- aFRR hvert 4. sekund kommer der et nyt setpunkt?
- Signalbehandling i SCADA af DME, hvem gør hvad og hvilken strategi har kunden for indmelding til balanceansvarlig?
- Fremover sendes kapacitetssignalet direkte videre til Fenagy Mastercontroller og så klarer Fenagy prækvalifikationen 100%



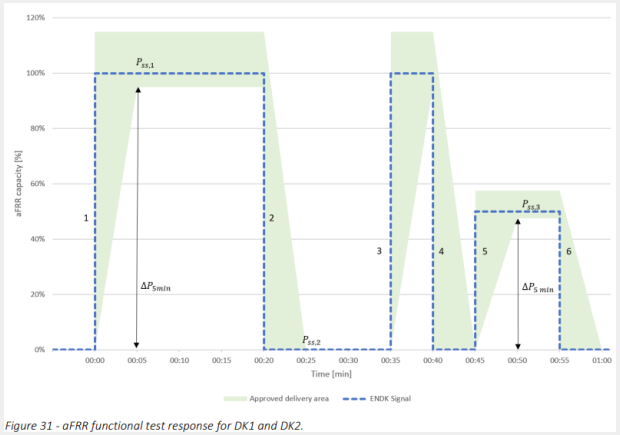


Figure 31 - aFRR functional test response for DK1 and DK2.