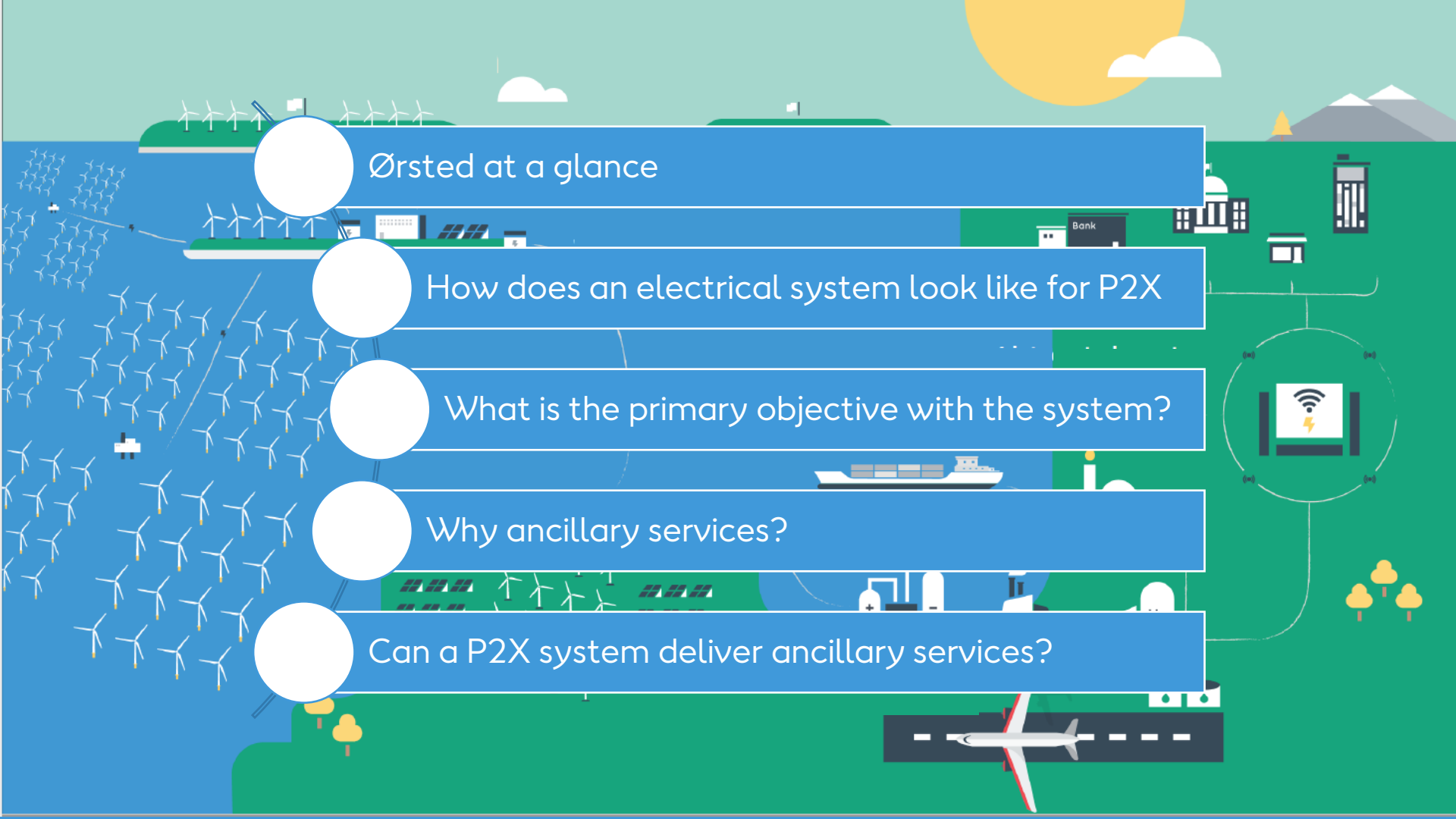
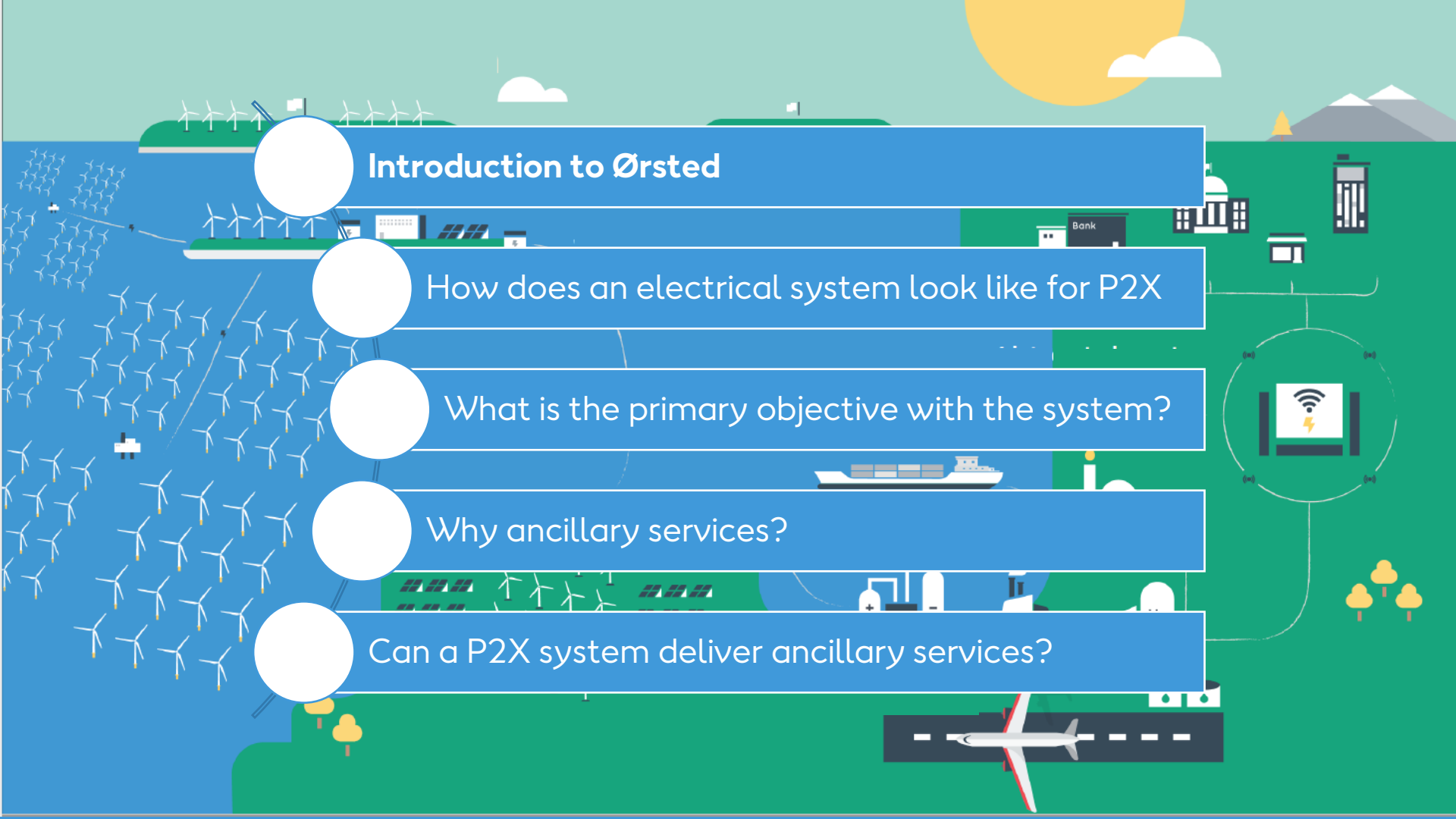
Ørsted

Brintbranchen – Ancillary service and P2X

November 2023


Bank
NH3
H2


Ørsted at a glance
How does an electrical system look like for P2X
What is the primary objective with the system?
Why ancillary services?
Can a P2X system deliver ancillary services?
Bank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Keys steps in Ørsted's transformation to a green energy major

2012
Transformation plan started

Strong **financial pressure** and **negative business outlook**

2016
Ørsted IPO

Restructuring of Ørsted business incl. stronger financials and exit from O&G activities

2017
Oil & Gas exit

Upstream oil and gas activities sold to INEOS and **liquified natural gas** activities to Glencore

2017
Name change

Name change **from DONG to Ørsted** and new vision set to create a world that runs entirely on green energy

2019
Divest power distribution

Ørsted **sold its Danish power distribution**, **residential customer** and **City Light businesses** to Andel

Ørsted develops energy systems that are green, independent and economically viable

Installed | Under construction

Offshore wind

- Global leader in offshore wind
- Develop, construct, operate and own offshore wind farms
- Ambition to reach ~28 GW installed capacity by 2030

Onshore renewables

- Strong presence in the United States and Europe
- Develop, operate and own onshore wind, solar PV and storage projects
- Ambition to reach ~17.5 GW installed capacity by 2030

Bioenergy & other

- Presence in Europe, including bioenergy plants, legacy gas activities and patented waste-to-energy technology
- Own and operate bioenergy and waste-to-energy plants, and optimise gas portfolio
- Ambition to reach ~2 GW installed capacity by 2030

Renewable hydrogen and green fuels

- Emerging platform with 10 pipeline projects (+2 GW) mainly in Europe
- Develop, construct, own and operate hydrogen facilities
- Ambition to become a global leader in renewable hydrogen and green fuels by 2030
- Ambition to reach >2 GW installed capacity by 2030

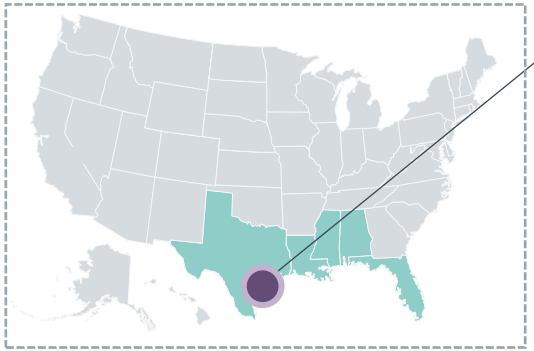
8.9

4.6

Source: Ørsted Interim report Q2 2023

Ørsted is developing a diverse range of global projects with various partners and key stakeholders

Product: Hydrogen eMethanol Multiple **Offtake segment(s):** Heavy transport Refineries Chemicals & fertilizers Steel



Project Star
• 580 MW
Ørsted MAERSK

Idomlund
• 150 MW
Ørsted SKOVGAARD ENERGY

FlagshipONE
• 70 MW
Ørsted

GFDK[1,2]
• 1.3 GW
MAERSK DFDS SAS DSV Ørsted MOLSLINJEN TOPSOE Everfuel COWI BCG nel

H2RES
• 2 MW
Brintbranchen DSV ENERGINET Everfuel nel Ørsted

SeaH2Land
• 1000 MW
ArcelorMittal YARA DOW Ørsted

Haddock[2]
• 100 MW
YARA Ørsted

Westküste 100[3]
• 30 MW
RAFFINERIE HEIDE REGION HEIDE Holcim hynamics hega Ørsted

1. Green Fuels for Denmark (GFDK)
2. Project has received IPCEI status
3. Project has received Reallabor status

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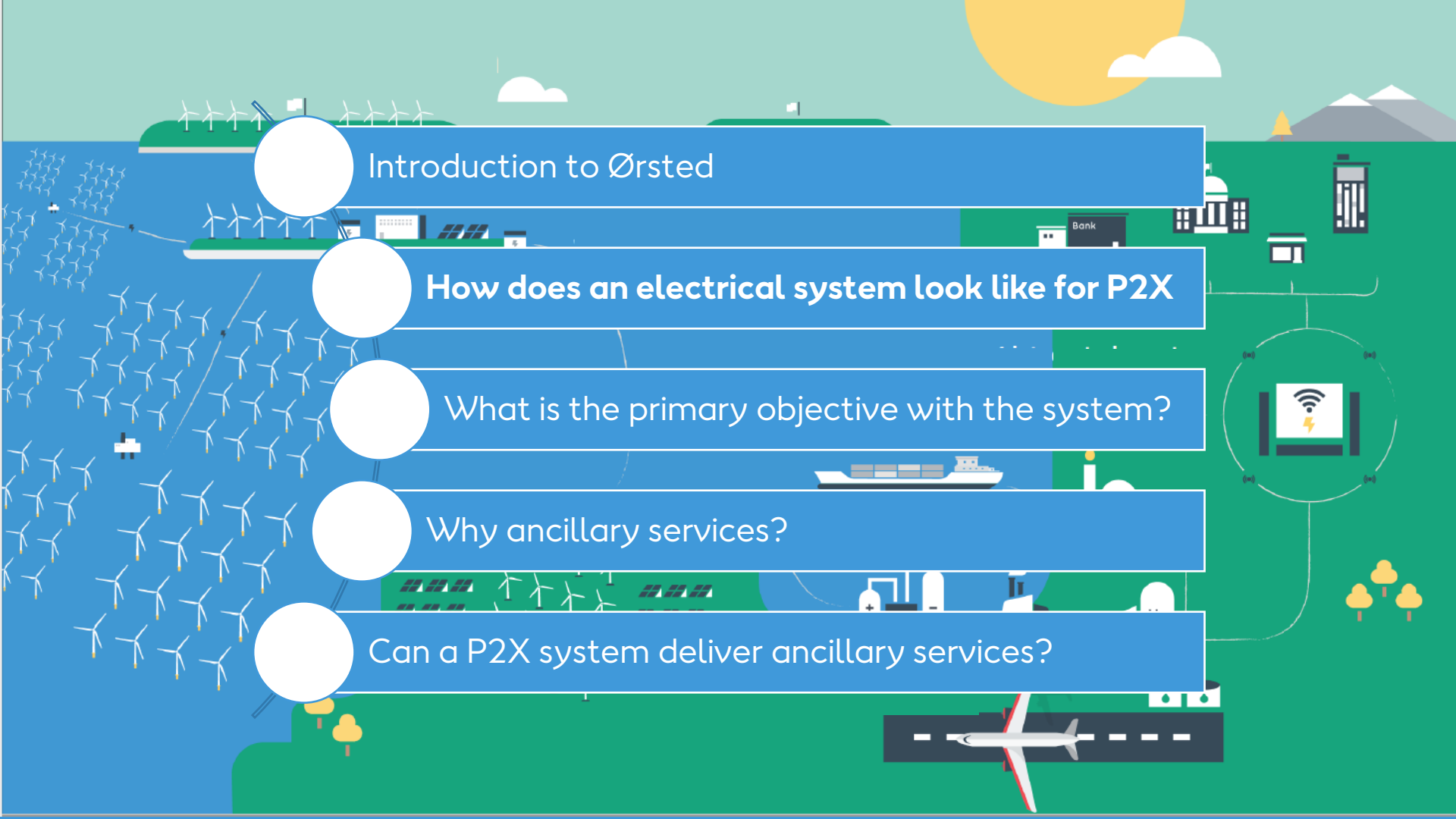
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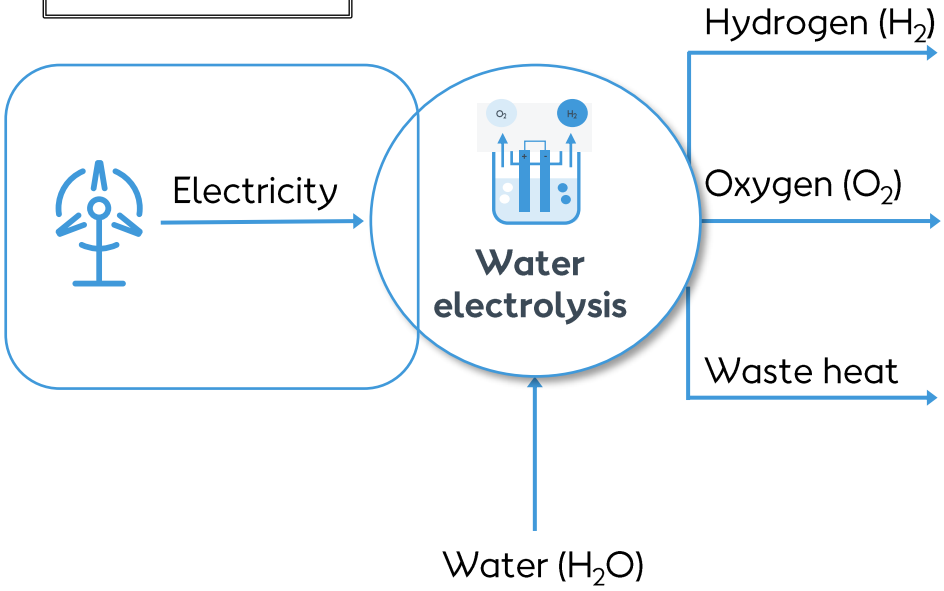
Energy efficiency and power consumption

Water electrolysis

In electrolysis, an external voltage is applied to drive a nonspontaneous reaction.

$$H_2O \rightarrow H_2 + ½O_2$$



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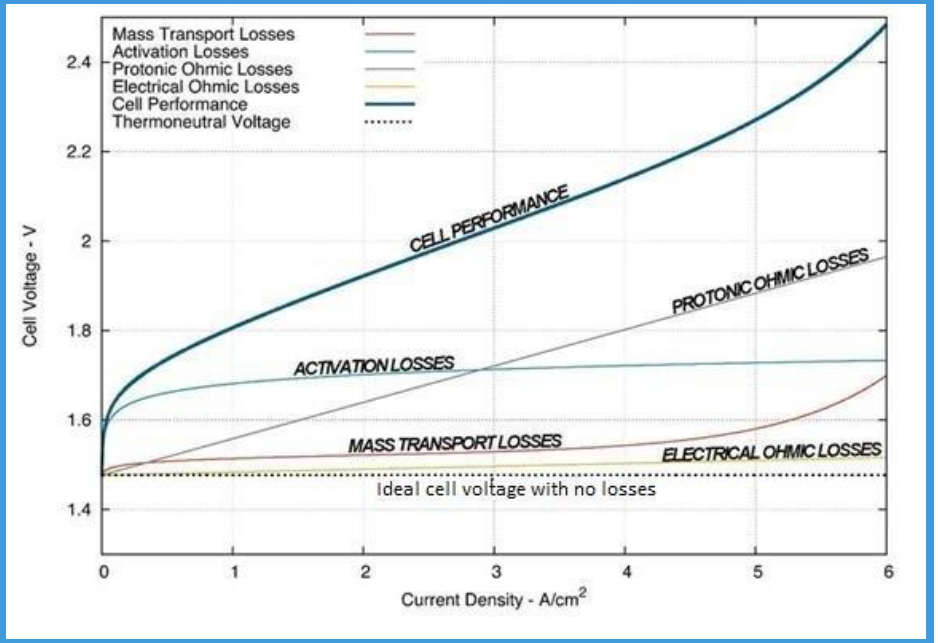


The stack size

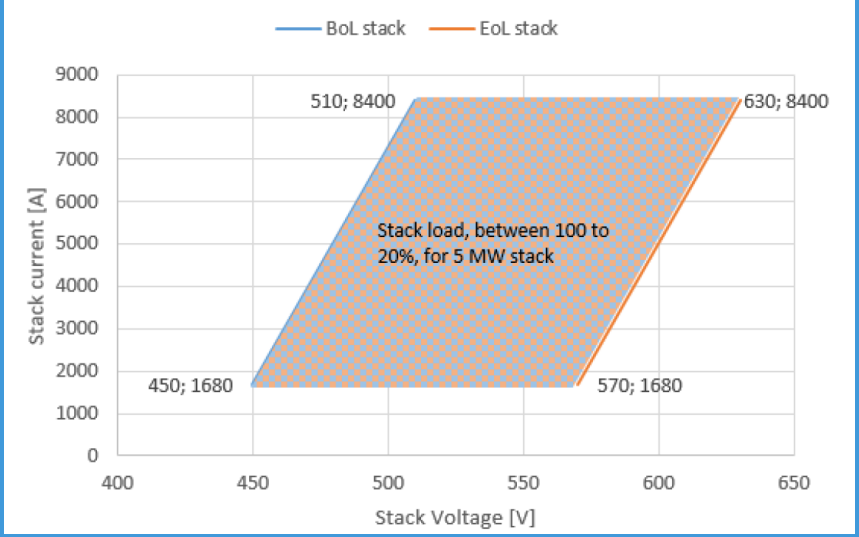
Each hydrogen cell will need between 1.5 to 2.3 V above.

To increase the voltage, the cell need to be connected in series

Higher voltage, more hydrogen, but less efficient

The hydrogen output, can be change, with varying the voltage above the cell

Polymer electrolyte membrane electrolysis - Wikipedia (wecanfigurethisout.org)



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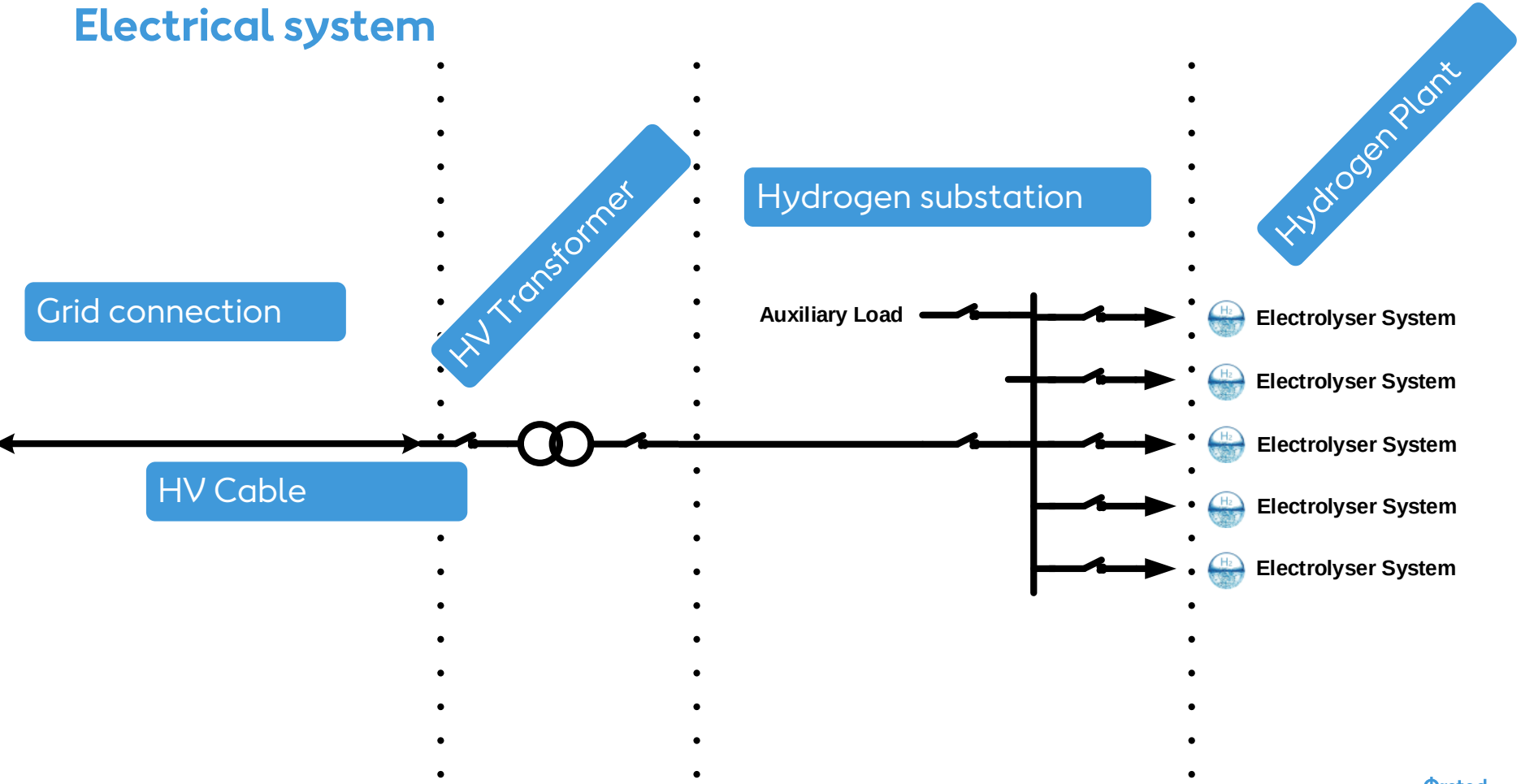
Electrical system



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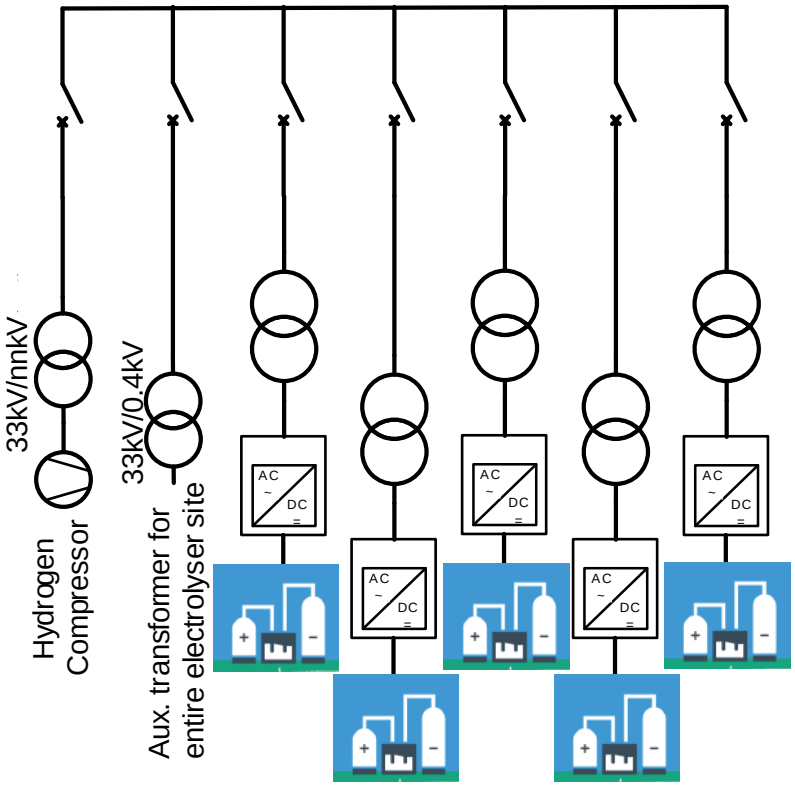
Electrical system – Electrolyser converter



Basic requirements for Electrolyser

- Convert electricity from 33kV, to around 1kV
- Create DC for the electrolyser
- Take care of volage variation over time

Electrical requirements

- Variable power profile (PPA)
- Ensure compliance with harmonic emissions

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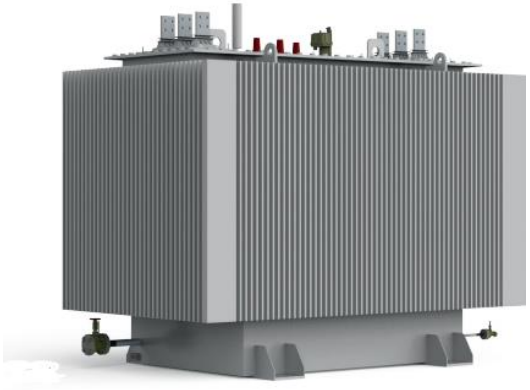
Electrolyser transformer

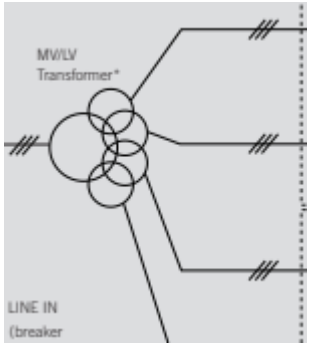
Why?

- Convert electricity from 33kV, to around 1kV
- Compensate harmonics
- Take care of voltage variation over time

Where?

- Connection to the Electrical transmission system





Power transformer - Ingeteam GmbH - immersed / for outdoor service / for photovoltaic applications (directindustry.com)

PRD_4427_Archivo_ingecon-h2-powerstation-fsk-e6000-e12000-en.pdf (ingeteam.com)

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Electrolyser transformer

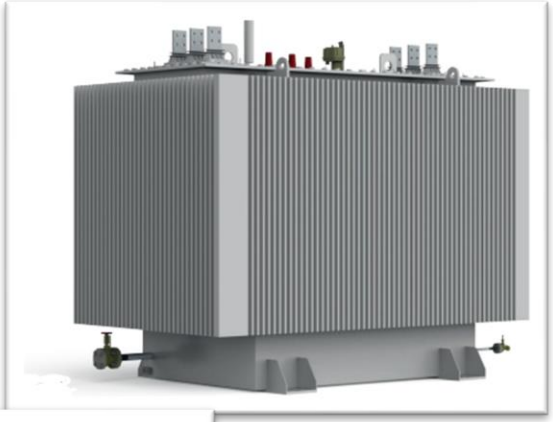
Can be of different type

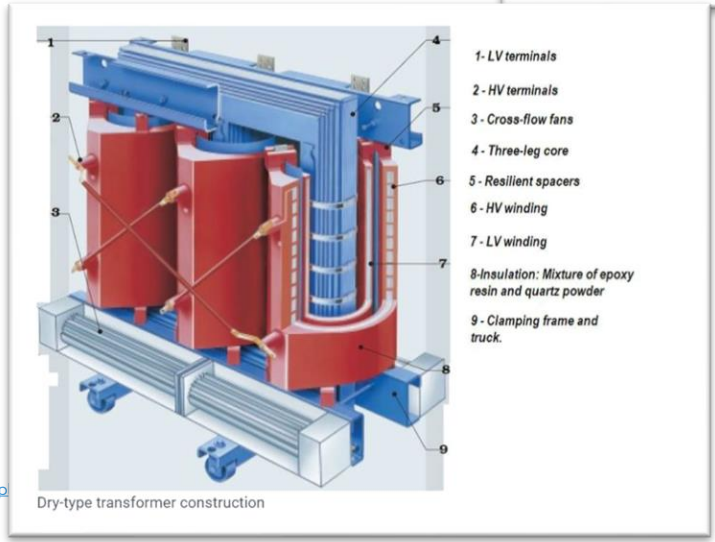
Out/Indoor installation

- Oil filled transformer
- Ester filled transformer

Indoor installation

- Dry type transformers





Dry-type transformer construction

Power transformer - Ingeteam GmbH - immersed / for outdoor service / for photovoltaic app (directindustry.com)

GEAFOL Transformers (siemens-energy.com)

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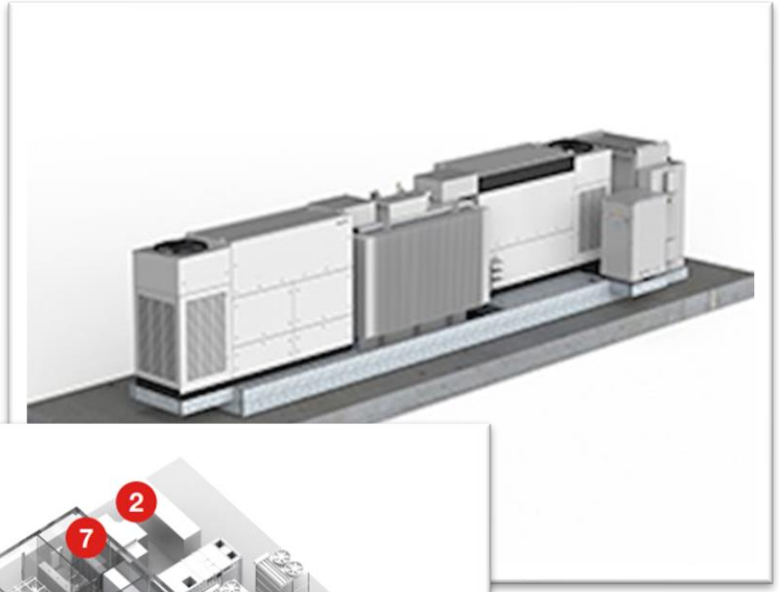
Electrolyser converter

Why?

- Convert electricity from AC to DC
- Compensate harmonics
- Take care of voltage variation over time

Where?

- Connection to the Electrolyser transformer
- Feeding power to the Electrolyser



cummins-hydrogen-generation-brochure-20210603.pdf

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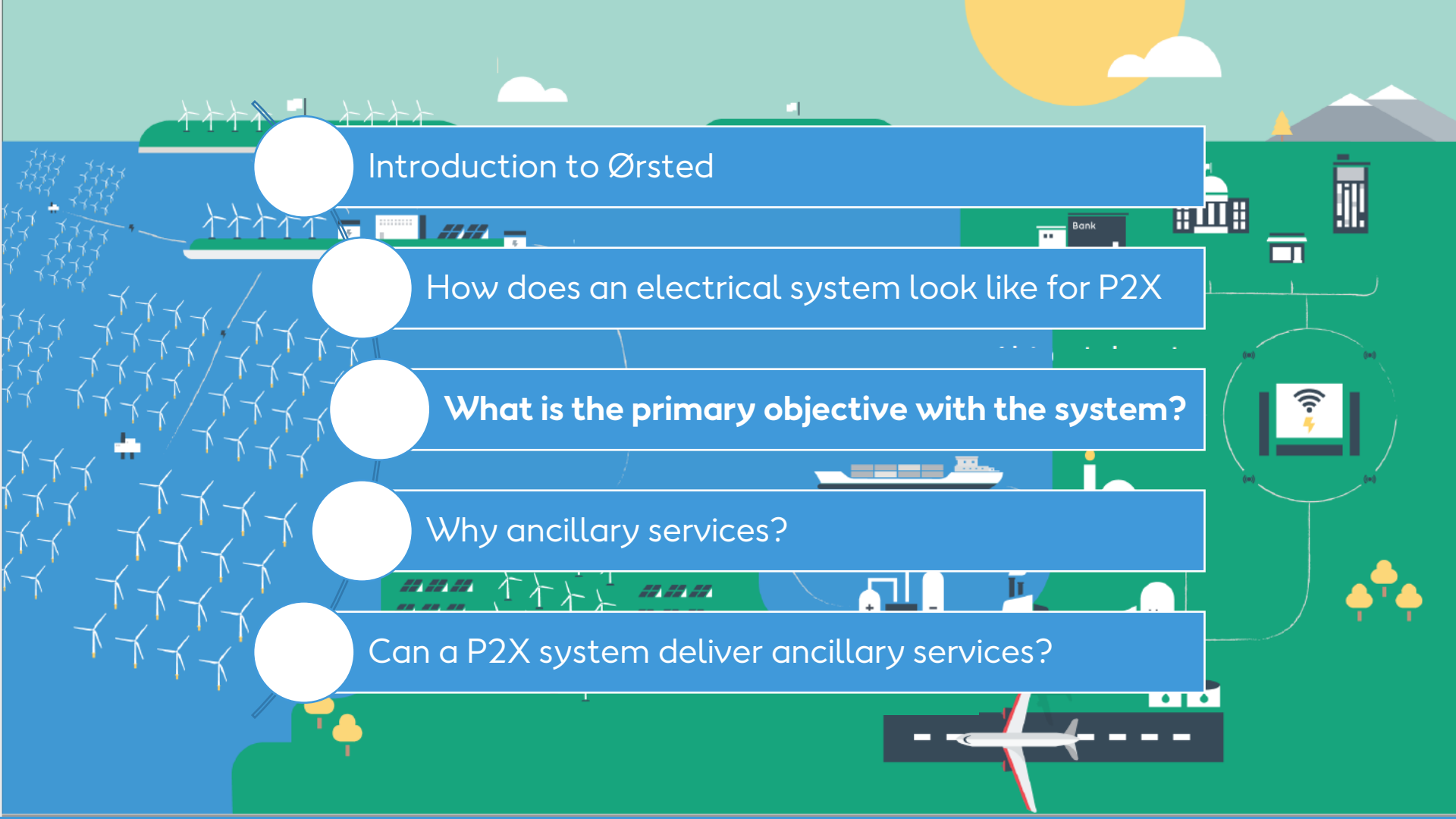
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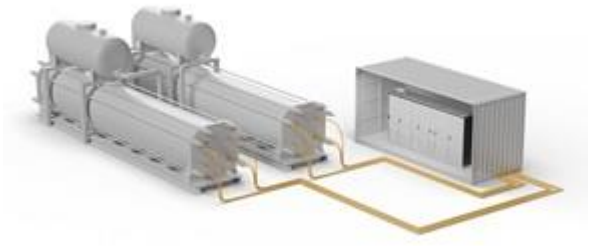
What is the primary objective with the system?

Deliver power to the electrolyser

- DC Power to the Electrolyser stack

Grid services?

- Lower hydrogen production
- Overcapacity in the system

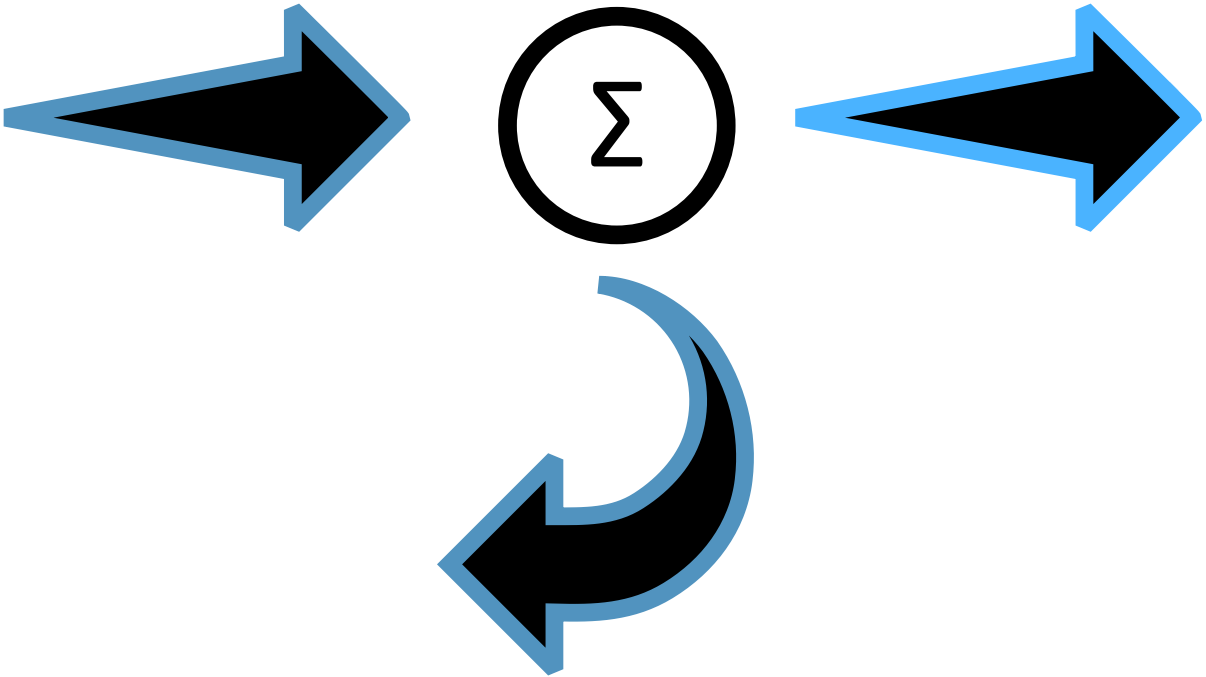


DC Power supply for Hydrogen production - DC drives and power controllers | ABB

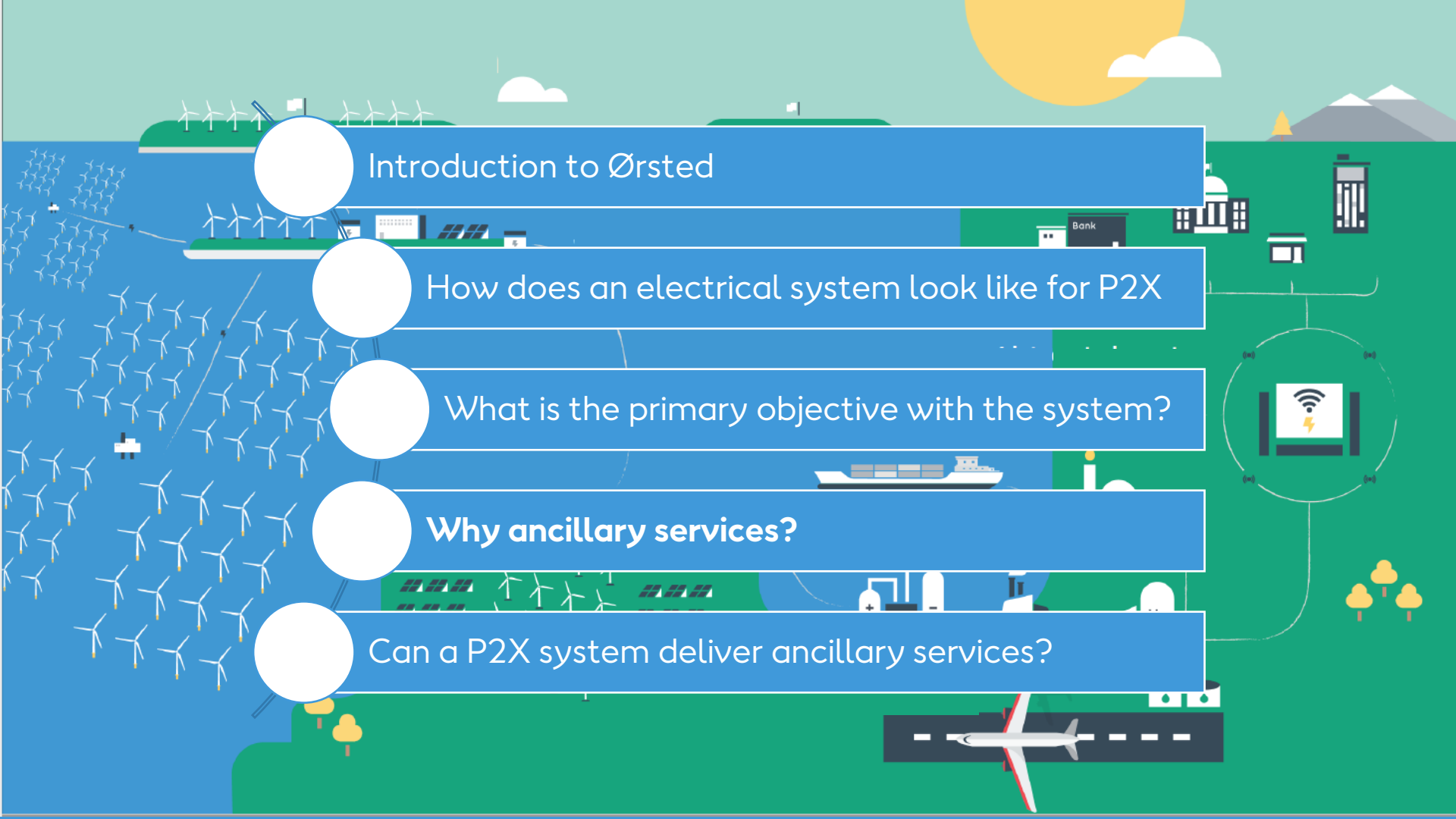
What is the primary objective with the system?

Renewable Power

Hydrogen



Grid services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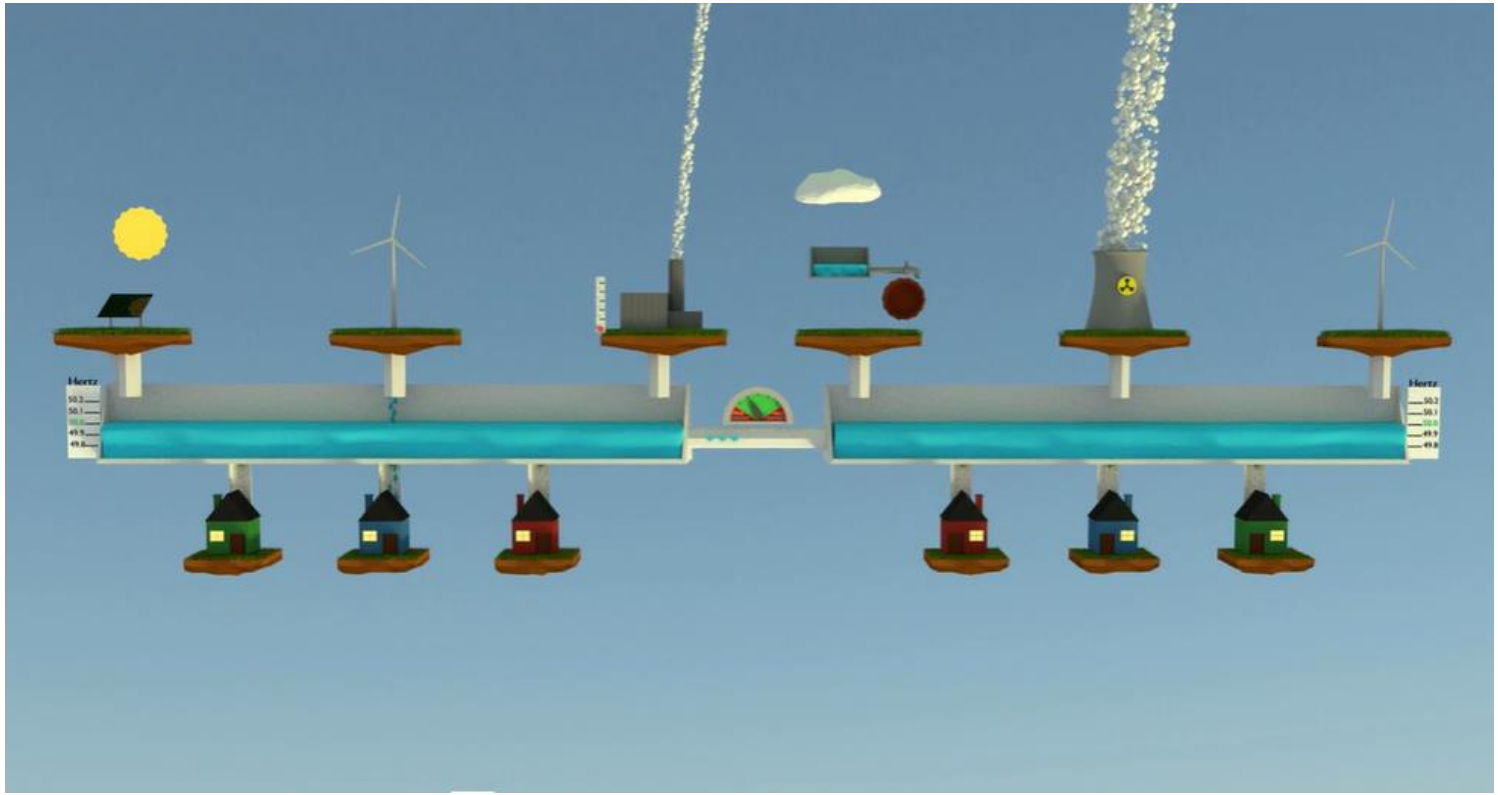
Why ancillary services?



Systemydelser (energinet.dk)

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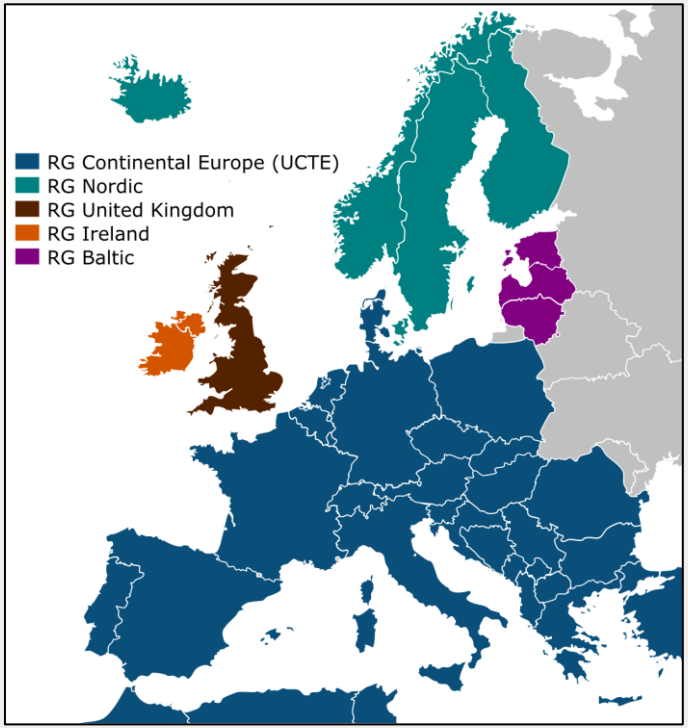
Synchronous areas

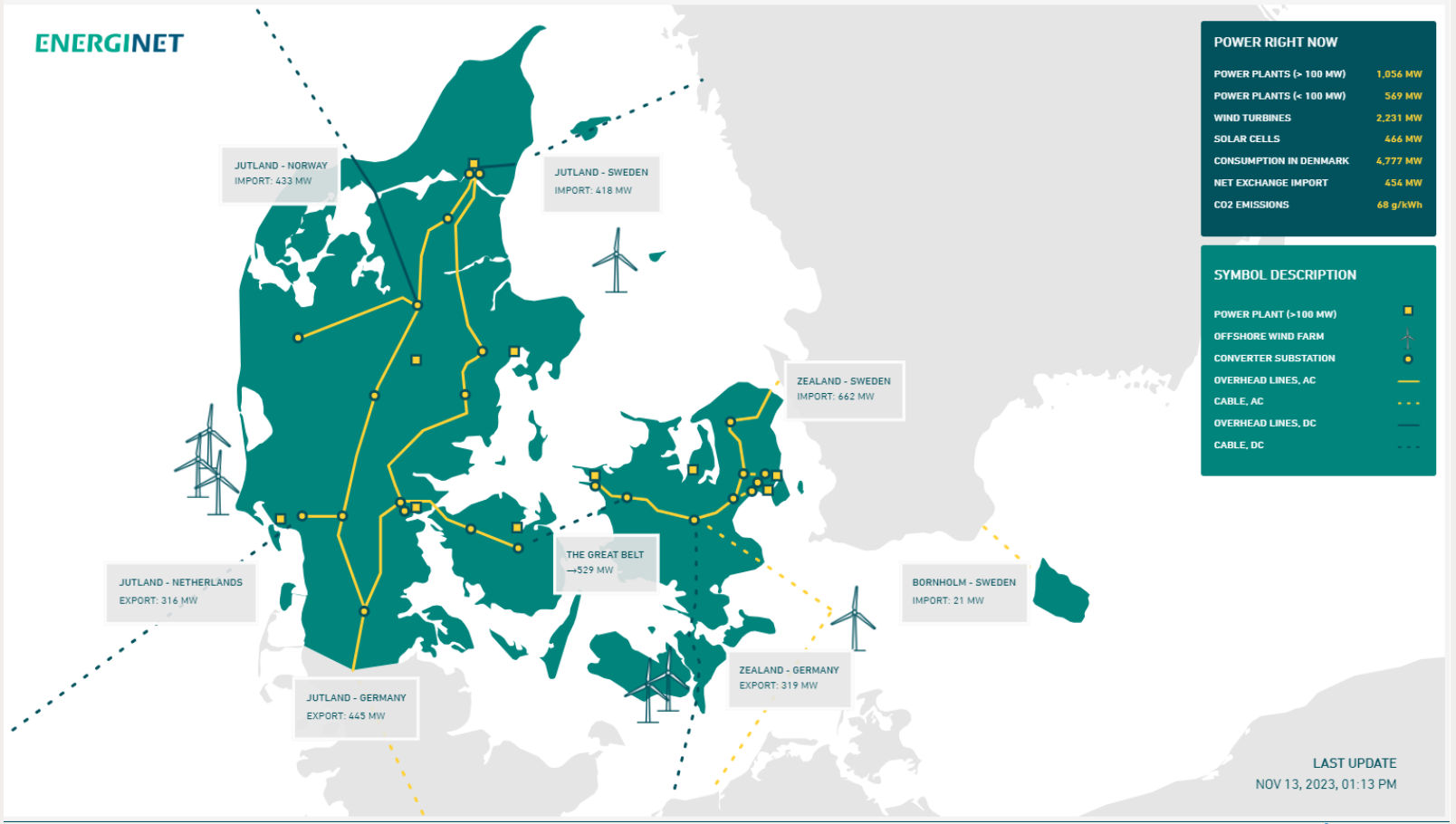


Jutland and Fuen are connected to continental Europe

Zealand is connected to the Nordic

Synchronous grid of Northern Europe - Wikipedia

Synchronous areas – Interconection



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Ancillary service types overview

Primary reserve

- **FFR : Fast Frequency Reserve (DK2)**
  - In the event of major system disturbances in low inertia situations, the Fast Frequency Reserve (FFR) is a fast reserve used to regulate the frequency in case of substantial frequency drops resulting from the outage of major generation units or lines. FFR is necessary in situations with low inertia as frequency-controlled disturbance reserves (FCR-D) in the Nordic synchronous area cannot by itself maintain frequency above the specified threshold values in these situations in the event of major outages.
- **FCR : Frequency-containment reserve (DK1**)
  - In the event of frequency deviations, the primary reserve regulation must ensure that the balance between generation and demand is restored, stabilising the frequency at close to, but deviating from 50 Hz
- **FCR – N :Frequency-controlled normal operation reserve (DK2)**
  - In the event of frequency deviations, the frequency-controlled normal operation reserve ensures that the equilibrium between generation and demand is restored, keeping the frequency close to 50 Hz.
- **FCR – D : Frequency-controlled disturbance reserve (up/down) (DK2)**
  - In the event of major system disturbances, the frequency-controlled disturbance reserve is a fast reserve used for regulating the frequency following substantial frequency drops resulting from the outage of major generation units or lines.

Secondary reserve

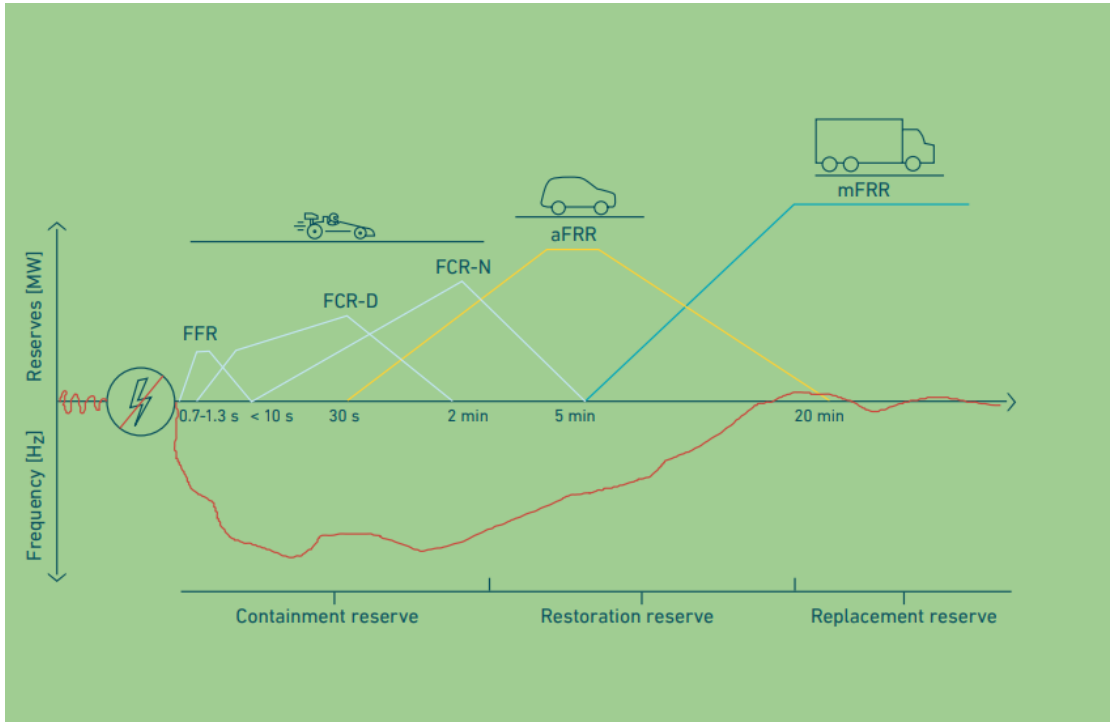
- **aFRR - Automatic Frequency Restoration Reserves**
  - In the event of major system disturbances, the aFRR reserves are used to indirectly restore frequency to 50 Hz following the stabilisation of the frequency by means of power frequency control.
  - The secondary reserve serves two purposes. One is to release the primary reserve if this has been activated, i.e. restore the frequency to 50.00 Hz. The other purpose is to restore any im-balances on the interconnections to the agreed plan.

Manual reserve

- **mFFR : Manual Frequency Restoration Reserve**
  - Manual reserve is a manual upward and downward regulation reserve which is activated by Energinet's Control Centre. The reserve is activated by manually ordering upward and downward regulation from the relevant suppliers. Energinet only buys upward regulation reserves. The reserve relieves the aFRR and the frequency-controlled normal operation reserve in the event of minor imbalances and ensures balance in the event of outages or restrictions affecting generation units and interconnections.

Ancillary service types overview

- Activation time for ancillary services.
- How often are they expected to be activated?
- How much energy do they need?
- Inertia



outlook-for-ancillary-services-2023-2040.pdf (energinet.dk)

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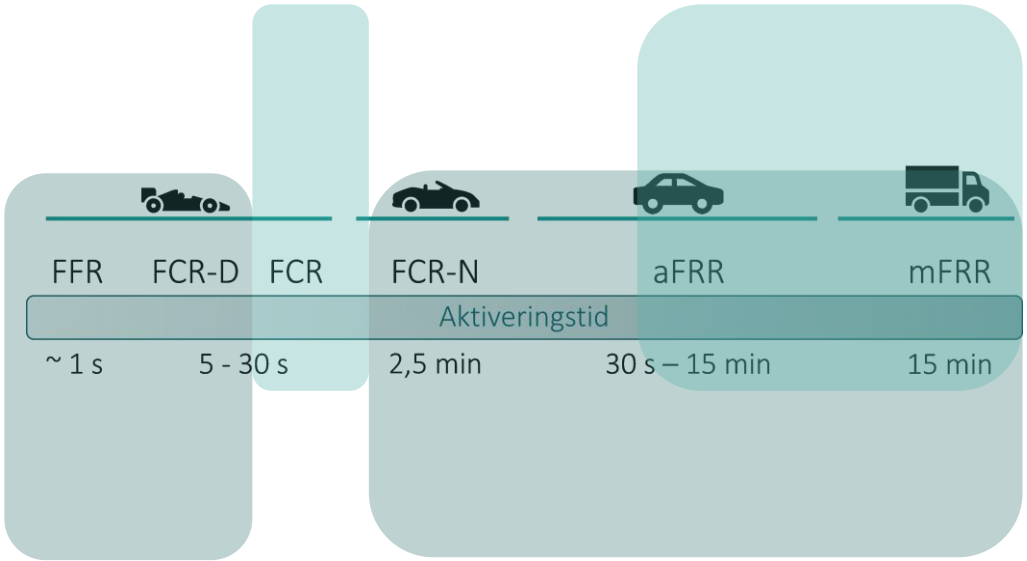
Ancillary service types overview



Oversigt over systemydelser (energinet.dk)

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MARKET OVERVIEW

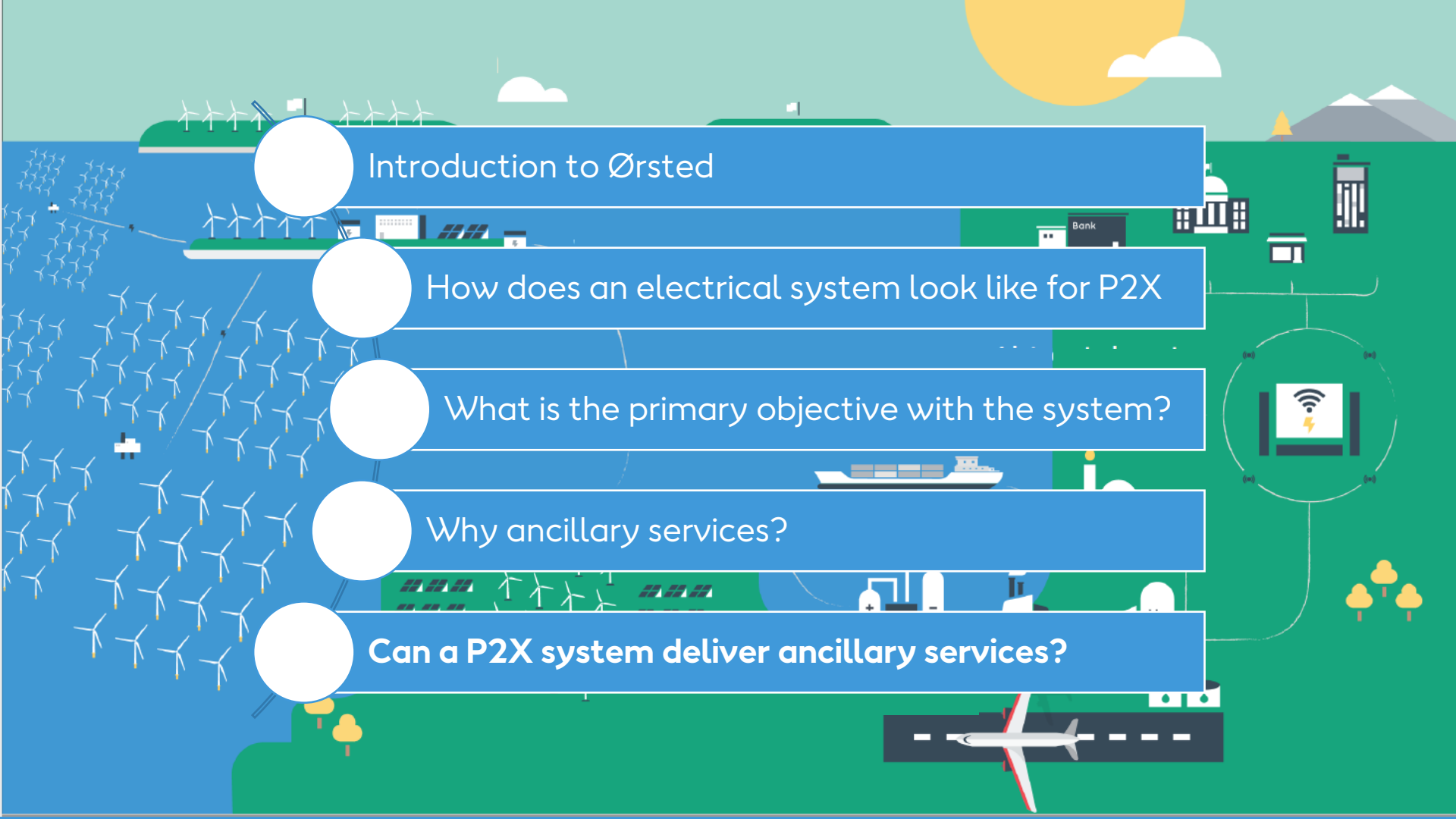
The tables below show how the different ancillary services are distributed on capacity and energy markets for DK1 (Western Denmark) and DK2 (Eastern Denmark).

DK1

PRODUCT	CAPACITY MARKET	ENERGY MARKET
FCR	Part of FCR Cooperation (European CM).	
aFRR	Part of common Nordic CM market (date unknown). Until then, local DK1 market.	Part of common European energy activation market PICASSO (by Q2 2024).
mFRR	Part of common Nordic mFRR CM (date unknown). Until then, a common DK1-DK2 market on the Nordic MMS.	Part of common Nordic mFRR EAM (by Q1 2025). Common European energy activation market MARI (by Q2 2026).

DK2

PRODUCT	CAPACITY MARKET	ENERGY MARKET
FFR	National FFR capacity market.	
FCR-D	Currently common market with Sweden.	
FCR-N	Currently common market with Sweden.	
aFRR	Common Nordic CM market (as of December 2022).	Part of common European energy activation market PICASSO (by Q2 2024).
mFRR	Part of common Nordic CM market (date unknown). Until then, a common DK1-DK2 market on the Nordic MMS.	Part of common Nordic mFRR EAM (by Q1 2025). Common European energy activation market MARI (by Q2 2026).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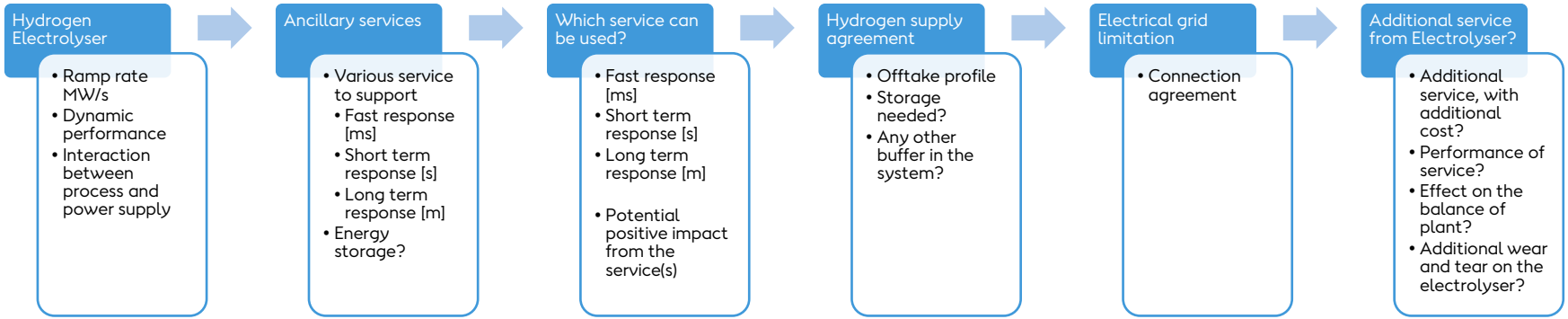
Ancillary Services – Decision process



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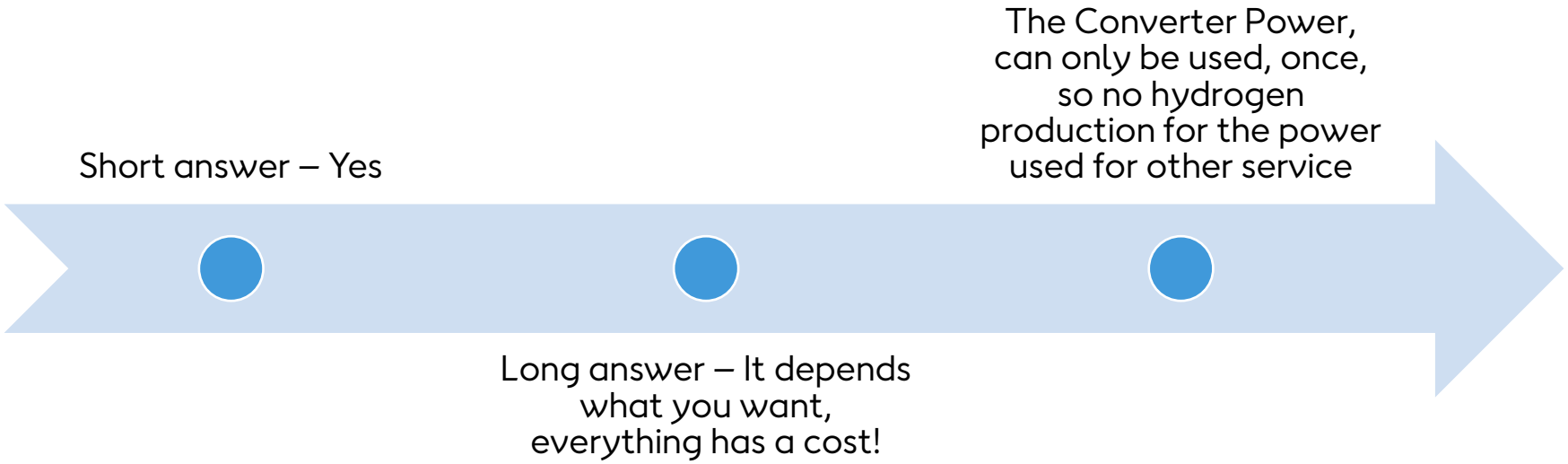
Can a P2X system deliver ancillary services?



What about the future?

More P2X!

Less rotating mass (power plants)

More renewable production, onshore/offshore wind and PV

Stability support

Future demands?

- Active power control
- Reactive power according to PQ diagram.
- Power factor control (within PQ diagram)
- Voltage control according to UQ diagram
- Fault ride through
- Post fault active power recovery control
- Robustness against
  - Phase jump
  - Frequency disturbances
  - Voltage change
- Verification of compliance through system studies and tests

Thank you!

Some use full links:
Oversigt over systemydelser (energinet.dk) (Danish)
ptx-case.pdf (energinet.dk) (Danish)
Ancillary Services (energinet.dk)

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Position

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