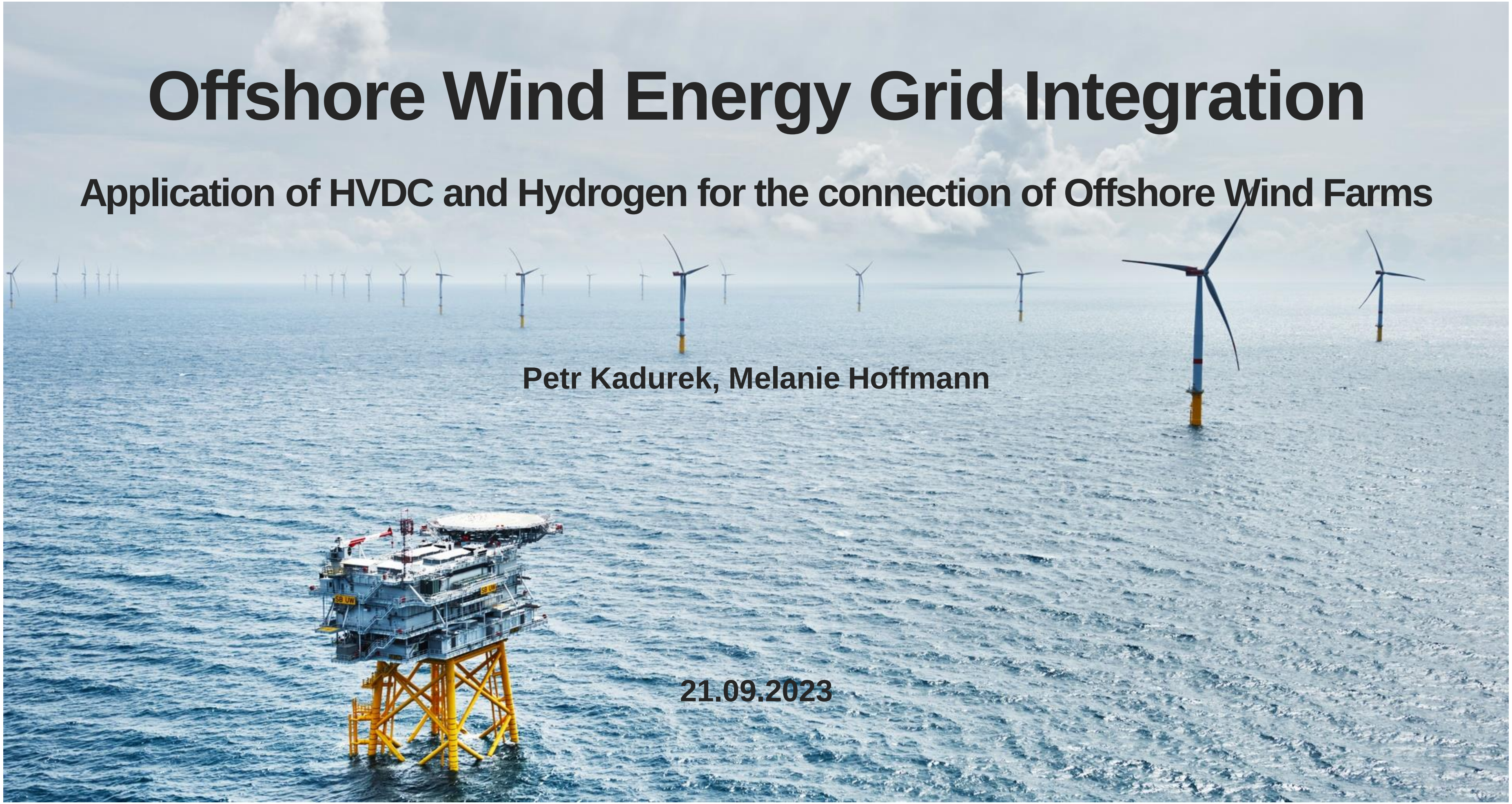
Offshore Wind Energy Grid Integration

Application of HVDC and Hydrogen for the connection of Offshore Wind Farms

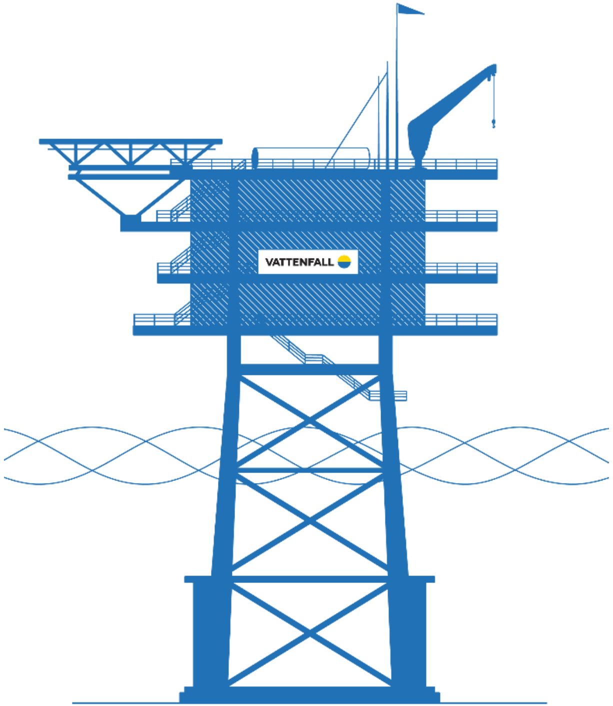


Petr Kadurek, Melanie Hoffmann

21.09.2023

Agenda

1. Introduction Offshore Wind Developments
2. Grid Connection Possibilities
3. Utilisation of Hydrogen for Offshore Wind Connections
4. Summary

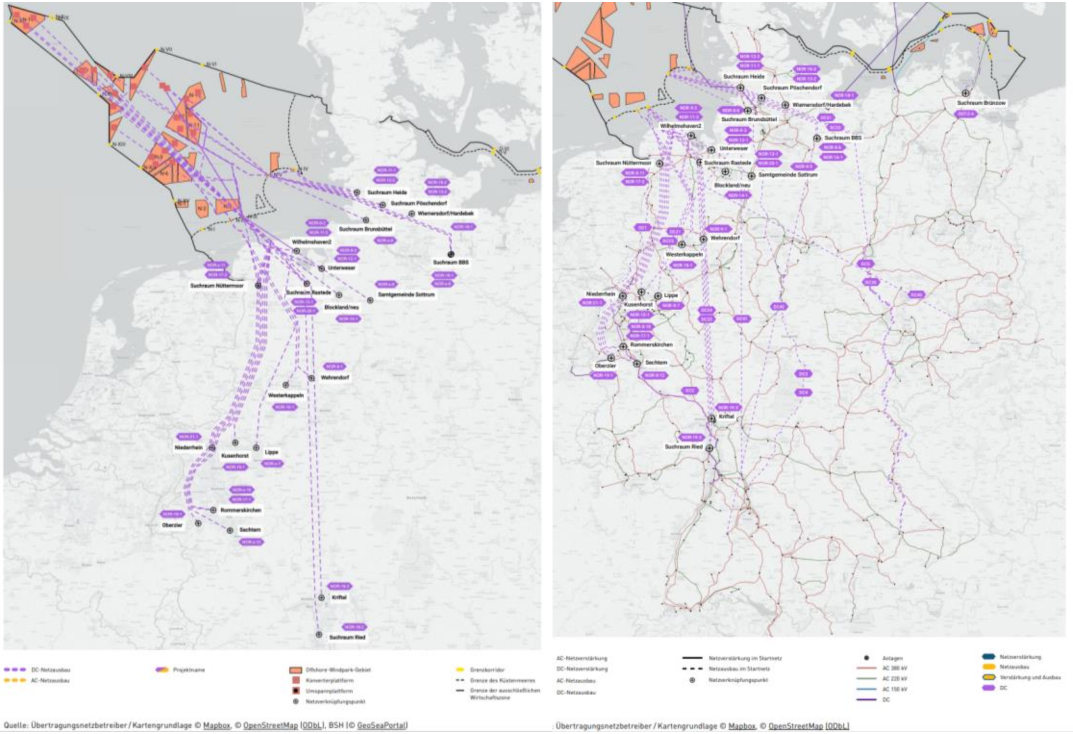


Introduction Offshore Wind Developments

- Large demand of energy in the form of electricity and gas/hydrogen for heating and energy heavy industrial applications, e.g. steel production, transportation.
- Stabilisation and flexibility of energy grid essential for security of supply.
- Offshore wind farms can provide high amount of energy:
  - Electricity: Electrical connections using Alternating Current (AC) or High-Voltage Direct Current (HVDC)
  - Hydrogen: Production offshore / onshore with decentralised or centralised H_2 production
- High capacity increase according to grid development plan (NEP):
  - Planned capacity offshore wind in 2045: 70 GW
  - Planned electrolyser capacity in 2045: 50 – 80 GW, depending on scenario
- **Offshore wind as a main enabler for the energy transition**

Grid Connection Possibilities - HVDC

- Many possibilities to connect offshore wind farms.
- In Germany mainly HVDC connections due to long distances to onshore grid connection point.
- Number of HVDC Connections is increasing on- and offshore.
- Offshore DC grid will be more interconnected in the future.
- New standard: 2GW concept with direct connection of offshore wind farm cables to the converter platform.

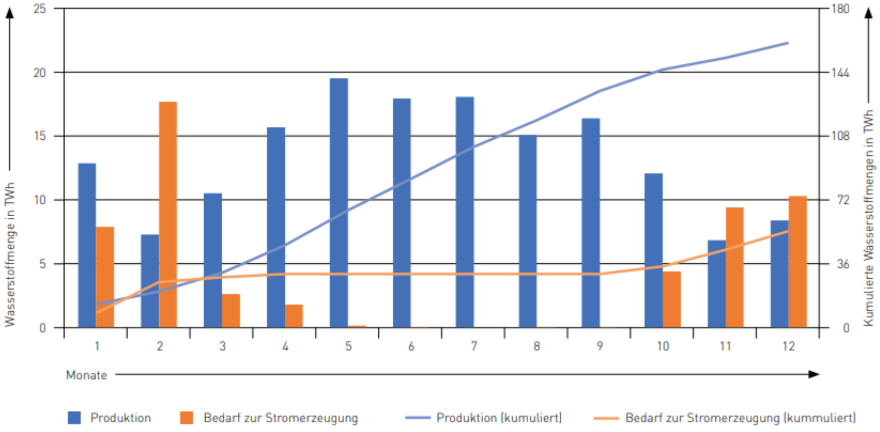


Hydrogen Demand in Germany

Production – Transportation – Storage

- High demand for hydrogen foreseen in German Grid Development Plan (NEP) depending on scenario and electrolyser efficiency.
- **Demand for electrolyser** for the electricity demand when using gas turbines only with hydrogen:
  - Hydrogen production in 2037: 71 – 116 TWh
  - Hydrogen production in 2045: 154 – 250 TWh
- Assumption: Meet hydrogen demand for gas power plants with hydrogen produced in Germany.
- **Transportation** of hydrogen important due to expected high demand for additional sectors other than electricity, which makes hydrogen imports necessary.
- Hydrogen **storage** essential to meet demand over whole year, considering the fluctuating production capacities during the year.

Monthly hydrogen production and hydrogen demand for electricity in scenario B 2045

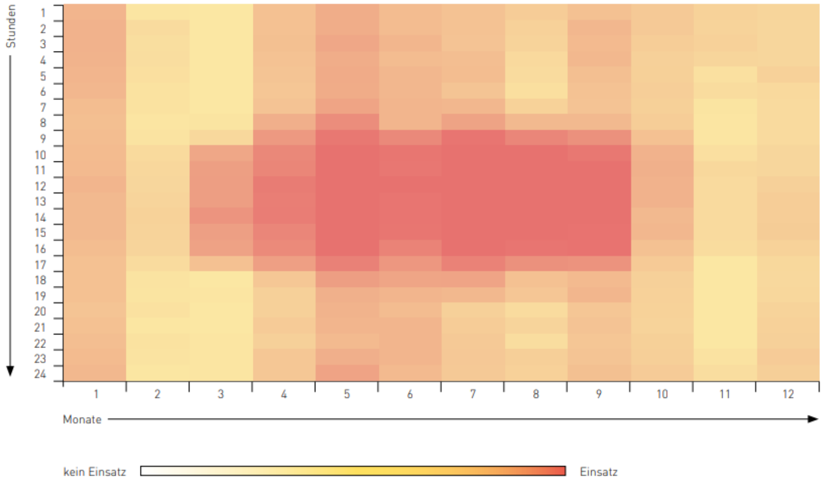


Source: NEP V2023, 2nd draft, part 1

Hydrogen Demand in Germany
Production – Transportation – Storage

- Use of electrolysers especially during summer months and around mid day due to high electricity production and low prices.
- Hydrogen **infrastructure** already foreseen for 2037
- Integration of 80 GW electrolyser capacity in infrastructure are planned.
- Development of electrical grid and hydrogen infrastructure are interdependent.
- Electrolyser **locations** are selected to minimize congestions in the transmission grid and to minimize the shut down of renewable energy generation during high generation phases.
- This involves high **uncertainties** and a multi-criteria assessment to identify the right locations for electrolysers.

Usage of electrolysers during a day and for an entire year



Source: NEP V2023, 2nd draft, part 1

Hydrogen Value Chain

From production facilities to customers

Production

- Electricity
- Hydrogen

Storage & Transport

- Storage
- Onshore network
- Ships
- Trucks
- Trains
- etc.

Customers

- Chemical
- Steel
- Refinery
- Fertilizer
- Electricity generation
- District heating
- Logistics
- etc.

Hydrogen Value Chain

From production facilities to customers

Production

Electricity

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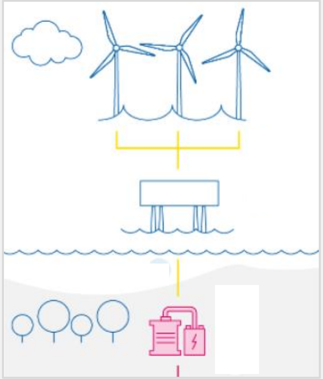
etc.

Offshore wind is particularly well suited to the production of green hydrogen

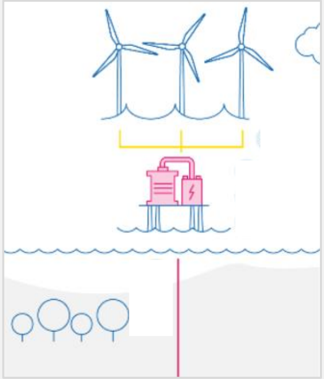
Offshore Hydrogen Concepts:

- Major **savings on** expensive offshore **power infrastructure** (e.g. substations / cables)
- **No** electricity **grid expansion** compared to onshore electrolysis
- **Transport and storage** of H_2 **cheaper and more efficient** than of electrons
- Significant savings and **lower** overall **energy losses** compared to onshore electrolysis[1]
- **High number of full load hours** of offshore wind
- Access to **water** for electrolysis and **site**
- Can be placed in locations with the highest capacity factor **without need for grid availability**

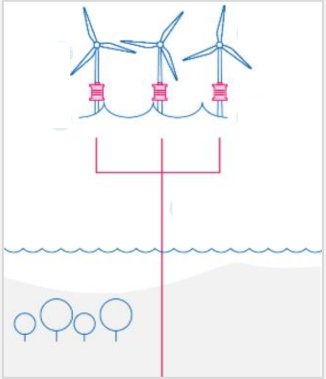
Centralized onshore H2 production



Centralzed offshore H2 production



Decentralized offshore H2 production



1 System integration of offshore wind 2030 – 2040 (GasUnie TenneT, Guidehouse report, 2021)

Hydrogen Value Chain

From production facilities to customers

Production

Electricity

Hydrogen

	Production Capacity in GW	Efficiency	~ kTons H2/year
Offshore Decentral	1	0.99	80
Offshore Central	1	0.99	80
Onshore Central	1	0.95	75

Storage & Transport

- Storage
- Onshore network
- Ships
- Trucks

Customers

- Steel
- Chemical
- Electricity generation
- District heating

Hydrogen Value Chain

From production facilities to customers

Production

PRODUCTION (WP1-WP2)

How should we produce H2 from offshore wind?

A) Central offshore
B) Central onshore
C) Deep-integrated offshore (in-house inputs)

Storage & Transport

TRANSPORT (WP3-WP5)

How should we Transport H2 from offshore to shore?

A) Pipeline technology
B) Compression
C) Deep-integrated offshore

Customers

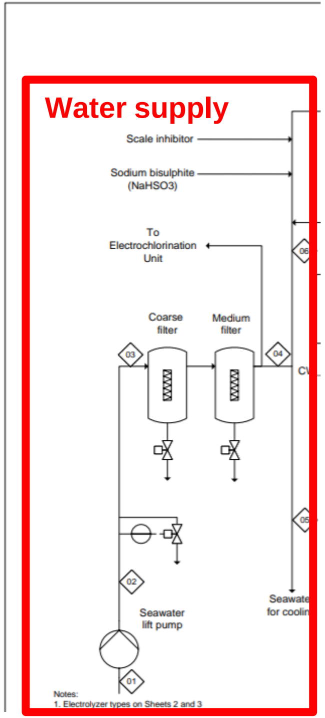
ONSHORE DELIVERY (WP6-WP8)

How do we deliver H2 to the shore?

A) Compression
B) Storage
C) Pipeline

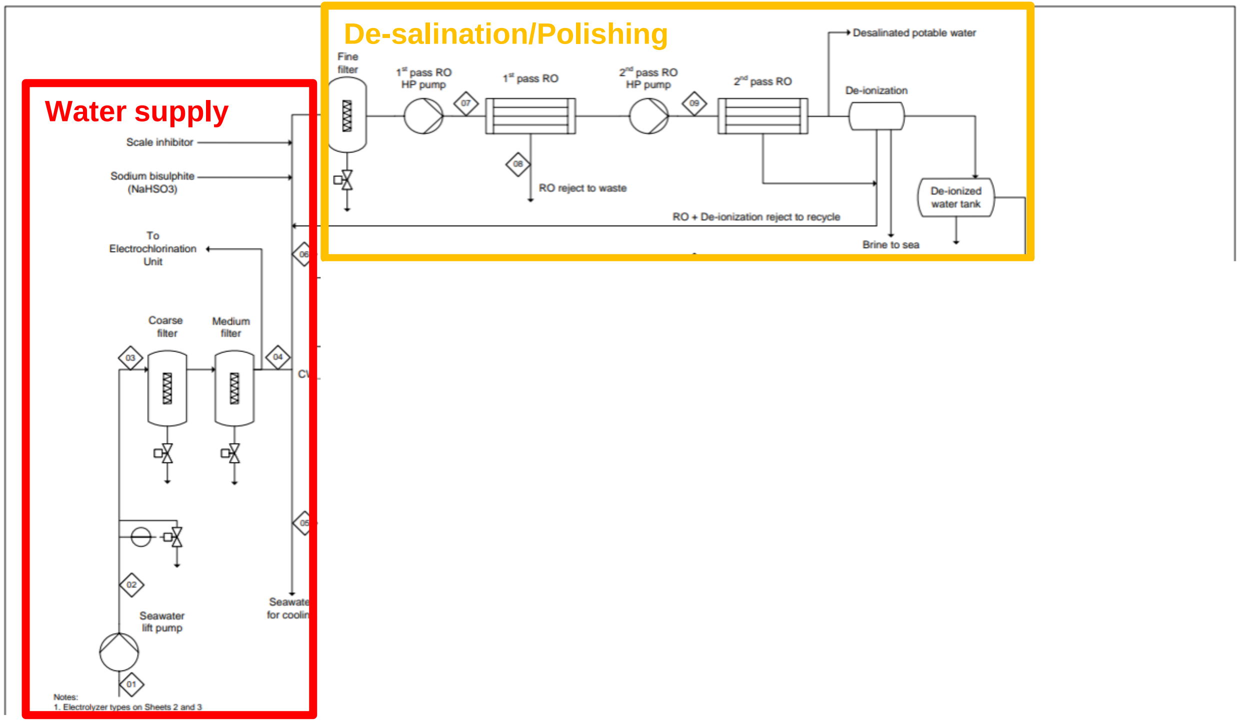
Hydrogen System Split

Electrical, Mechanical and Process Engineering



Hydrogen System Split

Electrical, Mechanical and Process Engineering



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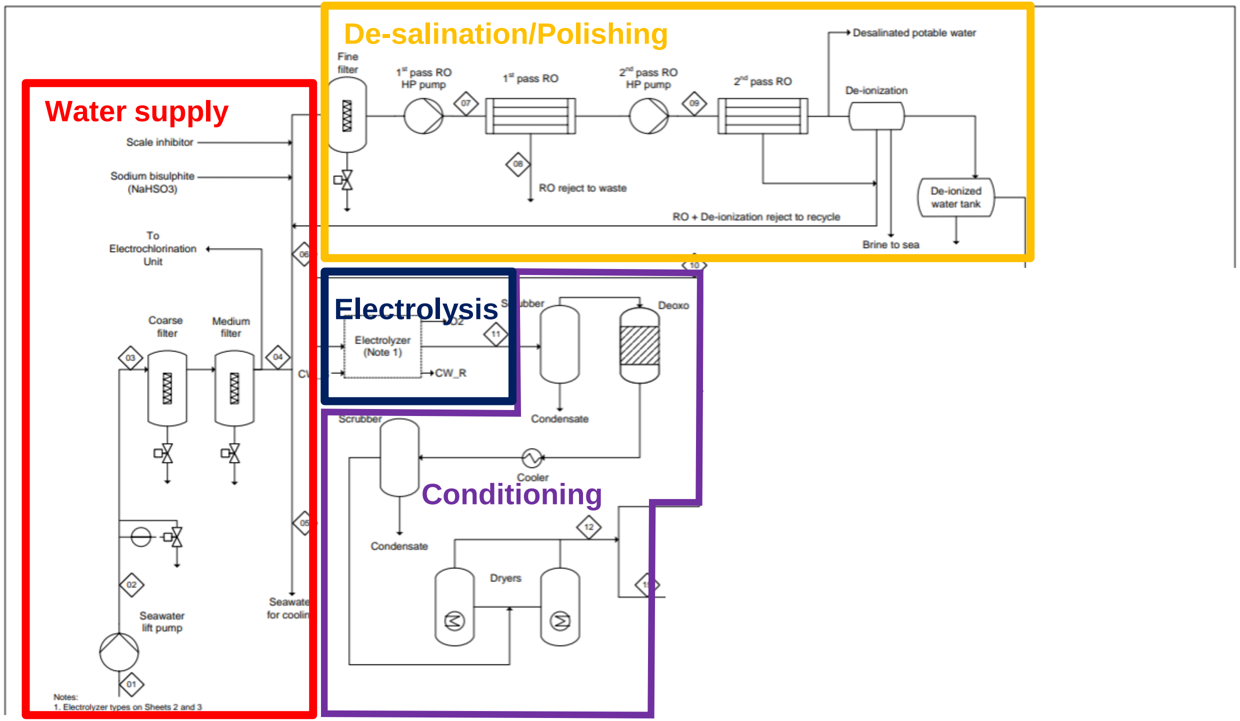
Electrical, Mechanical and Process Engineering



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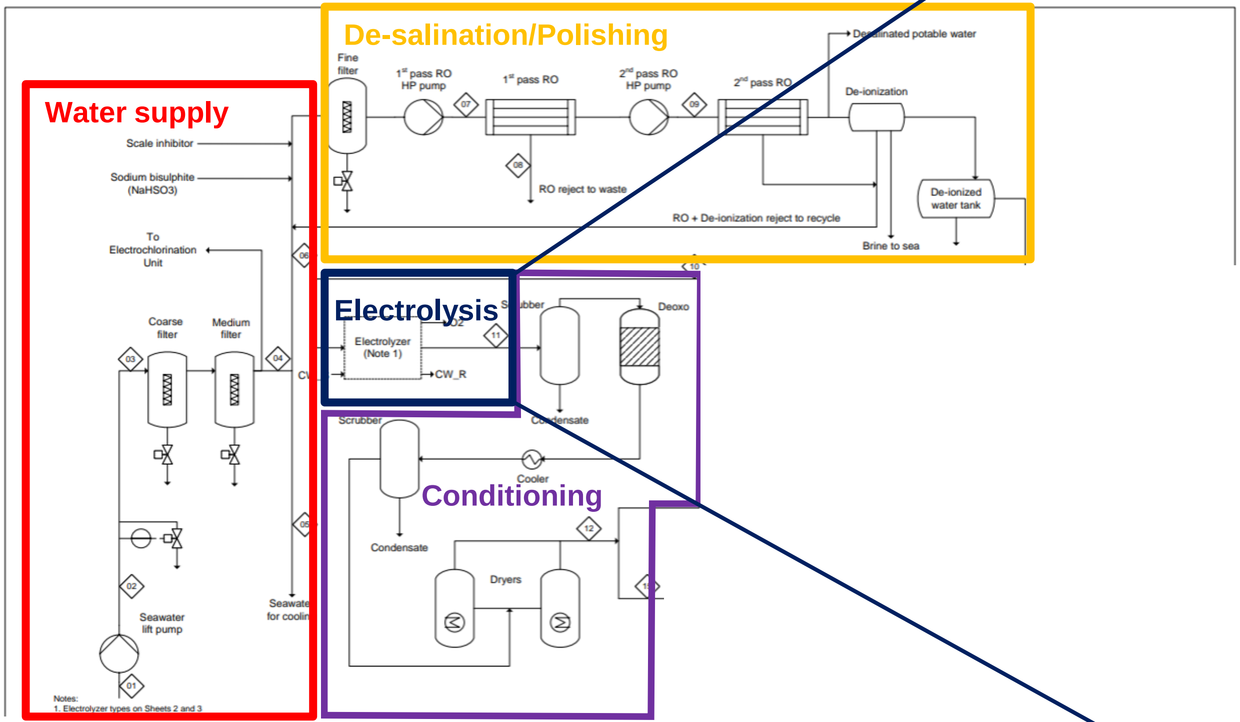
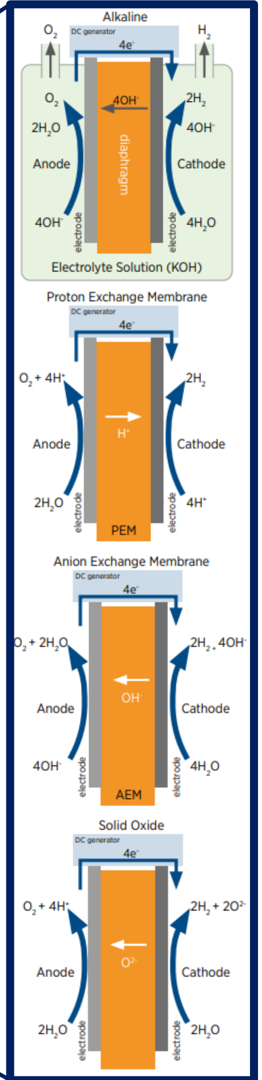
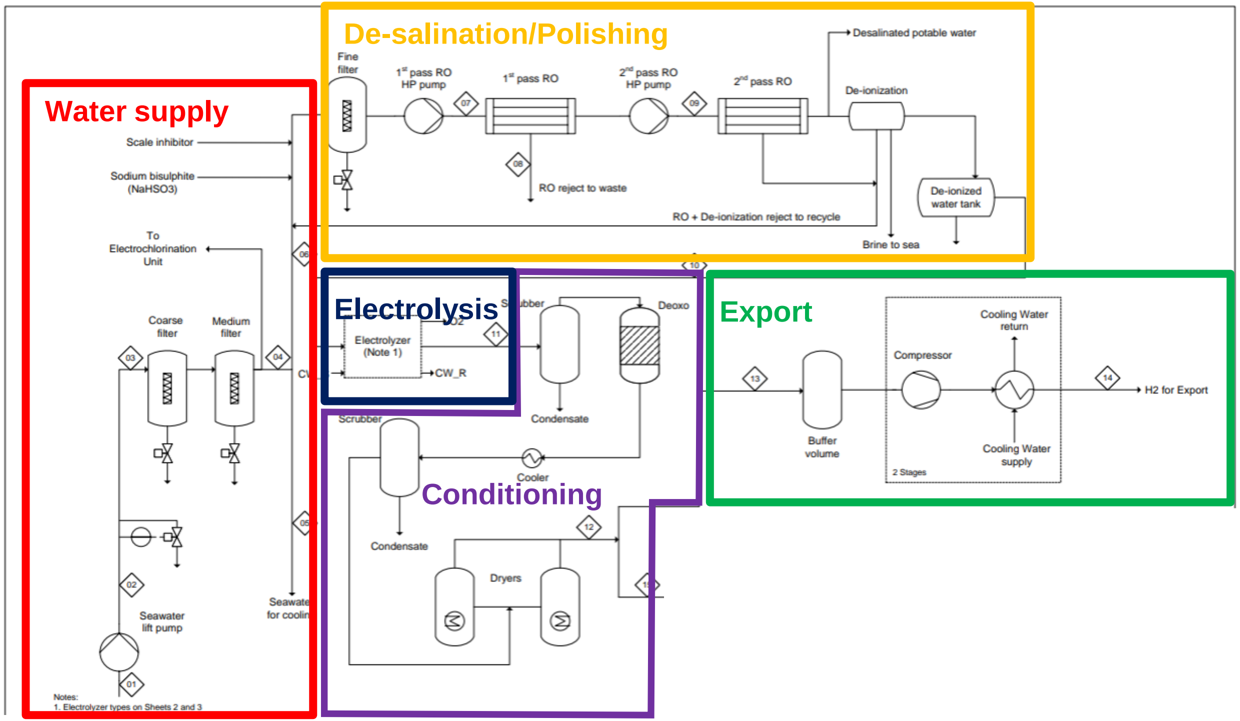




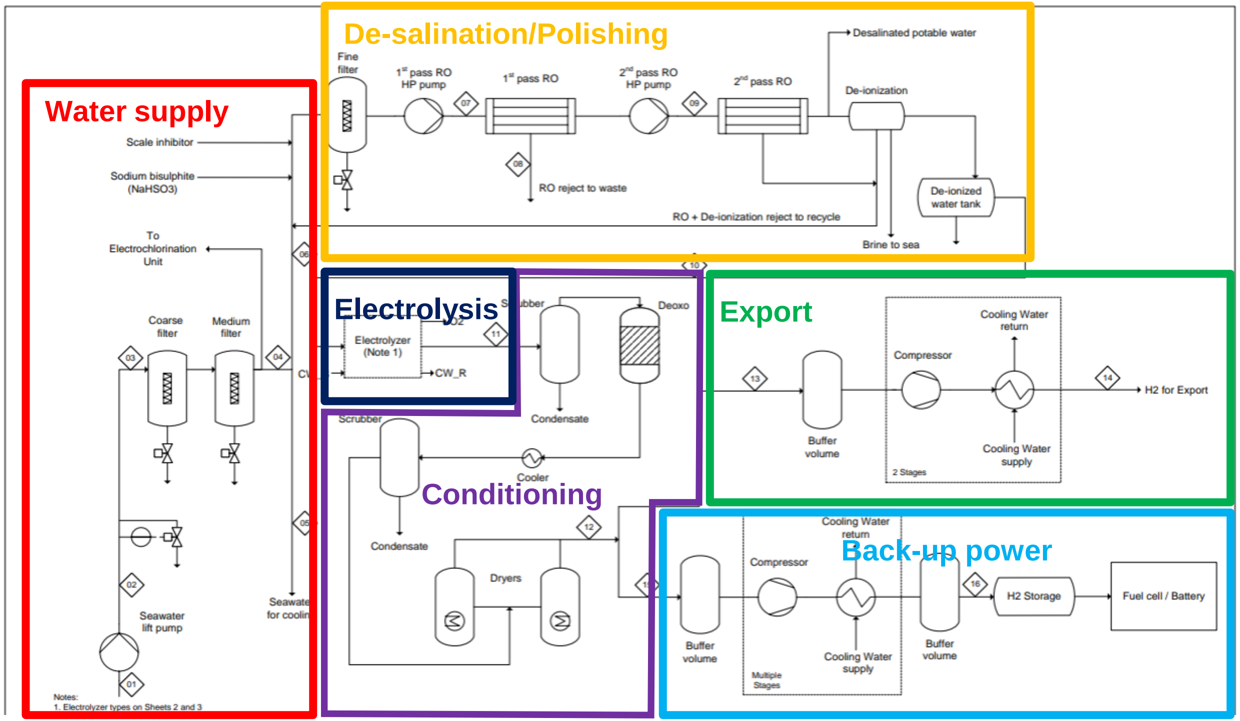
Hydrogen System Split

Electrical, Mechanical and Process Engineering



Hydrogen System Split

Electrical, Mechanical and Process Engineering



At Vattenfall, we are pursuing a three-step maturation approach towards GW-scale production of offshore hydrogen

Vattenfall Offshore Hydrogen Roadmap

Step 1
Onshore Pilot
2022

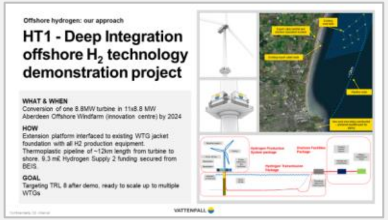
Step 2
Offshore pilots and smaller scale commercial projects
2025 - 2028

Step 3
Dedicated offshore wind farms
2029+

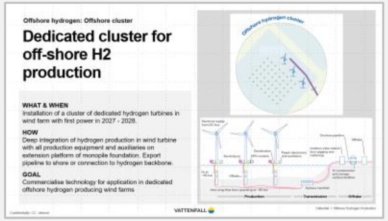
Development of knowledge and competence in hydrogen


Offshore hydrogen: our approach
Deep Purple – pilot of coupled offshore H2 and wind systems

Realization of offshore pilot through retrofitting an existing turbine


Offshore hydrogen: our approach
HT1 - Deep Integration offshore H_2 technology demonstration project

Production of hydrogen in a dedicated offshore cluster


Offshore hydrogen: Offshore cluster
Dedicated cluster for off-shore H2 production

GW-scale production with portfolio of dedicated hydrogen wind farms


Offshore hydrogen: our approach
Swedish West Coast – GW-scale dedicated H2 wind farm

We will qualify the technical solution for large-scale deployment with a first dedicated cluster as the market progresses towards the required levels of economic attractiveness


Thank you!