

# Offshore Wind Energy Grid Integration

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

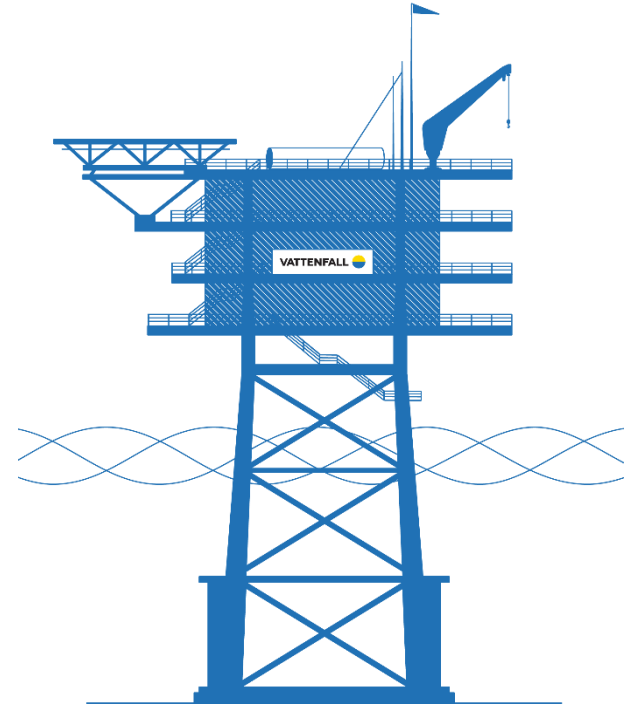
Petr Kadurek, Melanie Hoffmann

21.09.2023



# Agenda

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



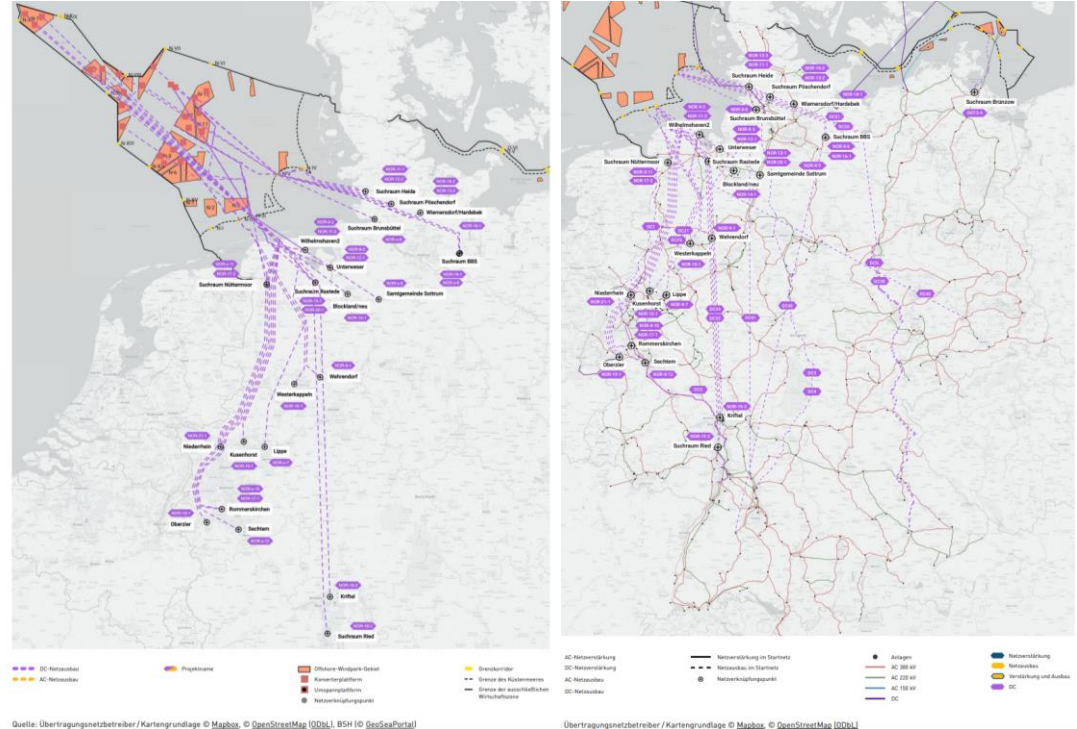
# Introduction Offshore Wind Developments

- 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<sub>2</sub> 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.



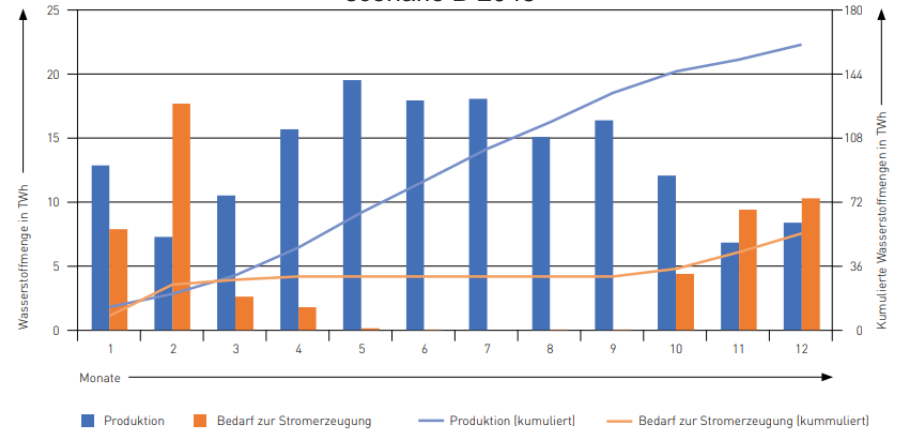


# Hydrogen Demand in Germany

## 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



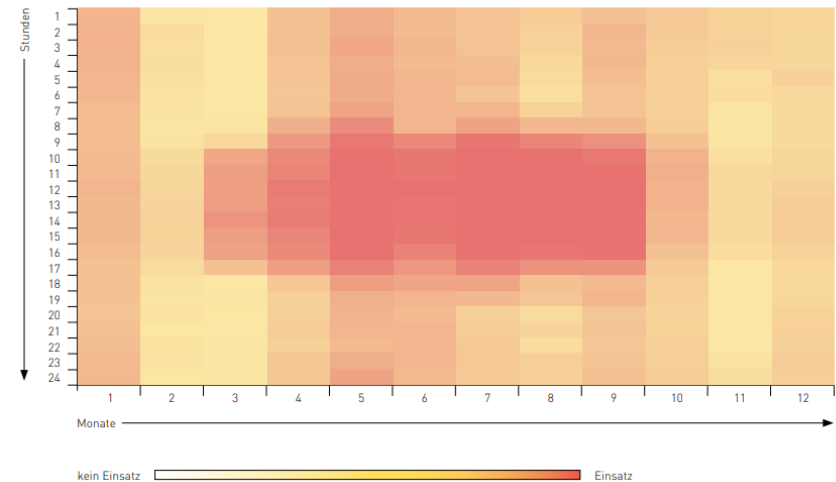
Source: NEP V2023, 2<sup>nd</sup> draft, part 1

# Hydrogen Demand in Germany

## Production – Transportation – Storage

- Use of electrolyzers 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 electrolyzers.

Usage of electrolyzers during a day and for an entire year



Source: NEP V2023, 2<sup>nd</sup> 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.

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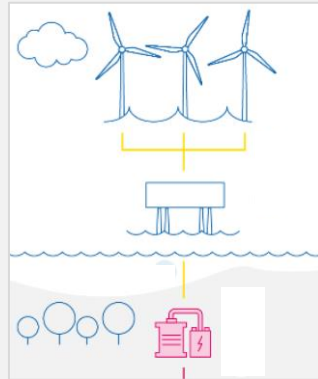
## Offshore Hydrogen: Why and What?

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

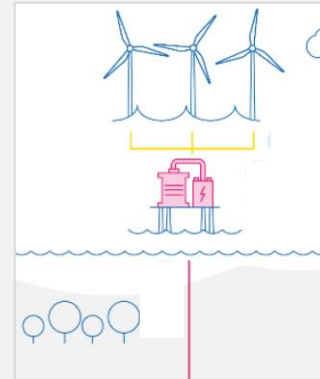
### Offshore Hydrogen Concepts:

- Major **savings on expensive offshore power infrastructure** (e.g. substations / cables)
- **No electricity grid expansion** compared to onshore electrolysis
- **Transport and storage of H<sub>2</sub> cheaper and more efficient** than of electrons
- Significant savings and **lower overall energy losses** compared to onshore electrolysis<sup>1</sup>
- **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**

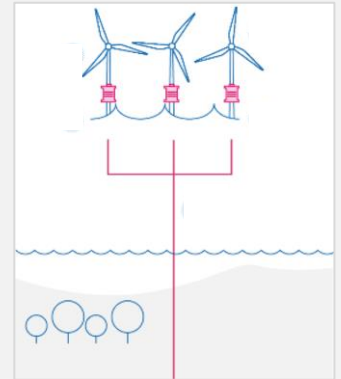
Centralized onshore H<sub>2</sub> production



Centralized offshore H<sub>2</sub> production



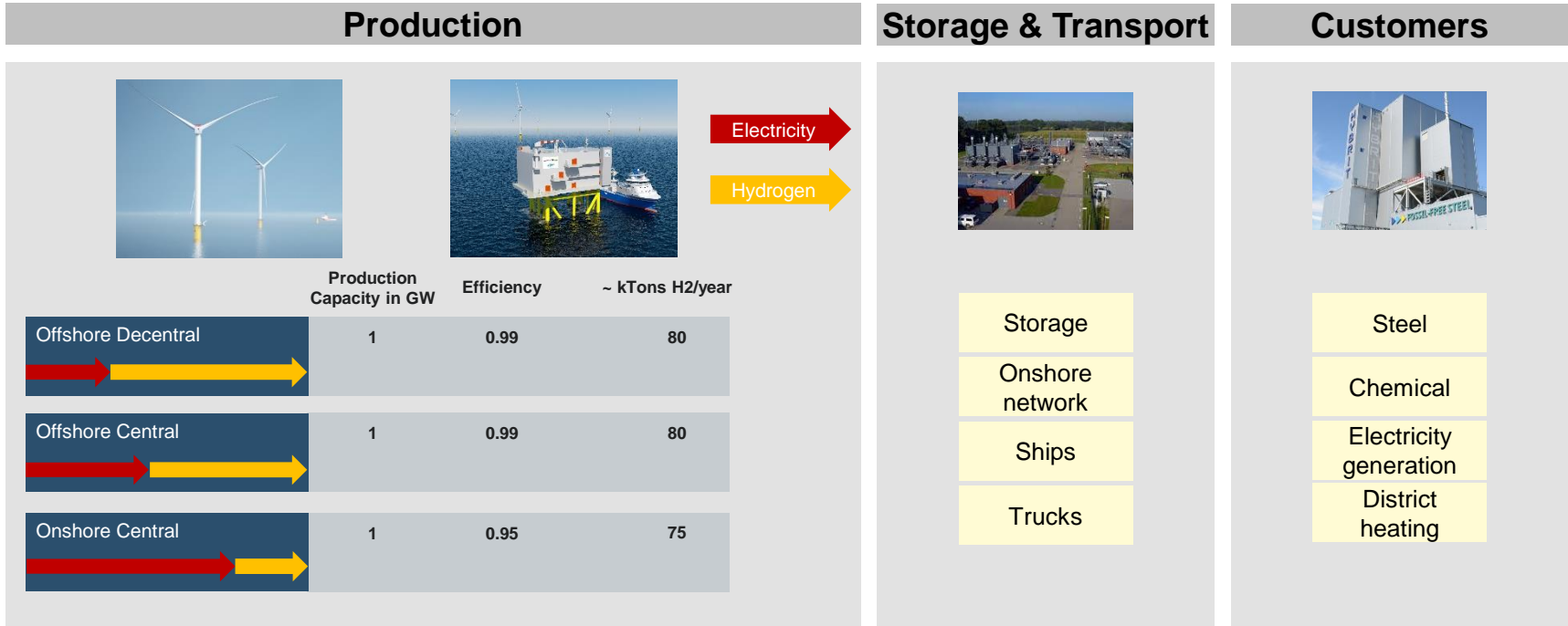
Decentralized offshore H<sub>2</sub> production



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

# Hydrogen Value Chain

## From production facilities to customers



# 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



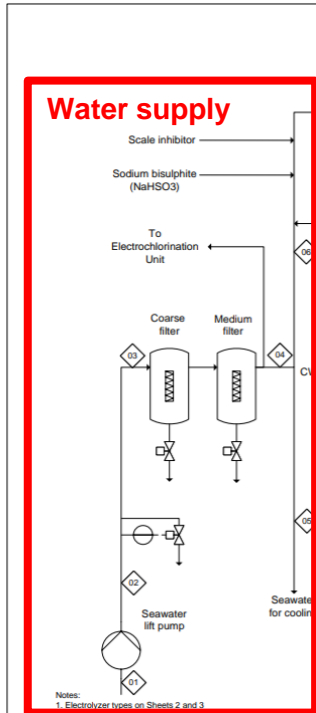
#### ONSHORE DELIVERY (WP6-WP8)

How do we deliver H2 to the shore?

- A) Compression
- B) Storage
- C) Pipeline

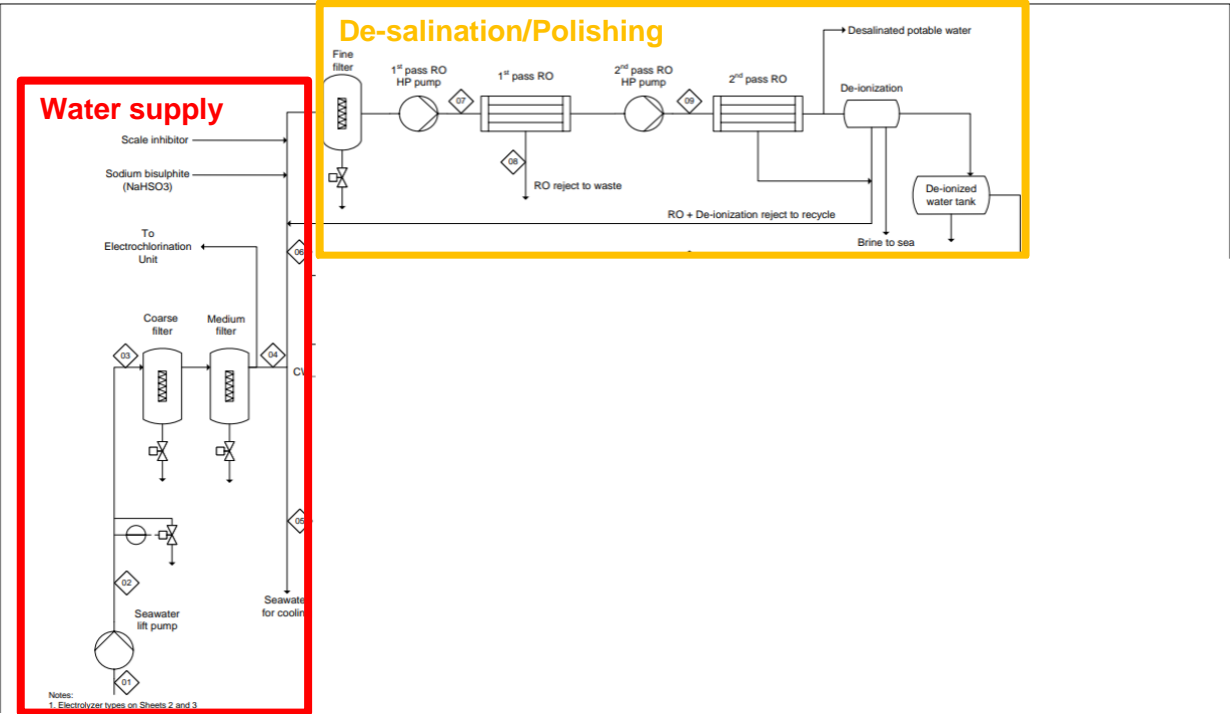
# Hydrogen System Split

## Electrical, Mechanical and Process Engineering



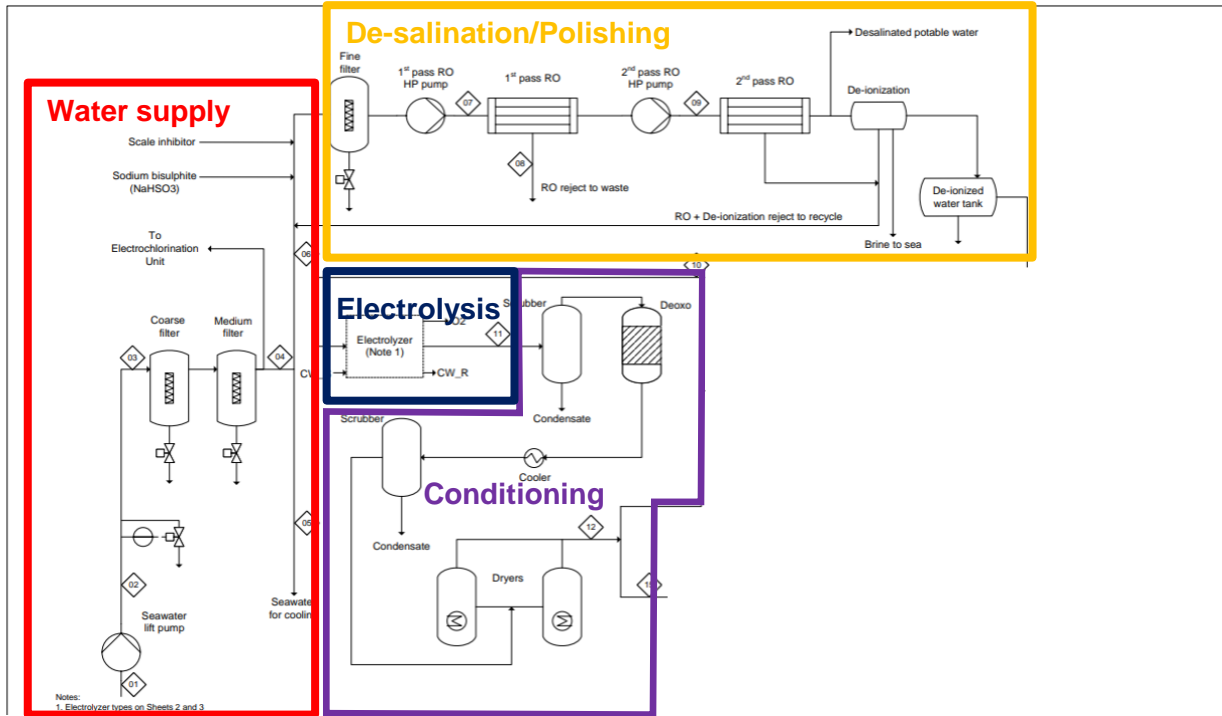
# Hydrogen System Split

## Electrical, Mechanical and Process Engineering



# Hydrogen System Split

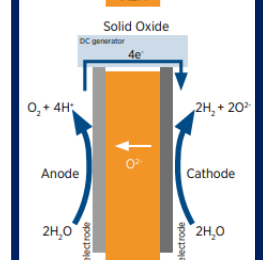
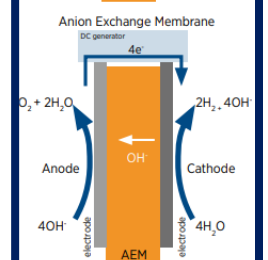
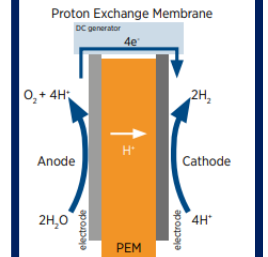
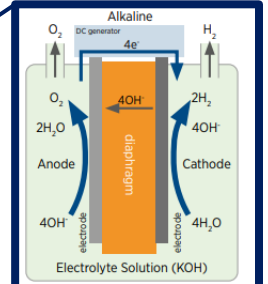
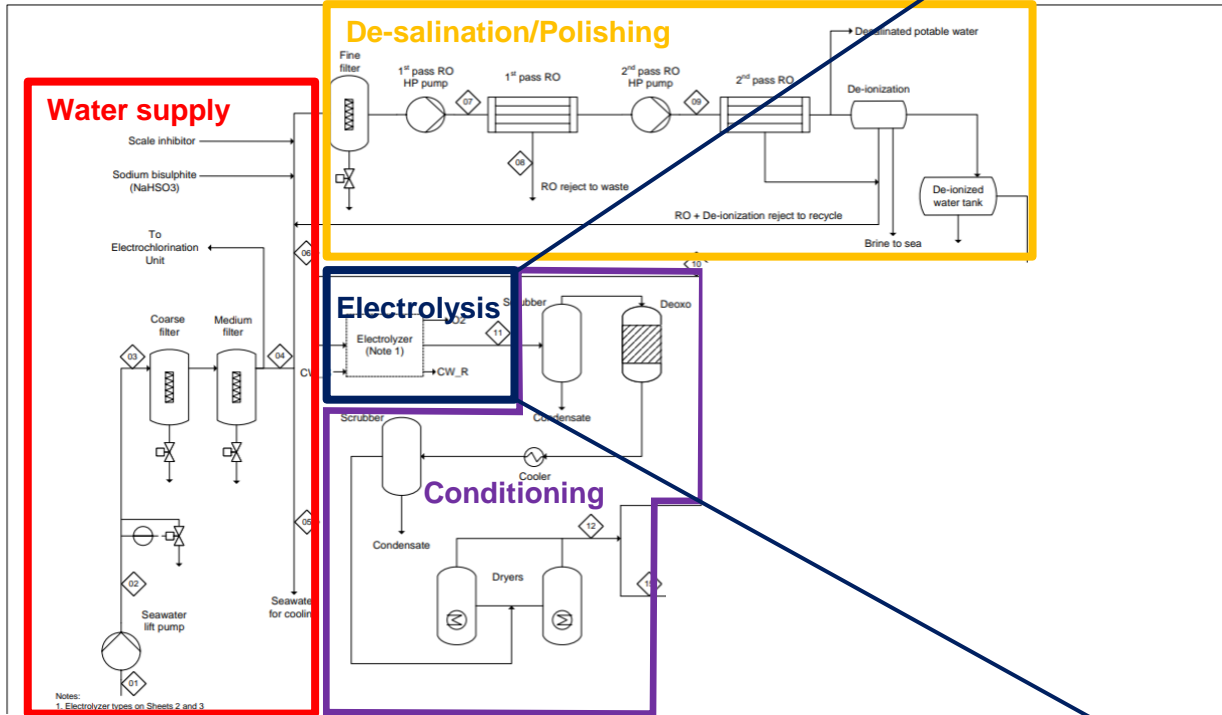
## Electrical, Mechanical and Process Engineering





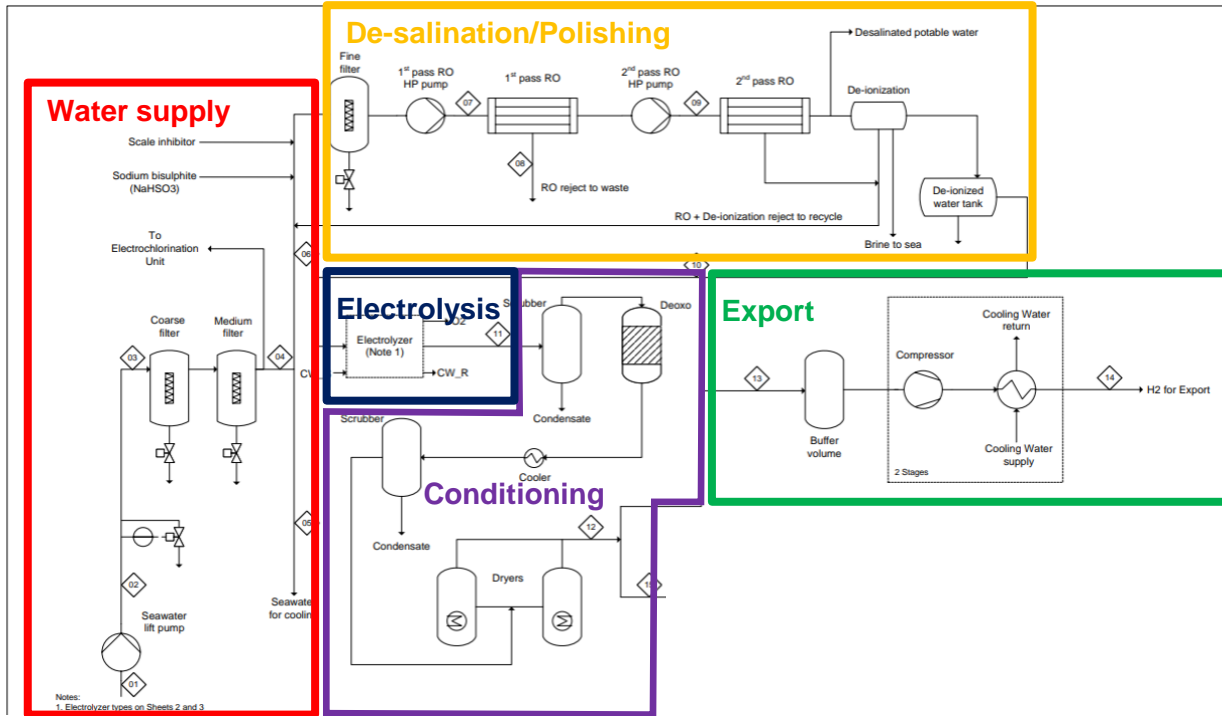
# Hydrogen System Split

## Electrical, Mechanical and Process Engineering



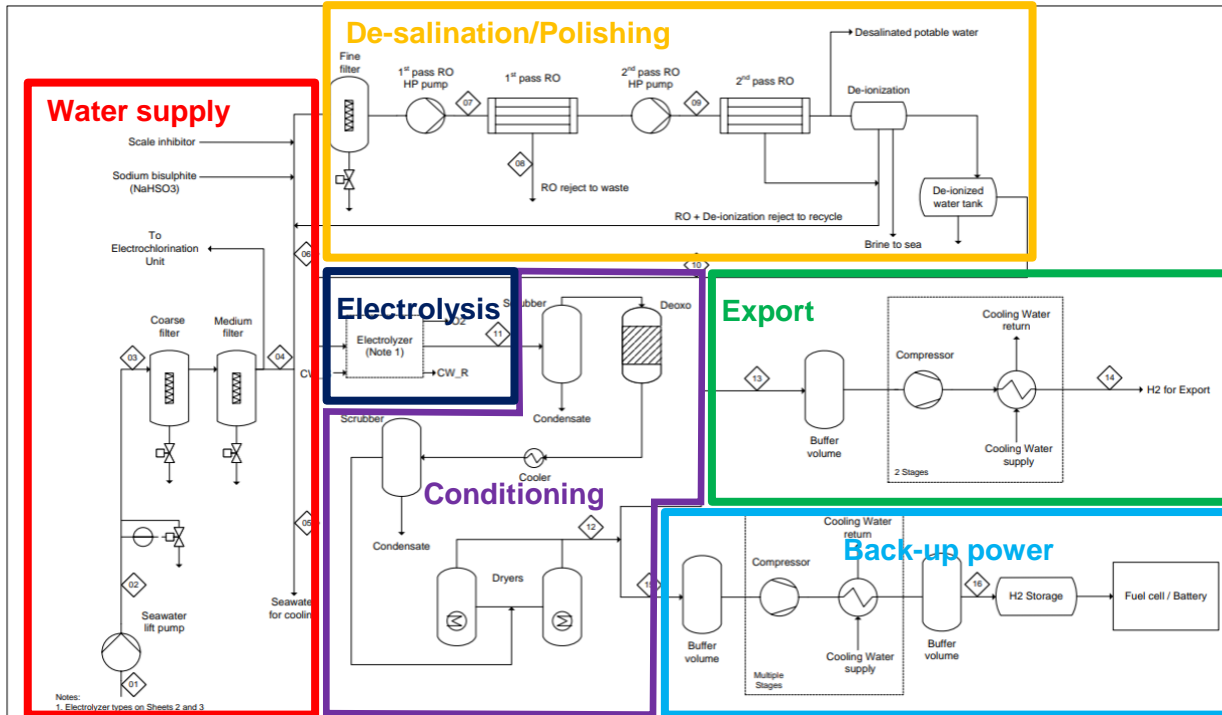
# Hydrogen System Split

## Electrical, Mechanical and Process Engineering



# Hydrogen System Split

## Electrical, Mechanical and Process Engineering



## Offshore Hydrogen: Our approach

# 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



Development of knowledge and competence in hydrogen

Offshore hydrogen: our approach

### Deep Purple – pilot of coupled offshore H2 and wind systems

**WHAT & WHEN**  
Concept and test the Deep Purple Concept with electrolyser, compressor, storage and fuel cell in a concept with embedded wind and last profiles.  
Project timeline is 2021-2023.

**HOW**  
A consortium of experts will build and test the project over a 2.5 year horizon with government funding from Innovation Norway.

**GOAL**  
Qualify the energy system to TR1.6. Test and optimize for operation of offshore wind and hydrogen system.



### Step 2

Offshore pilots and smaller scale commercial projects  
2025 - 2028

Realization of offshore pilot through retrofitting an existing turbine


Offshore hydrogen: our approach

### HT1 - Deep Integration offshore H<sub>2</sub> technology demonstration project

**WHAT & WHEN**  
Conversion of one 8.8MW turbine in T148 8 MW Aberdeen Offshore Windfarm conversion centre by 2024

**HOW**  
Extension platform intended to existing WTG jacket foundation with all H2 production equipment. The maximum capacity of 10m length from turbine to shore. 8.3 mH<sub>2</sub> hydrogen supply 2 funding secured from SES.

**GOAL**  
Targeting TR1.8 after demo, ready to scale up to multiple VTCs.



### Step 3

Dedicated offshore wind farms  
2029+

Production of hydrogen in a dedicated offshore cluster

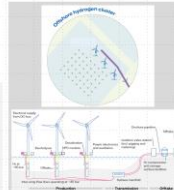
Offshore hydrogen: Offshore cluster

### Dedicated cluster for off-shore H2 production

**WHAT & WHEN**  
Installation of a cluster of dedicated hydrogen turbines in wind farm with first power in 2027 - 2028.

**HOW**  
Deep integration of hydrogen production in wind turbine with all production equipment and auxiliary on extension platform of monopile foundation. Export pipeline to shore in connection to hydrogen backbone.

**GOAL**  
Commercialize technology for application in dedicated offshore hydrogen producing wind farms.



GW-scale production with portfolio of dedicated hydrogen wind farms


Offshore hydrogen: our approach

### Swedish West Coast – GW-scale dedicated H2 wind farm

**WHAT & WHEN**  
Sweden: West Coast cluster of development projects with up to 4.8 GW total capacity offers opportunities to realize 8.5 GW-scale dedicated H2 wind farm.

**HOW**  
Technology choice will be based on site conditions, available infrastructure and customer needs. Cluster also offers opportunity for potential medium sized commercial projects on the way to GW-scale. Vattenfall has close relationships with large scale customers in the area.

**GOAL**  
Develop dedicated GW-scale H2 wind farm by 2030.



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

A blue wind turbine is positioned in the foreground, its three blades extending across the frame. In the background, a large construction vessel with a crane is visible on the ocean. The sky is a clear, light blue, and the water is a deep blue with some whitecaps.

# Thank you!