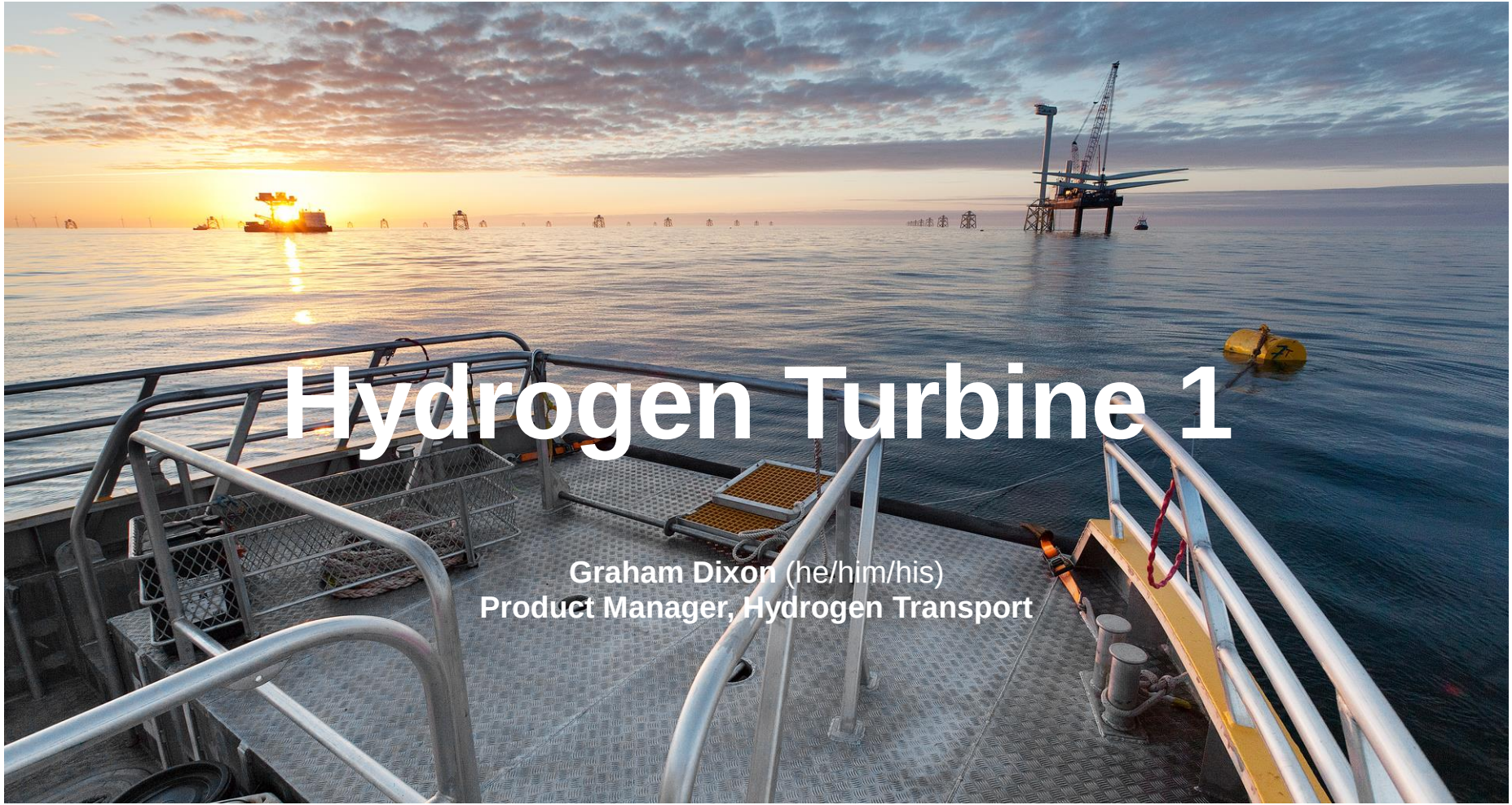


Hydrogen Turbine 1

Graham Dixon (he/him/his)
Product Manager, Hydrogen Transport

Introduction

100%
Owned by the Swedish State

7.1 million
Electricity customers

1.0 million
Electricity network customers

1.8 million
Heat customers

2.4 million
Gas customers

18,883
Employees

Introduction

Vattenfall’s geographical footprint

Sweden
Finland
Norway
Denmark
Poland
Germany
The Netherlands
Belgium
France
United Kingdom

Introduction

Location of our operations and major plants

Click on energy source to show locations

Wind

Biomass

Hydro

Gas

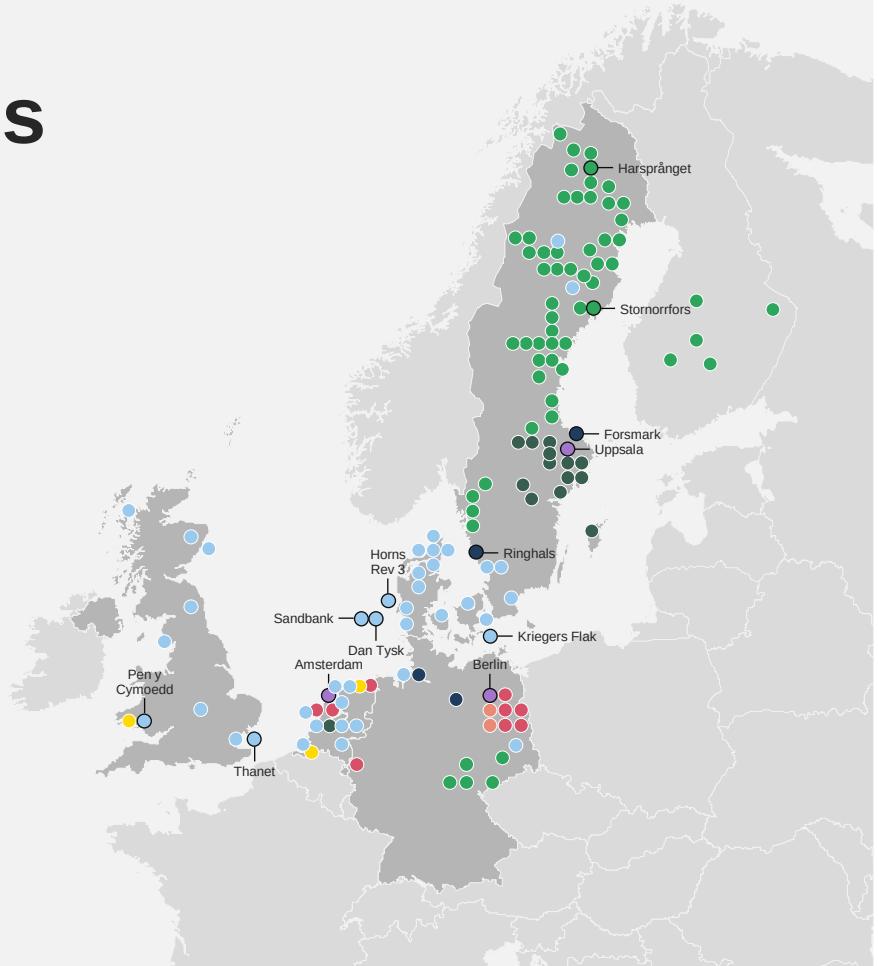
Nuclear

Coal

Solar

District heating

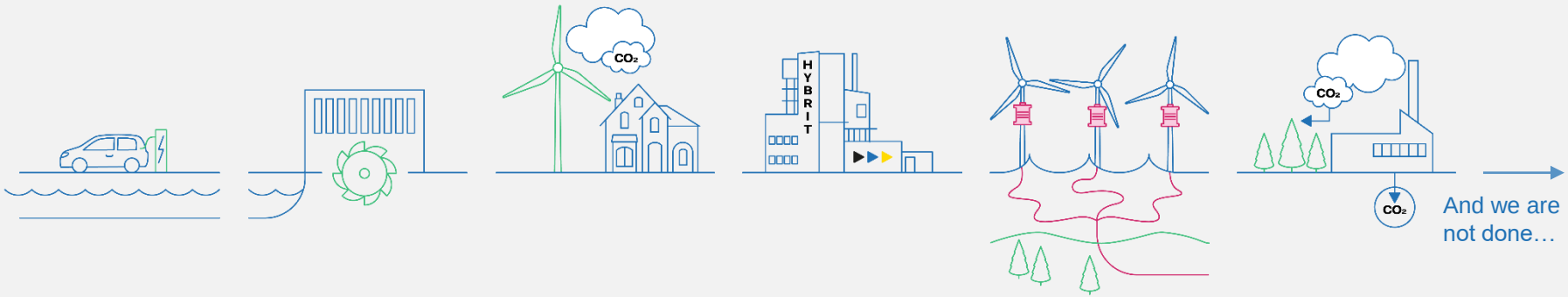
Largest facilities marked with a circle




Fossil-free living
within one generation

Fossil-free living within one generation

Vattenfall has defined key milestones towards its mission of fossil-free living within one generation



2023
Electric charging for 1 billion fossil-free kilometers annually

2024
750 MW of additional flexible hydro capacity

2025
Reduce CO_2 intensity by 43% from 2017

2026
HYBRIT partnership: full-scale fossil-free steel production

~2030
GW-scale dedicated H2 windfarm

2030
Reduce CO_2 intensity by 77% from 2017

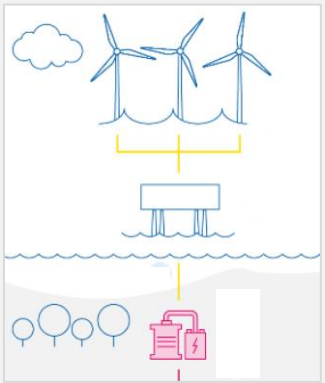
Offshore wind is particularly well suited to the production of green hydrogen

Offshore hydrogen has a strong business case…

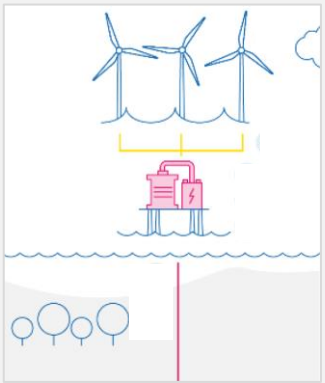
- Major **savings on** expensive offshore **power infrastructure** (e.g. substations / cables)
- Requires **no** electricity **grid expansion** compared to onshore electrolysis
- **Transport and storage** of H_2 **cheaper and more efficient** than of electrons
- Significant savings and **lower** overall **energy losses** compared to onshore electrolysis[1]
- **High number of full load hours** of offshore wind
- Access to **water** for electrolysis
- Can be placed in locations with the best wind resource, **irrespective of need for grid availability**

… and its production can take a number of forms

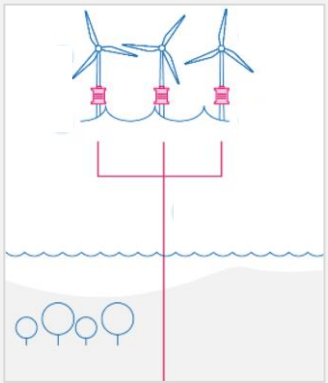
Centralized onshore H2 production



Centralized offshore H2 production



Decentralized offshore H2 production



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

Offshore Hydrogen: Our approach

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

Vattenfall Offshore Hydrogen Roadmap

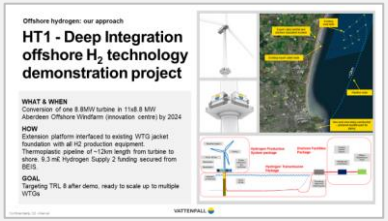
Step 1
Onshore Pilot
2022

Development of knowledge and competence in hydrogen

Deep Purple[1]

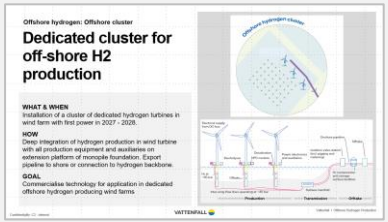
Step 2
Offshore pilots and smaller scale commercial projects
2025 - 2028

Realization of offshore pilot through retrofitting an existing turbine



HT1

Production of hydrogen in a dedicated offshore cluster



Other Projects

Step 3
Dedicated offshore wind farms
2029+

GW-scale production with portfolio of dedicated hydrogen wind farms

Swedish West Coast

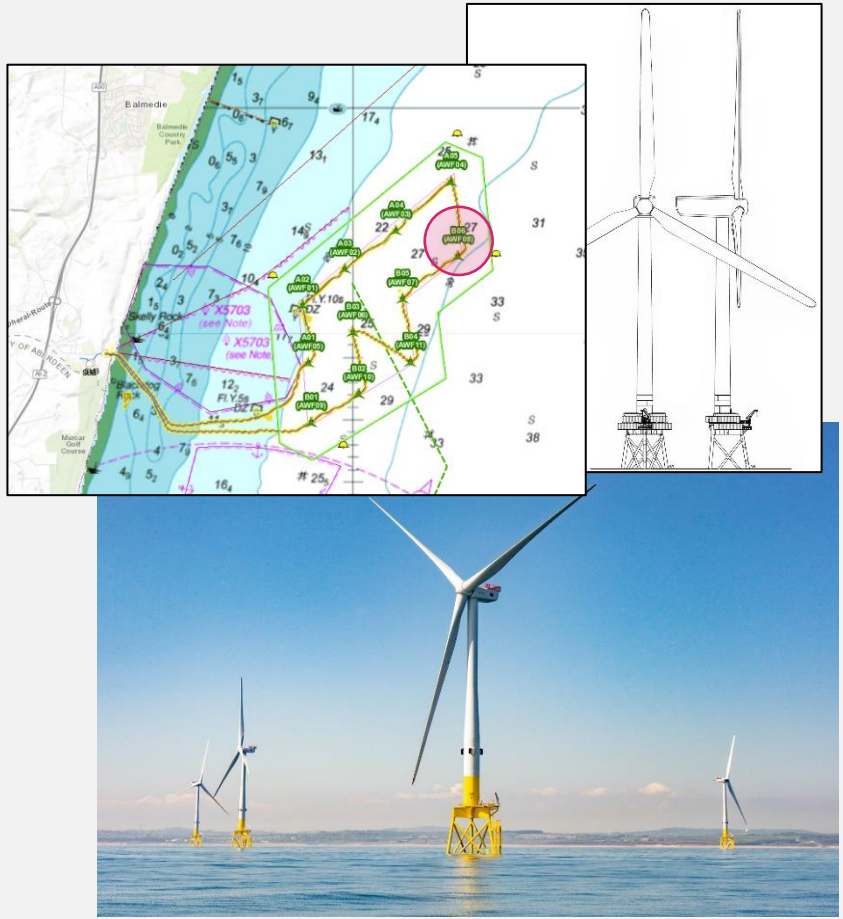
We will qualify the technical solution for large-scale deployment with a first dedicated cluster as the market progresses towards the required levels of economic attractiveness

[1] Consortium led by TechnipFMC

Hydrogen Turbine 1

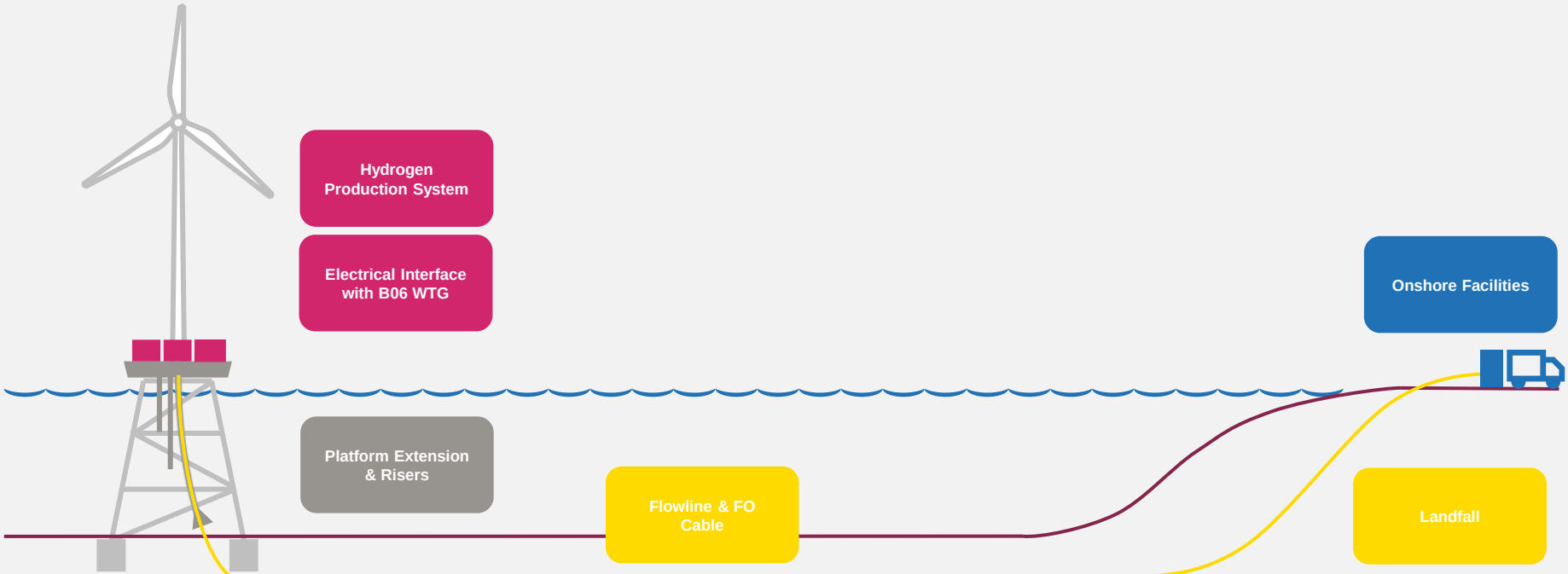
Project Overview

- Aberdeen Offshore Wind Farm (AOWF) is an existing farm and innovation centre approx. 3-5km off the coast of Aberdeen.
- Selected due to requirement to bring innovation to the farm, located in Aberdeen, a city planned to be an energy transition hub, and close to shore to minimise tieback cost.
- Turbine B-06 selected due to position at the Normally Open Point (NOP) of the inter array cable and distance from shore.
- Hydrogen production modules will be fitted on a platform extension, retrofitted to the existing jacket foundation. Turbine will be reconfigured to direct power to hydrogen production, rather than the grid.
- Hydrogen to be exported to shore via a small diameter flowline where it will be compressed and stored for trailer offtake at a new dedicated onshore facility.
- Project will run for approx. 10 years.
- Project has been awarded £9.3m funding by UK Government

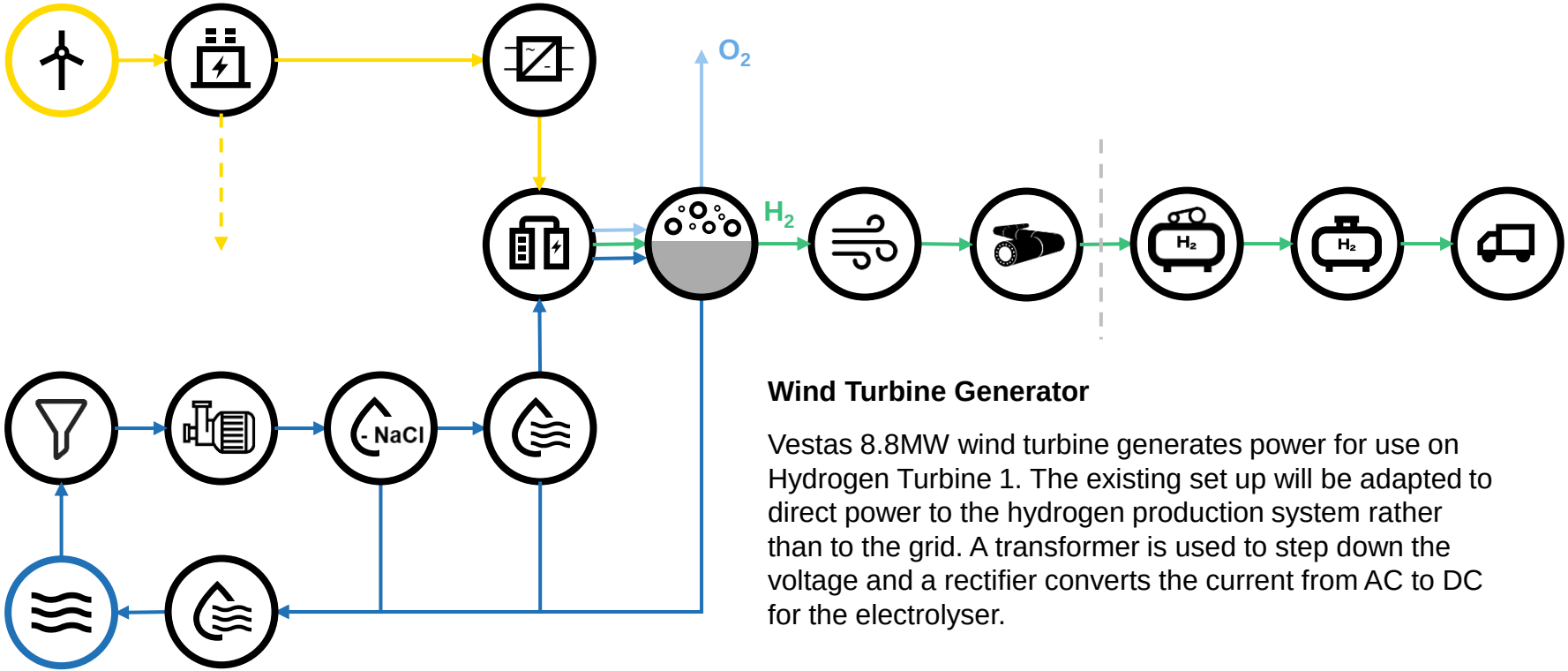


Hydrogen Turbine 1

“Scope in a Nutshell”



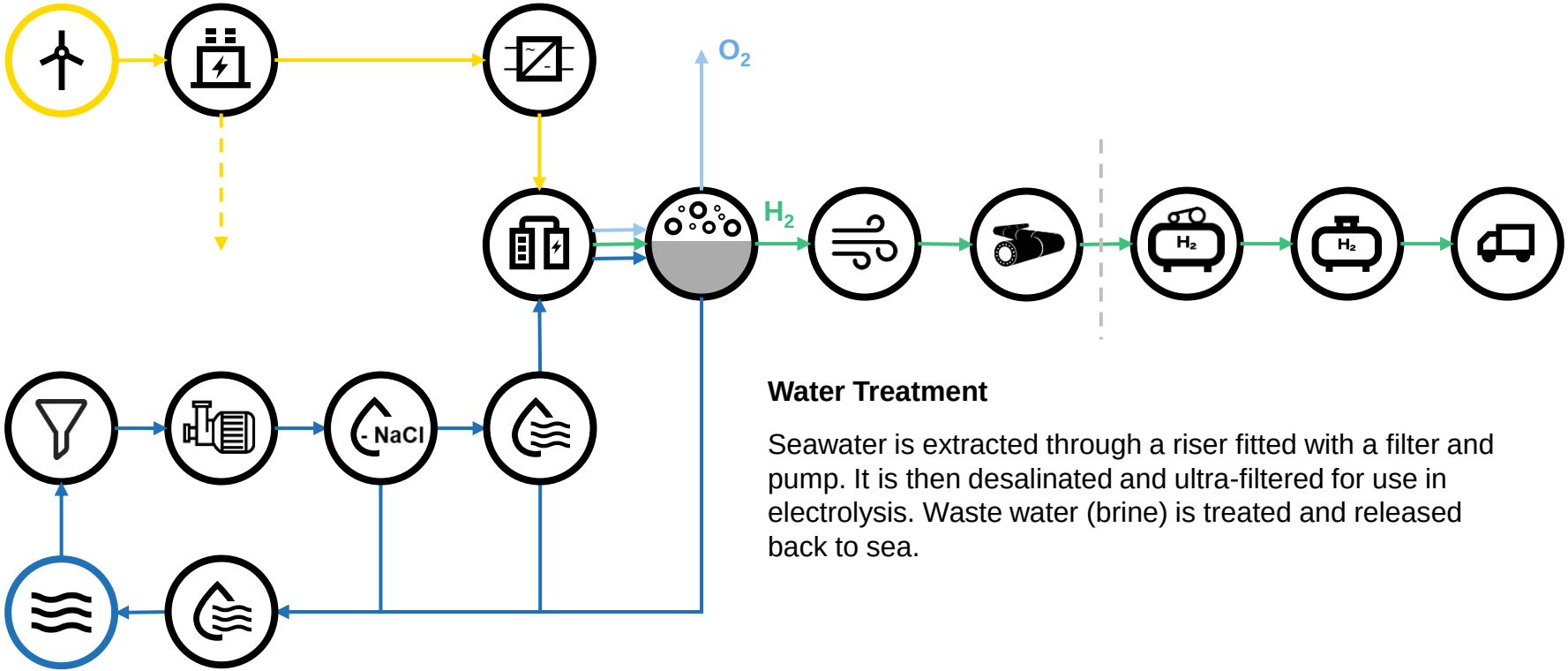
How the system will operate, from Turbine to Truck



Wind Turbine Generator

Vestas 8.8MW wind turbine generates power for use on Hydrogen Turbine 1. The existing set up will be adapted to direct power to the hydrogen production system rather than to the grid. A transformer is used to step down the voltage and a rectifier converts the current from AC to DC for the electrolyser.

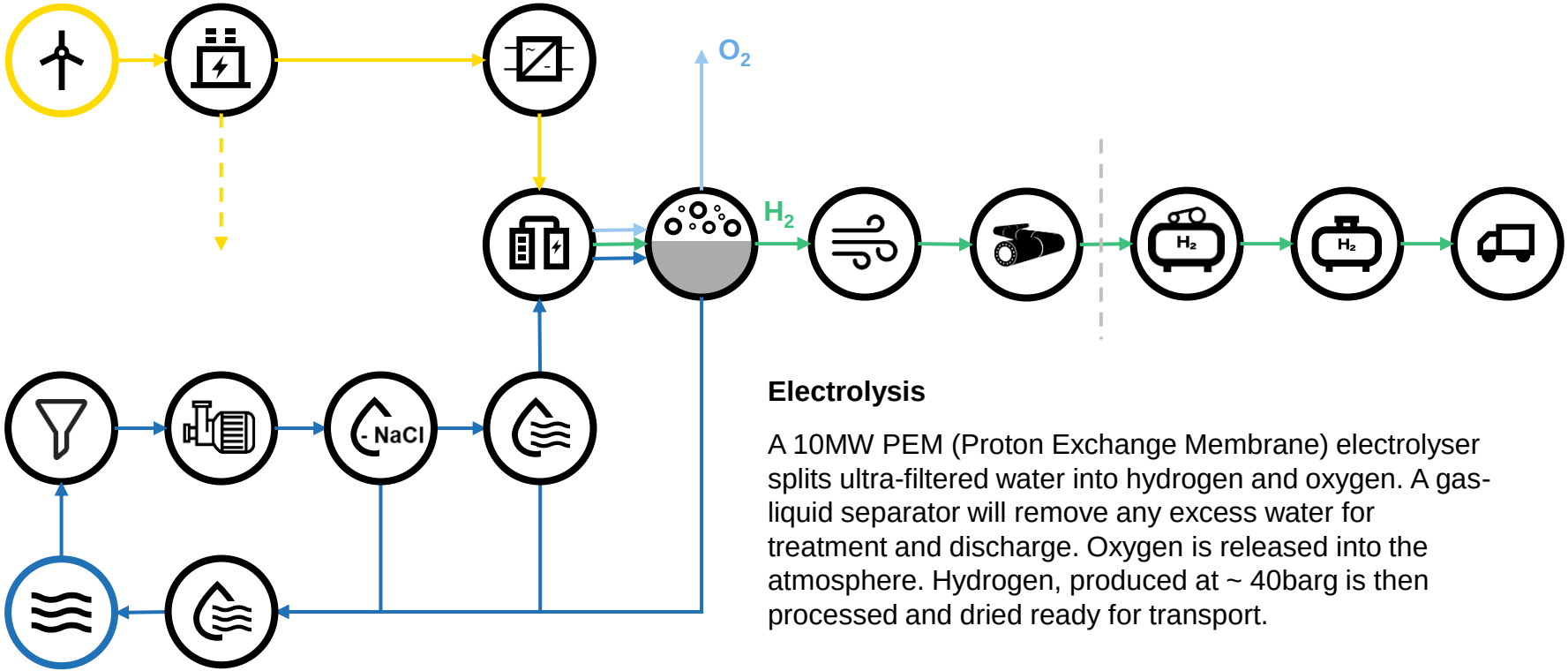
How the system will operate, from Turbine to Truck



Water Treatment

Seawater is extracted through a riser fitted with a filter and pump. It is then desalinated and ultra-filtered for use in electrolysis. Waste water (brine) is treated and released back to sea.

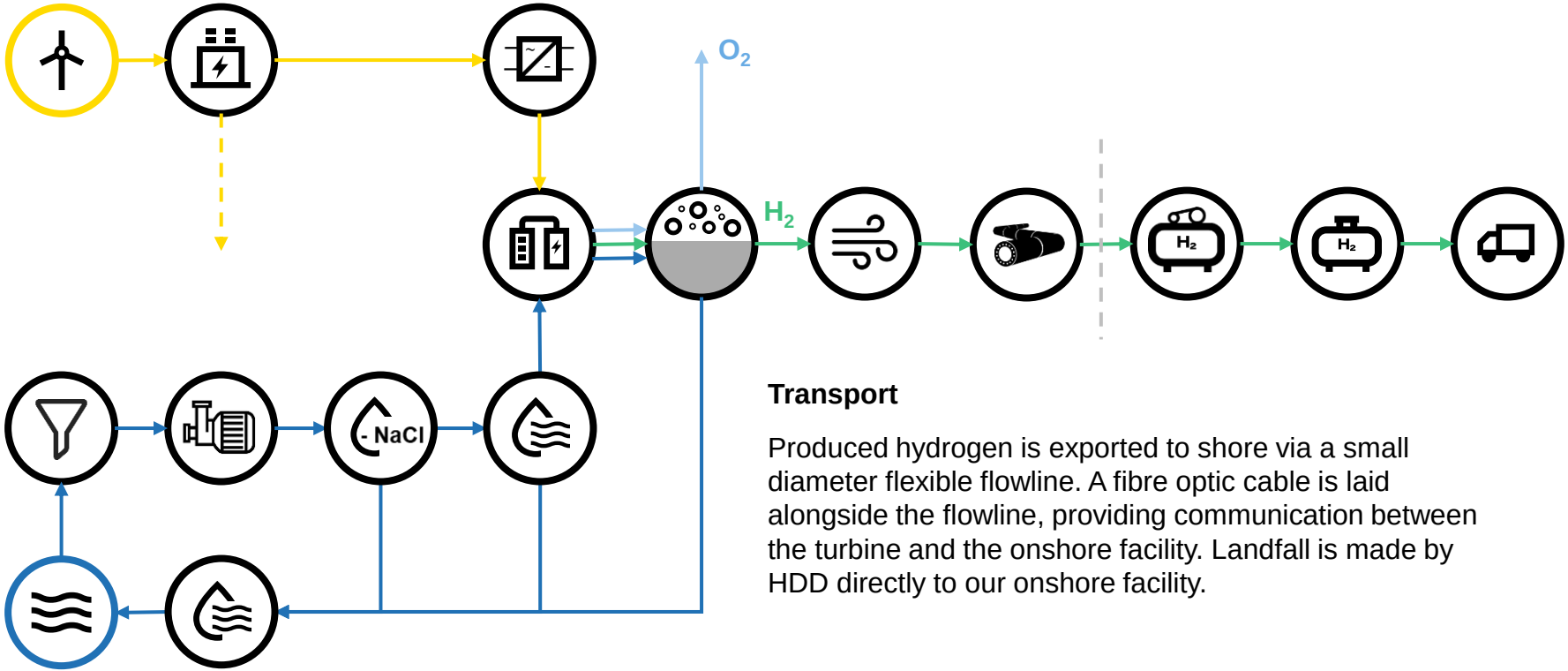
How the system will operate, from Turbine to Truck



Electrolysis

A 10MW PEM (Proton Exchange Membrane) electrolyser splits ultra-filtered water into hydrogen and oxygen. A gas-liquid separator will remove any excess water for treatment and discharge. Oxygen is released into the atmosphere. Hydrogen, produced at ~ 40barg is then processed and dried ready for transport.

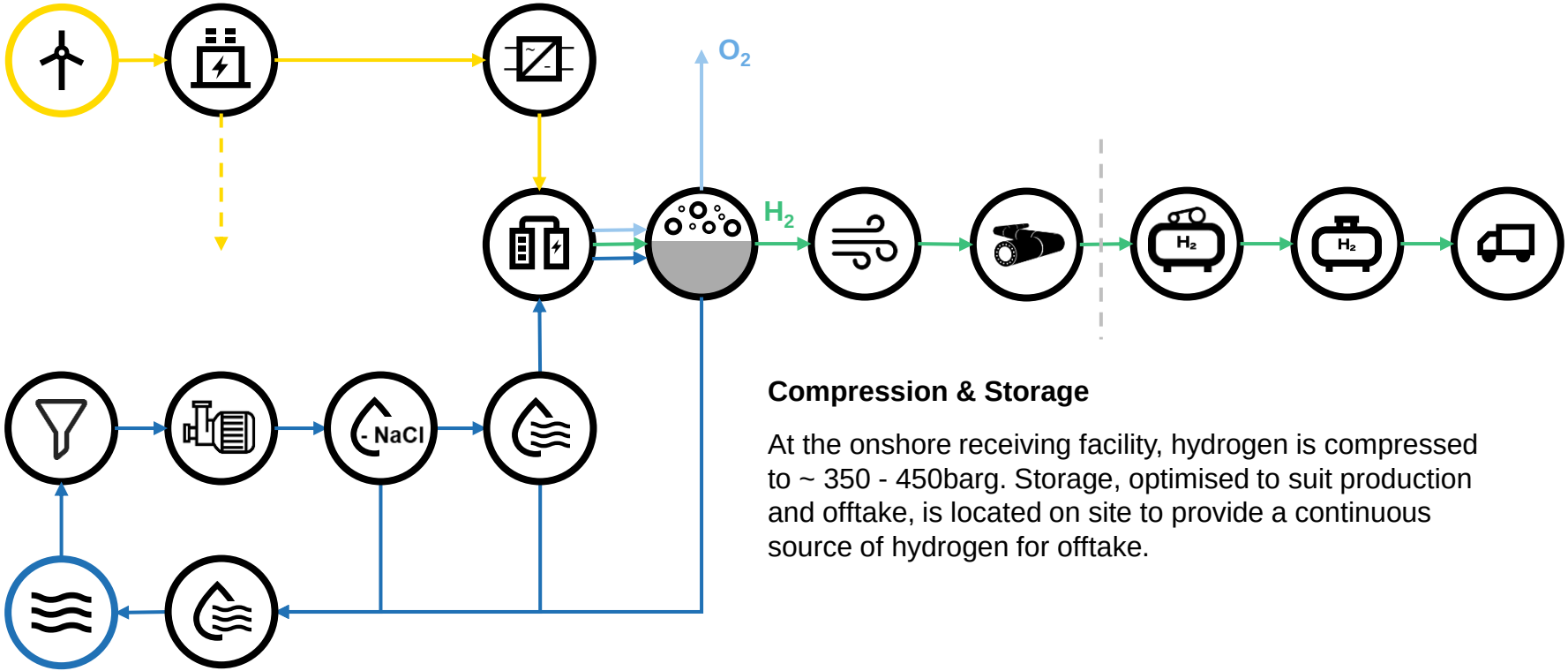
How the system will operate, from Turbine to Truck



Transport

Produced hydrogen is exported to shore via a small diameter flexible flowline. A fibre optic cable is laid alongside the flowline, providing communication between the turbine and the onshore facility. Landfall is made by HDD directly to our onshore facility.

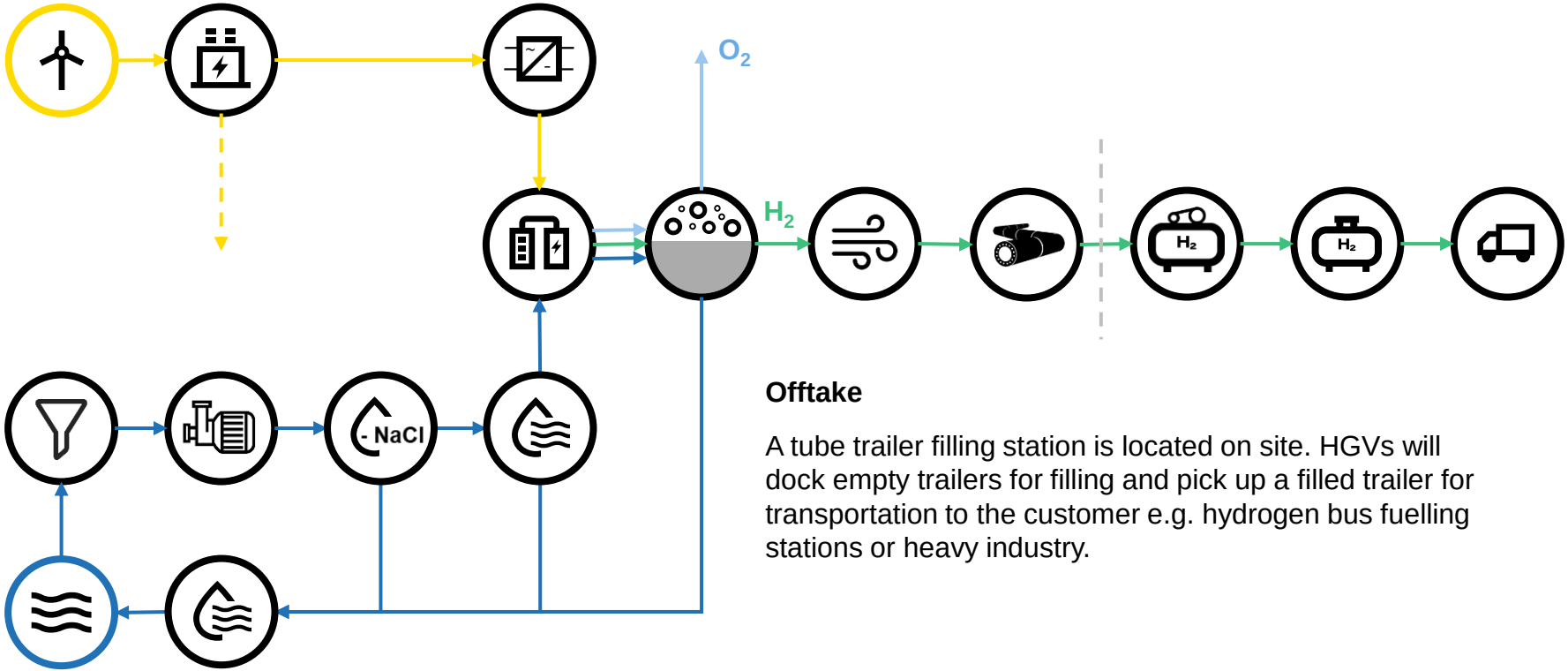
How the system will operate, from Turbine to Truck



Compression & Storage

At the onshore receiving facility, hydrogen is compressed to ~ 350 - 450barg. Storage, optimised to suit production and offtake, is located on site to provide a continuous source of hydrogen for offtake.

How the system will operate, from Turbine to Truck



Offtake

A tube trailer filling station is located on site. HGVs will dock empty trailers for filling and pick up a filled trailer for transportation to the customer e.g. hydrogen bus fuelling stations or heavy industry.

Hydrogen Turbine 1

Hydrogen Production System

- Hydrogen Production System (HPS) will use existing technology adapted for use in an offshore environment.
- HPS design will be adapted to fit in standard sized containers, simplifying installation process and change-out of sub systems during operation phase.
- Single storey concept adopted for safety, ease of access and to maximise clearance between the blade tip and the HPS.
- A nitrogen purging system may be used to make the system safe for intervention, or in the event of failure of a component in the system.
- A Hybrid Park Controller (HPC) will divert power from the grid to the HPS for start up.
- Operation and Maintenance of the system will be remote, as much as possible, minimising requirement for personnel on the turbine.
- The system will be fully tested onshore prior to deployment on the turbine.

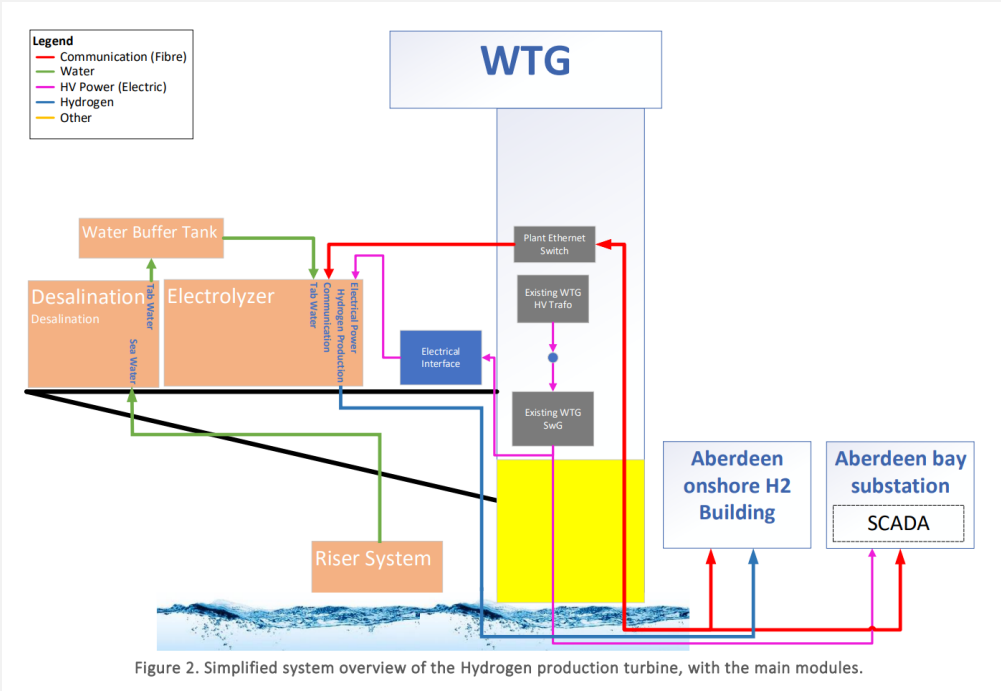
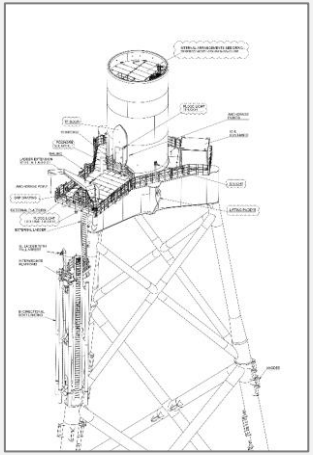


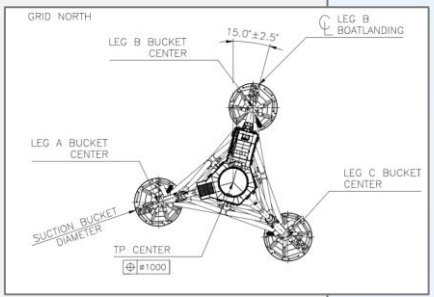
Figure 2. Simplified system overview of the Hydrogen production turbine, with the main modules.

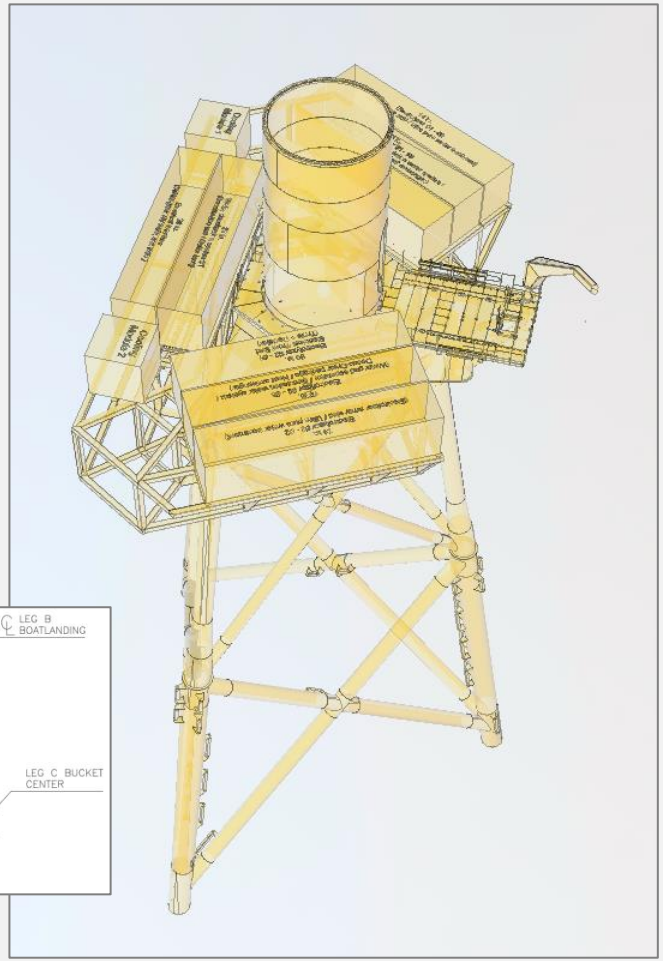
Hydrogen Turbine 1

Foundation

- Turbine is installed on a three leg jacket foundation with suction buckets on each leg that penetrate the seabed.
- Currently, a small platform sits atop the foundation providing access to the turbine tower.
- Inter Array Cables (IAC) enter and exit from the through J-tubes located in each leg of the foundation.
- The platform extension will wrap around the existing turbine, primarily using existing pad-eyes used for jacket installation. The concept minimises welding, using mechanical connections to the jacket where possible.
- Platform will be installed in two or three sections for ease of installation, possible from either a jack-up or floating vessel.
- Three risers will be retrofitted to the jacket: 1) for seawater extraction; 2) for discharge of brine; and 3) a J-tube to house the export flowline.







Hydrogen Turbine 1

Flowline and Landfall

- Aberdeen South Harbour was selected as the landfall location following a review of the onshore and offshore constraints and planned development of the Energy Transition Zone in the surrounding area.
- The route was selected following a study into the various hard and soft constraints between the turbine and the harbour, along with collaboration with local stakeholders.
- A geotechnical and geophysical route survey was conducted in Q1 2022, showing favourable soil conditions and some minor geological features. Boulders and debris have been identified along the route requiring a clearance campaign. A UXO clearance campaign is scheduled prior to installation.
- A flexible flowline solution (bonded or unbonded) has been selected to export hydrogen and a FO cable will be laid alongside to provide communication between the turbine and onshore facility. Both will be trenched and buried.
- Landfall is anticipated to be made via HDD directly from the onshore facility located within the Energy Transition Zone