REFHYNE

CLEAN REFINERY HYDROGEN FOR EUROPE

REFHYNE Project

10 MW Electrolyser Rhineland Refinery

General Overview

Submission date: September 2018

Status: V1.1

Dissemination Level: Public

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

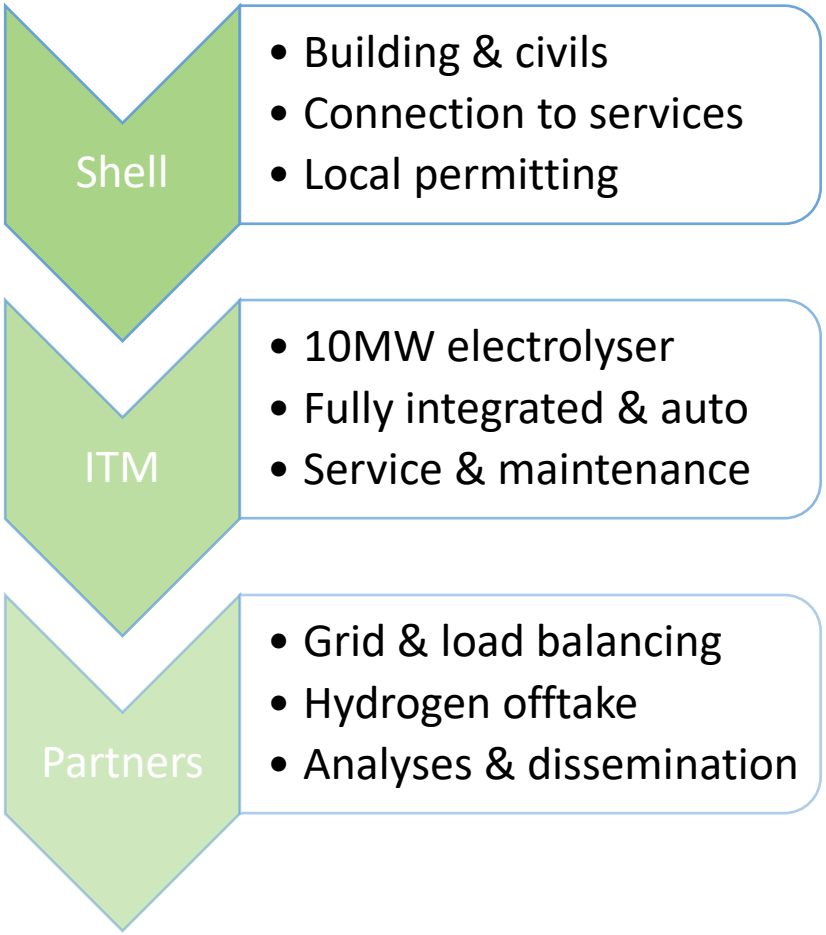
How the stars aligned for the Rhineland Refinery Project

- **Shell Germany reflected on the ongoing energy transition in Germany**
  - Shell Energy Scenarios for Germany 2050 established in 2016/17
  - Cross-Business Idea Gathering July 2016
  - Electrolyser identified as an opportunity
- **Building on the existing Shell / ITM Power co-operation in hydrogen**
  - Good track record for hydrogen in Germany
  - UK retail sites with small electrolysers
  - Good experience with EU funding
- **The EU FCH-JU Funding Round 2017 opened the door to enable it**
  - Fuel Cell & Hydrogen Joint Undertaking (FCH-JU)
  - Funding calls in various Fuel Cell Hydrogen areas
  - One call for a large 10 MW electrolyser

Project Overview- World's Largest PEM Electrolyser

- Deployment of 10 MW PEM electrolyser
- On-site hydrogen and oxygen generation
- Hydrogen to be fed to existing pipeline
- Option to recover oxygen
- Flexible & rapid response electrical load
- Capable of site load balancing and wider grid balancing

- ITM & Shell jointly developed a bid for EU funding
- Successful bid securing ~60% funding
- Requirement to undertake certain test profiles
- 5 year project
- 2 years design, build and deploy
- 3 years test operation



REFHYNE Revenue Overview

REFHYNE Launch

FORMAL KICK-OFF ON JAN, 18TH 2018: EUROPEAN CONSORTIUM WITH SHELL AND ITM POWER ANNOUNCE AGREEMENT TO BUILD ELECTROLYSER AT RHINELAND REFINERY

Shell and ITM Power will build the world's largest hydrogen electrolysis plant at Rhineland refinery, Germany. With a peak capacity of 10 MW, the hydrogen will be used for the processing and upgrading of products at the refinery's Wesseling site as well as testing the technology and exploring applications in other sectors.

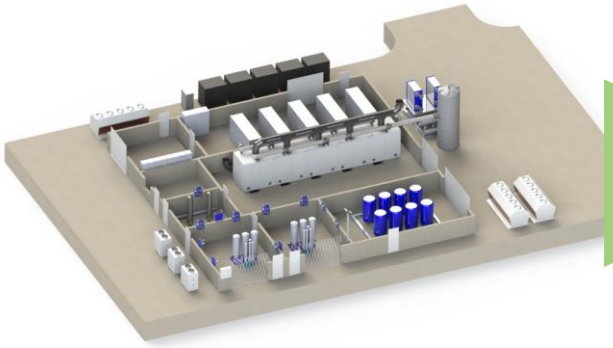
The European partner consortium of Shell, ITM Power, SINTEF, thinkstep and Element Energy has now secured 10 million euros in funding from the European "Fuel Cell Hydrogen Joint Undertaking". The project's total investment, including integration into the refinery, is approximately 20 million euros.

Detailed technical planning and the approval process will now begin. The plant, named "REFHYNE", is scheduled for operation in 2020 and will be the first industrial scale test of the polymer electrolyte membrane technology process.

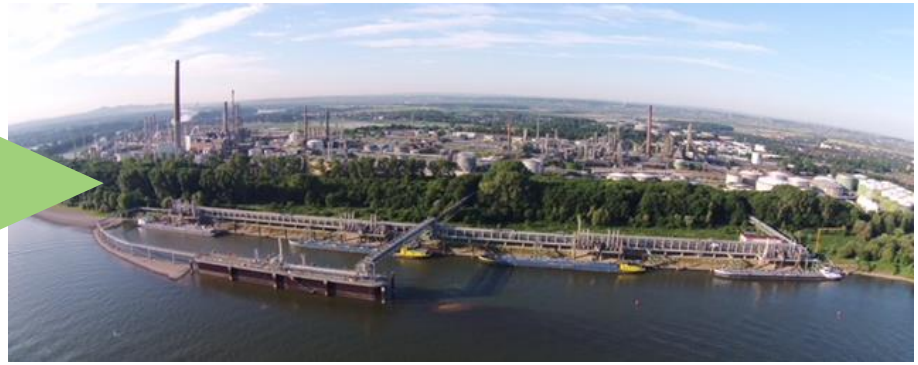
REFHYNE will deploy the world's largest PEM electrolyser

- The REFHYNE project will install a 10 MW PEM electrolyser at the Shell Rhineland Refinery
- It will be the largest of its kind in the world
- The Rhineland Refinery Complex is the largest in Germany

10 MW ITM Power Electrolyser



Rhineland Refinery (Wesseling, Germany)



Revenue streams

Supply to local gas network replacing steam reformed hydrogen

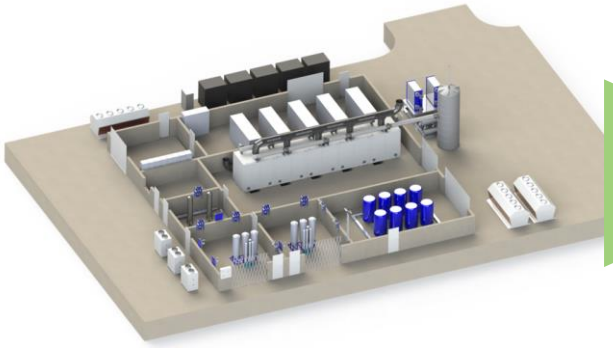
Load balancing for refinery site

Grid balancing

REFHYNE Objectives

- Assessing the economic, technical & environmental impact of the deployment of a large scale electrolyser
- Developing and testing business models based on existing & future revenue streams in a changing energy setting
- Exploring the policy implications of the technology and disseminating the project results across Europe

10 MW ITM Power Electrolyser



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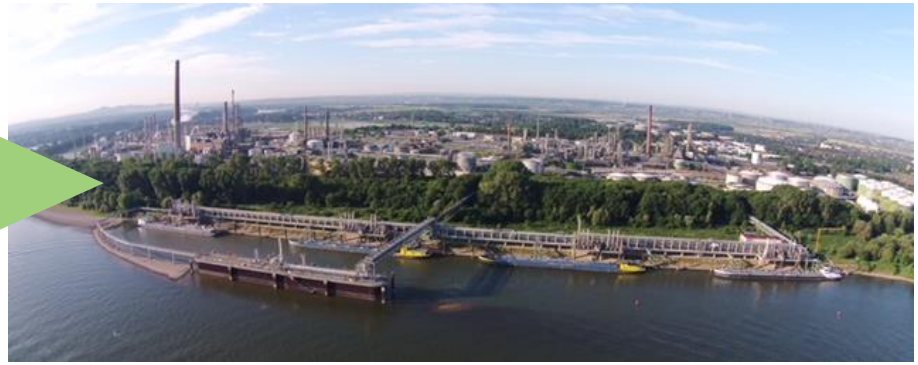

Revenue streams

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- Load balancing for refinery site
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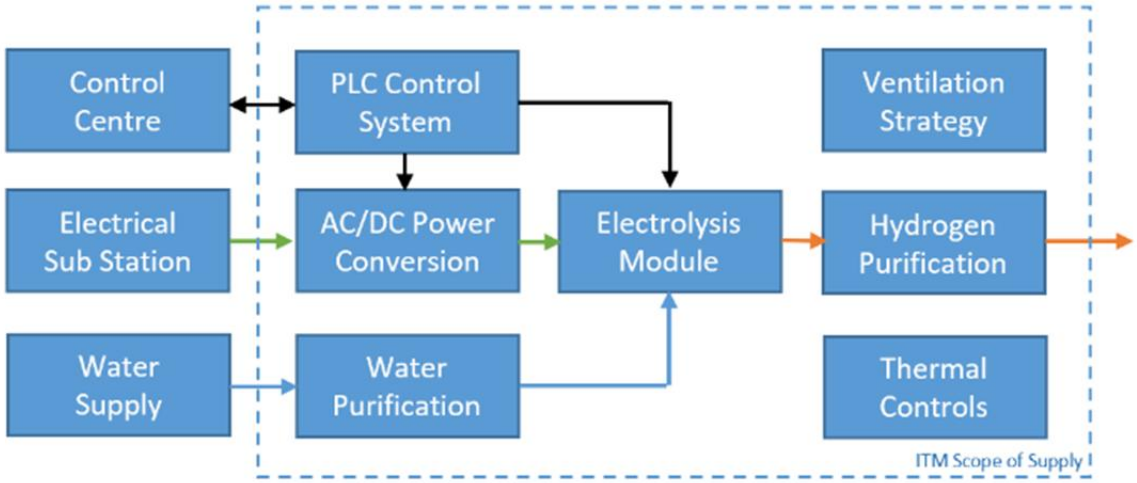
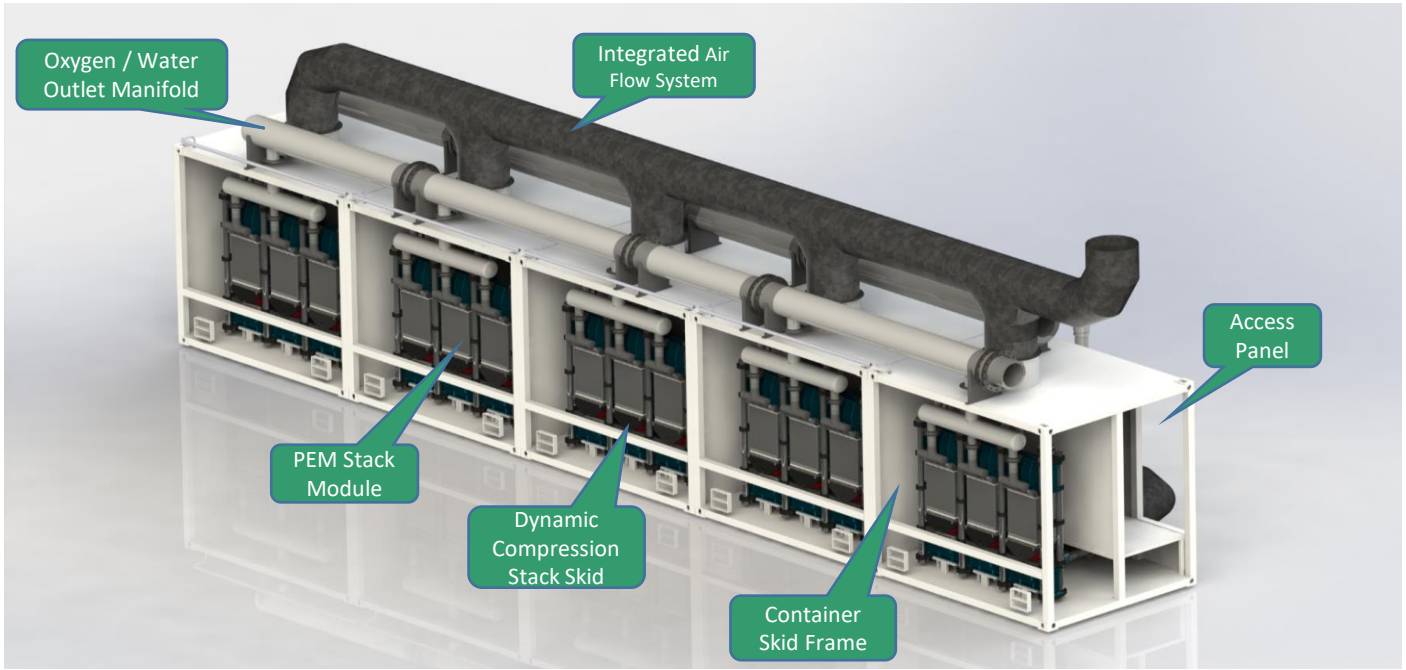
The electrolyser will enable large scale hydrogen production

- The traditional route for hydrogen production at large scales is Steam Methane Reformation (SMR), directly producing CO_2
- Electrolysers split water into oxygen & hydrogen using an electro-chemical reaction and thus, when using low CO_2 electricity, can reduce H_2 production emissions
- ITM Power's electrolyser will be a fully integrated and autonomous system using a 10 MW stack skid
- At full load, the plant will be capable of generating 4 tonnes H_2 per day



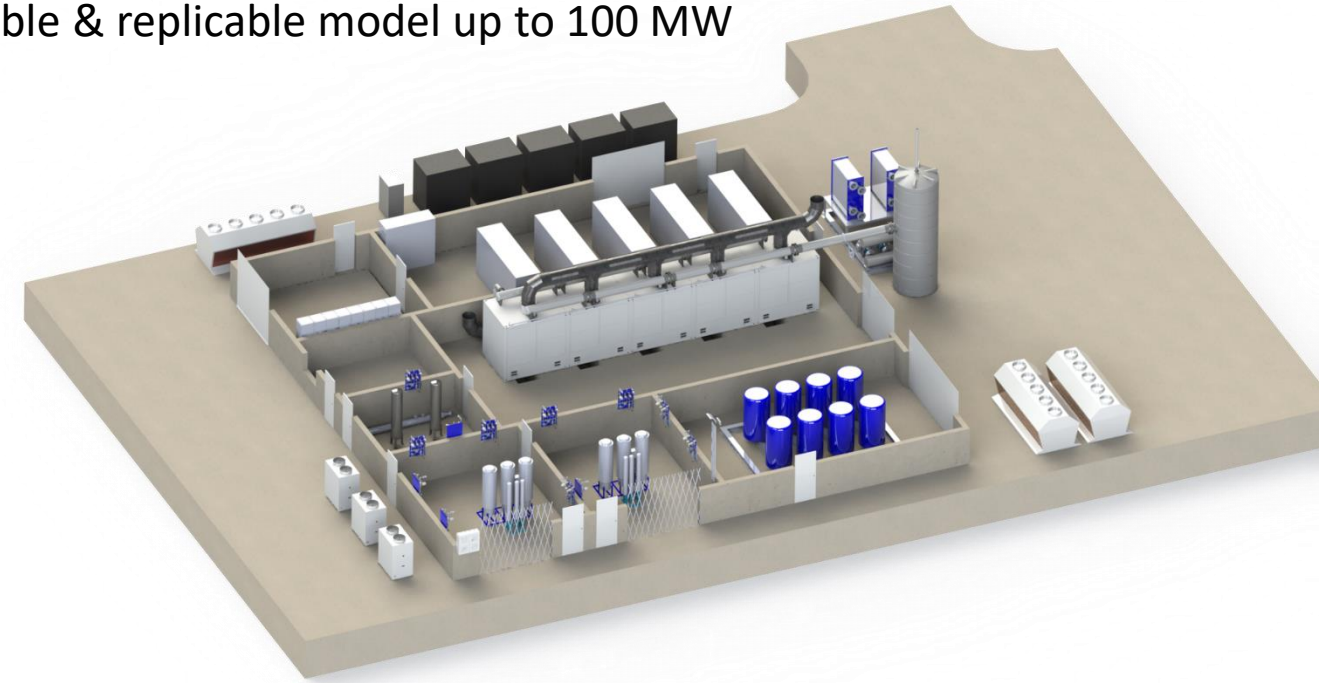
The 10 MW ITM Power Stack Skid

- The 10MW stack skid comprises 5x 2MW sub modules packaged into one unit
- Each sub-module can be operated independently providing operational flexibility and resilience
- Well proven PEM technology enabling ultra-fast response – Stack efficiency will be between 45 and 55 kWhr/kg

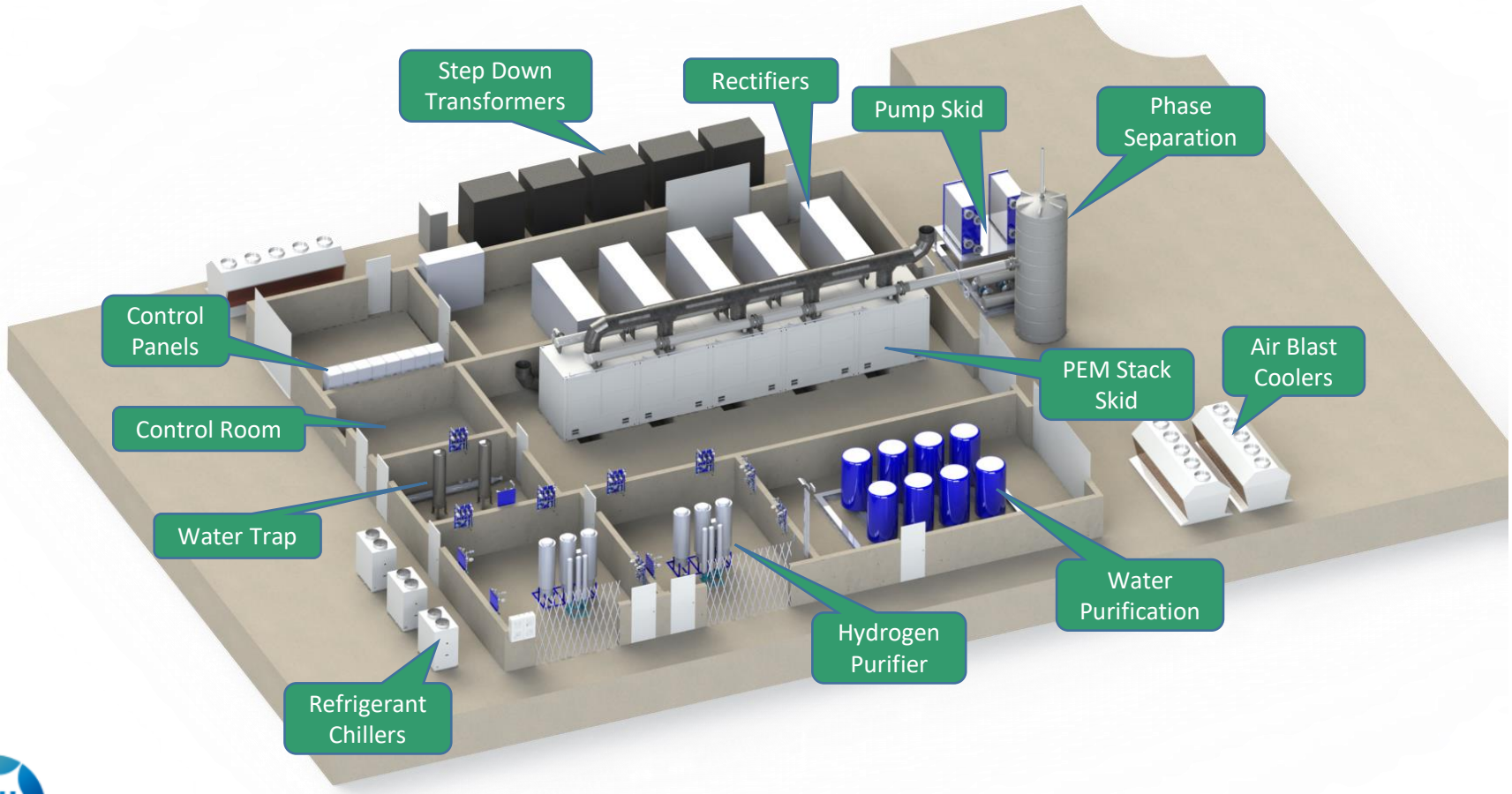


System Layout Concept

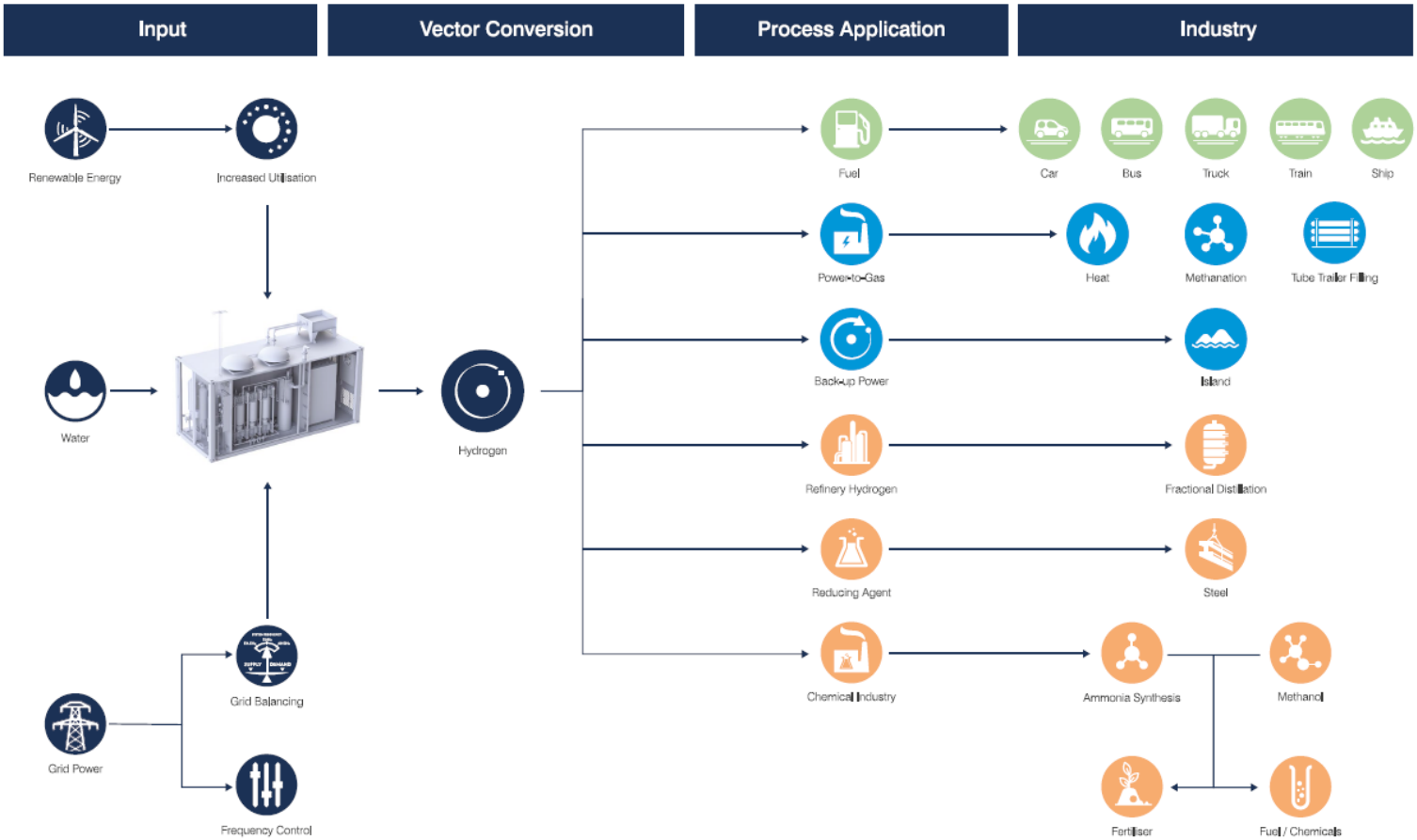
- The electrolyser system incorporates all necessary balance of plant from rectifiers to hydrogen purification
- The equipment will be located in a new, single storey building in the refinery – Building footprint approx. 25x25m
- Sub-systems will be located in different rooms according to AtEx requirements
- Expandable & replicable model up to 100 MW



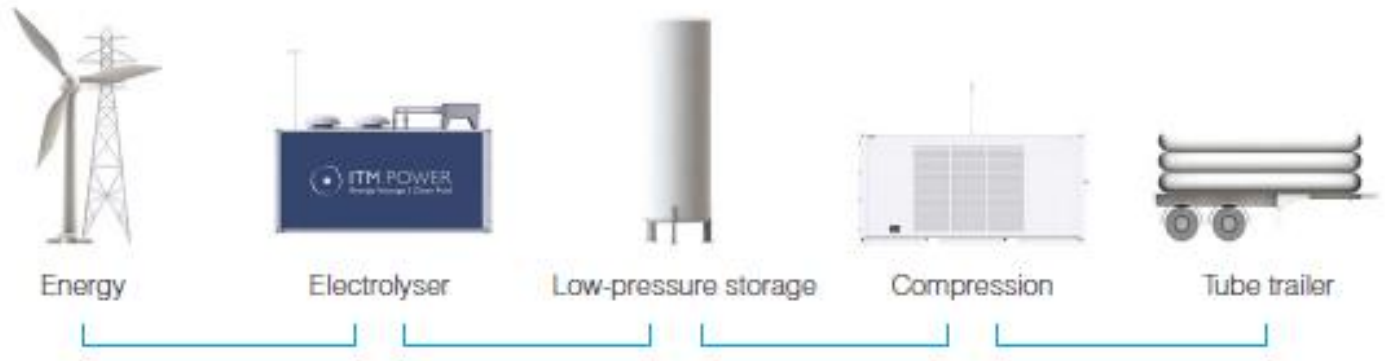
REFHYNE – ITM Power PEM Electrolyser Expected Layout

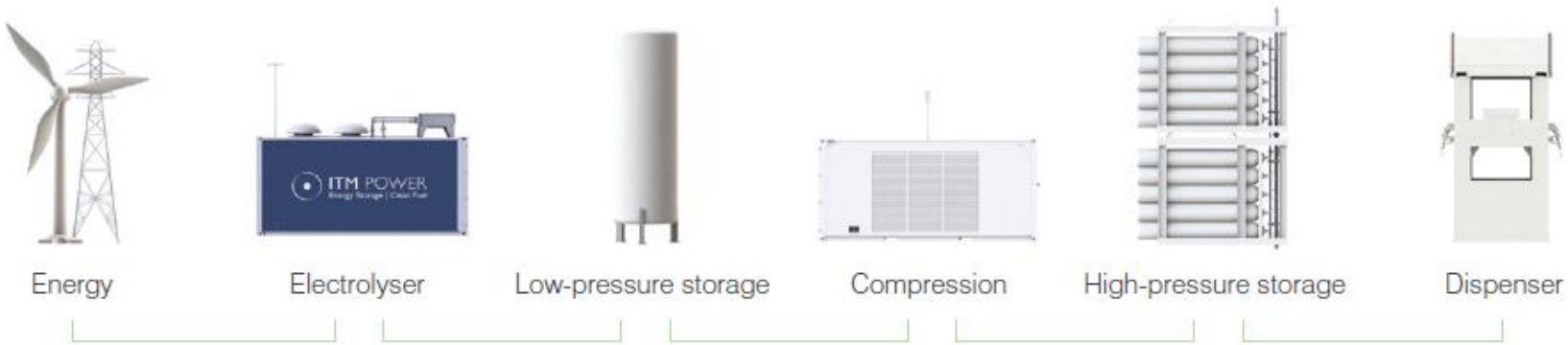


There are many applications for Hydrogen from PEM Electrolysers



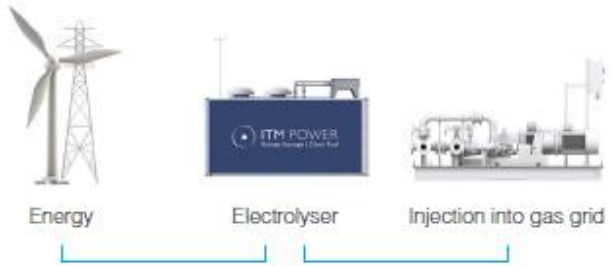
Mobility – Supply to Fuel Cell Cars: Refueling Stations



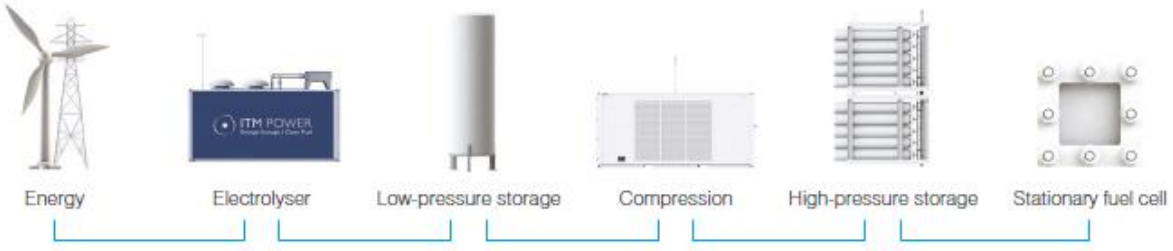


Energy Transition: Potential Energy Storage Solutions

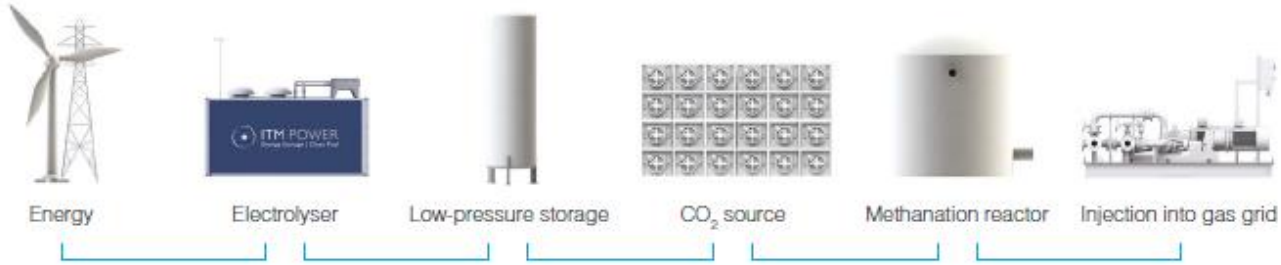
POWER-TO-GAS



ISLAND SYSTEMS



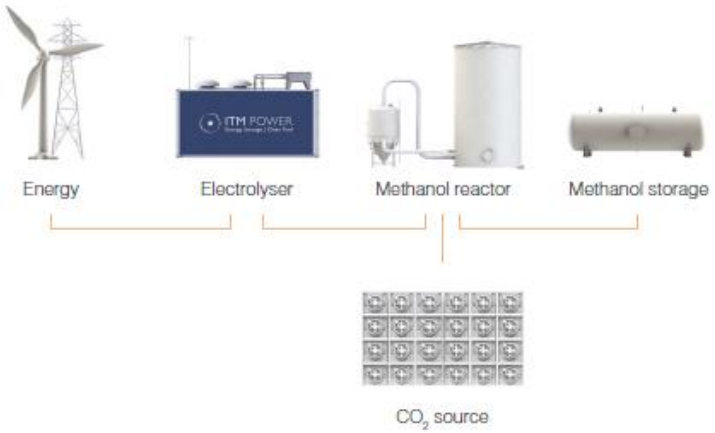
METHANATION



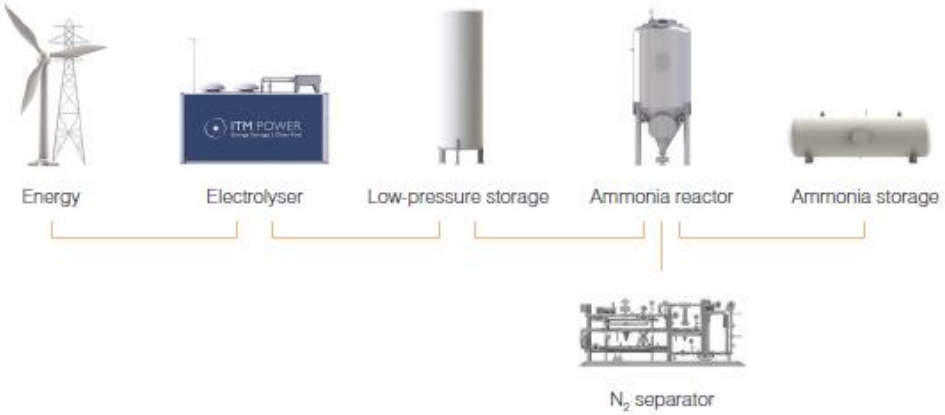
Hydrogen from Electrolysers for Large Industry Applications

REFINERIES

METHANOL SYNTHESIS



AMMONIA SYNTHESIS



STEEL PRODUCTION

Acknowledgments

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