HIPS-NET ANNUAL WORKSHOP 14TH JUNE 2018

HYDROGEN IN THE ENERGY SYSTEM - LATEST DEVELOPMENTS AND ITM KEY PROJECTS

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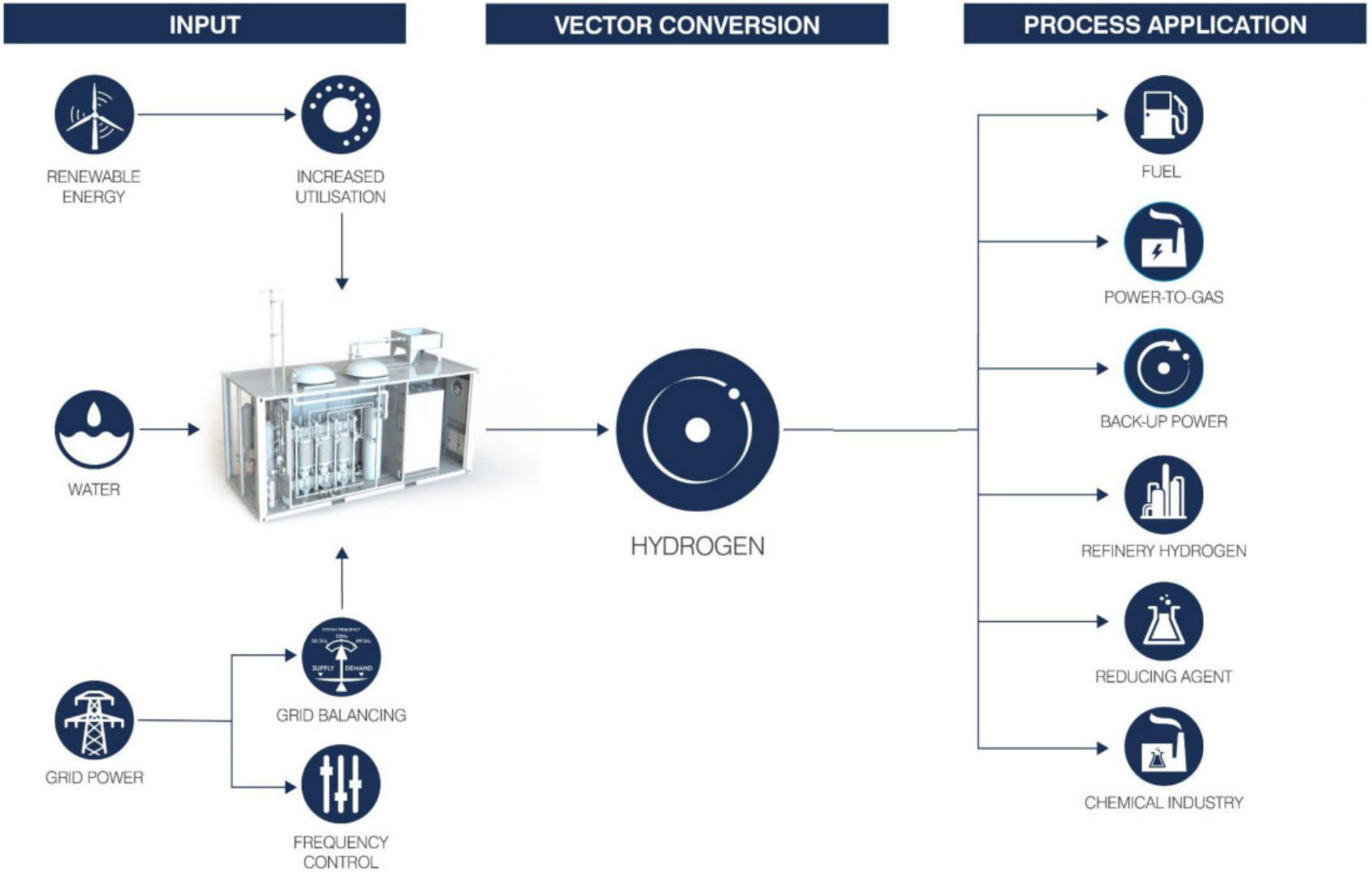

MULTIPLE SECTOR APPLICATIONS

HYDROGEN ENERGY SYSTEMS

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POWER TO GAS

HYDEPLOY

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HyDeploy

Keele UNIVERSITY

Cadent

Northern Gas Networks

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Progressive energy

HEALTH & SAFETY LABORATORY

Project Objective

To demonstrate for the first time that a blend of hydrogen and natural gas can be distributed and utilised safely & efficiently in the UK distribution network without disruptive changes for consumers.

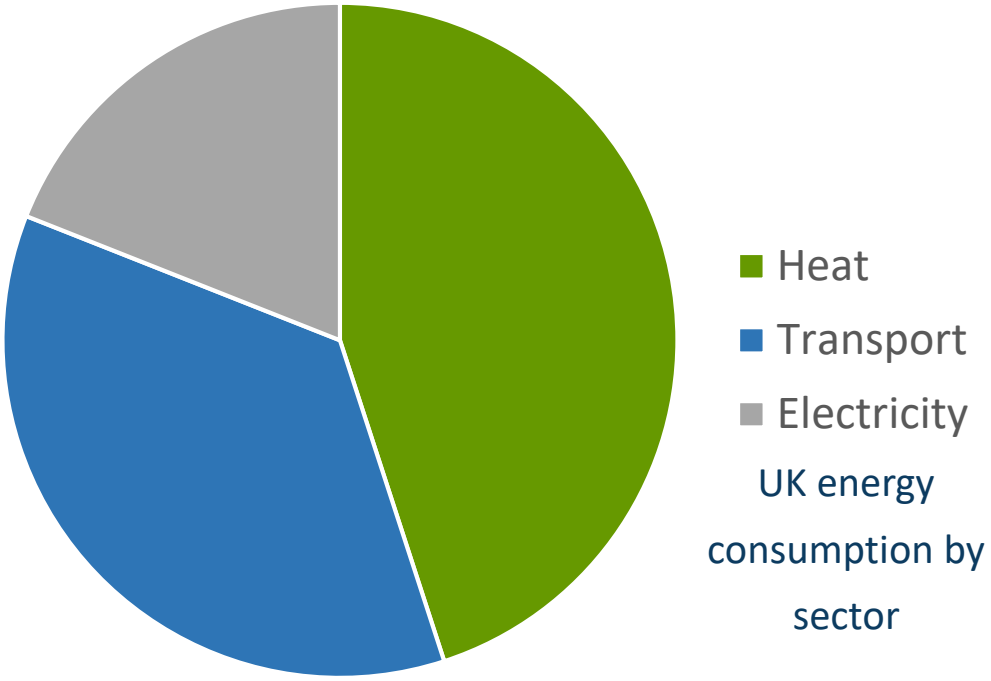
Potential to Deliver

29TWh of low carbon heat per annum equating to saving:

CO_{2e} of 120 million tonnes & £8 billion cumulatively by 2050

Project Funded under OFGEM's Network Innovation Programme

Heat



UK energy consumption by sector

Heat represents nearly half of UK energy consumption

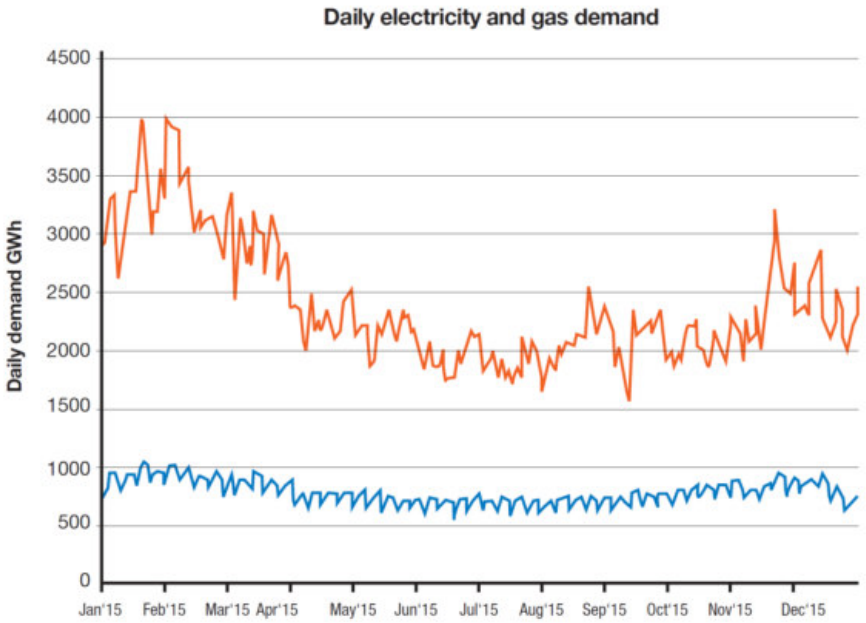
We need to reduce the carbon impact of heat

Gas: flexible & convenient delivery of heat

Gas provides 80% of heat at times of peak demand

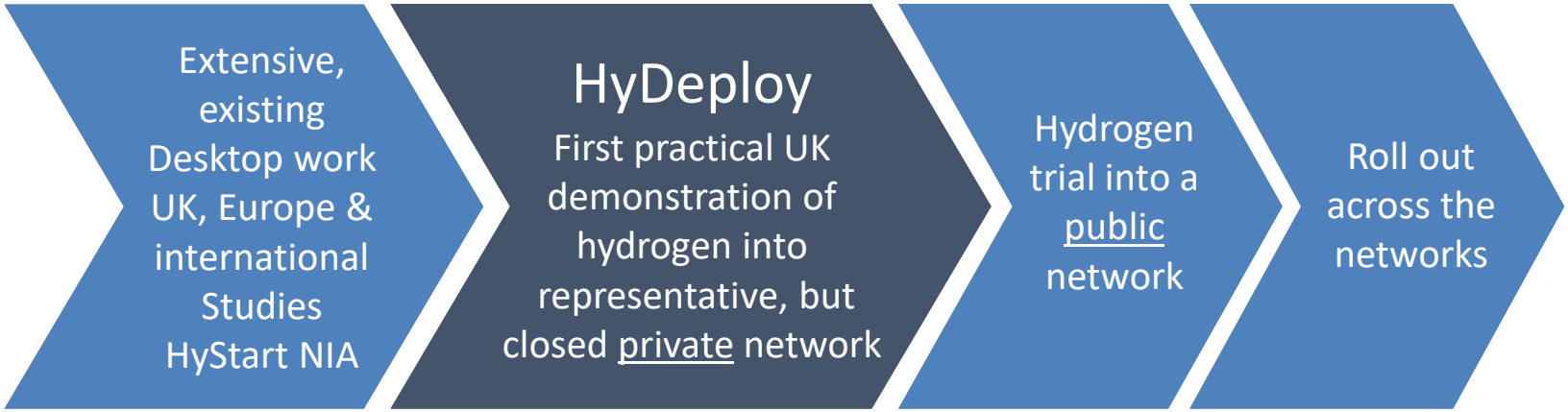
320TWh per annum to domestic customers

Over 23 million gas UK customers through world class infrastructure



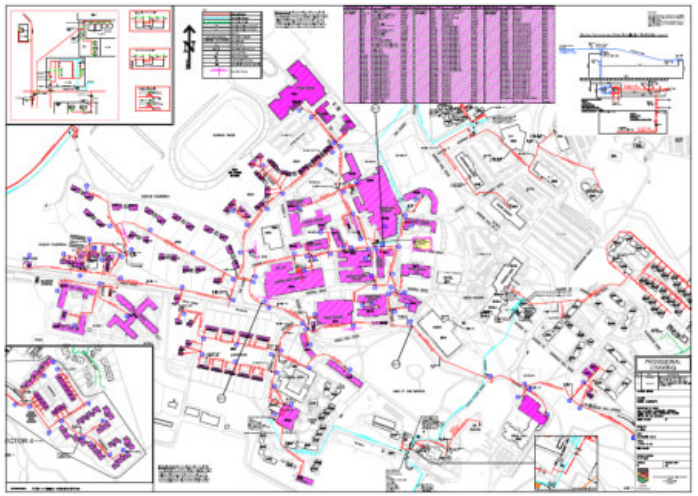
The HyDeploy Demonstration Project

- HyDeploy: A reference work to be used by the industry now & into future
- Build on existing work on the impact of H_2 on appliances & networks & best practice for running new gas trials
- A closed private network is ideal for the first UK trial



The Keele Campus - a small town on gas

- The Campus the size of a small town
  - 101 residential houses
  - 8 multi-residential buildings
  - 17 extensive office blocks & laboratories
  - 7 recreational & service facilities
- Keele is licensed transporter & supplier
- Engaged with BEIS and HSE to use its energy network as a *'Living Laboratory'*

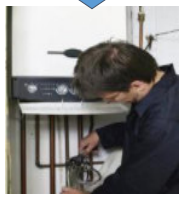


Programme Overview

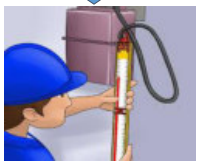
Phase 1

Engagement

Appliance Lab test



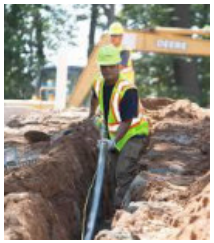
Onsite testing



Tightness testing

Specify & design H_2 equipment

Assessment of technical attributes with regard to safety & performance



Pre-development activities

HSE

Safety case

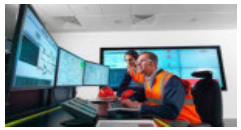
Clearances to Phase 2

Commissioning & pre-injection processes

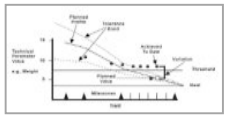
Installation: H_2 &infrastructure

Place orders

Phase 3



Operation



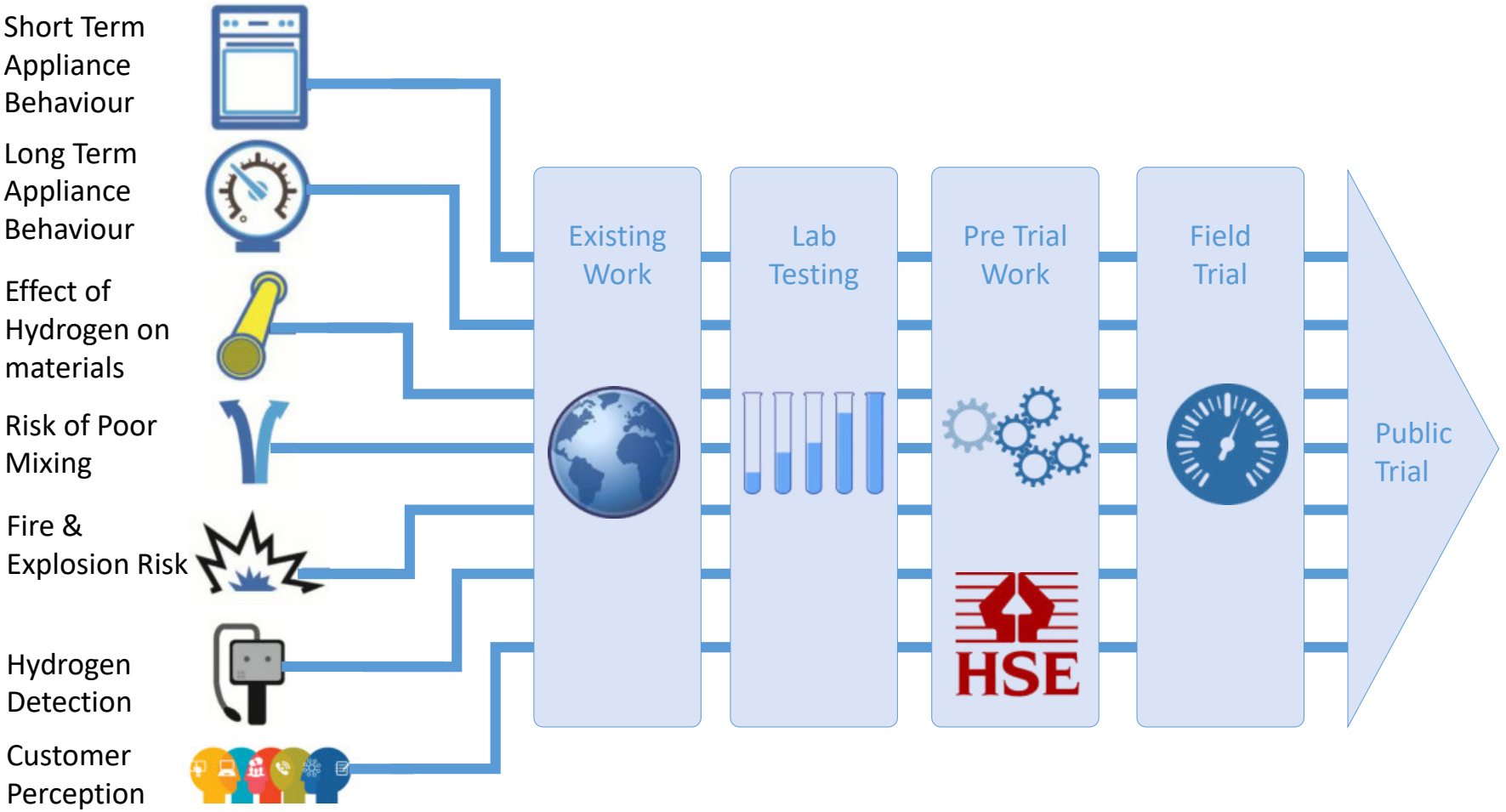
Analysis

Plan public trial

Reinstate

Dissemination

Key Issues to Address & Demonstrate



REFINERY APPLICATIONS

REFHYNE

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REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE

REFHYNE Project
10 MW Electrolyser Rhineland Refinery

Overview

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SINTEF

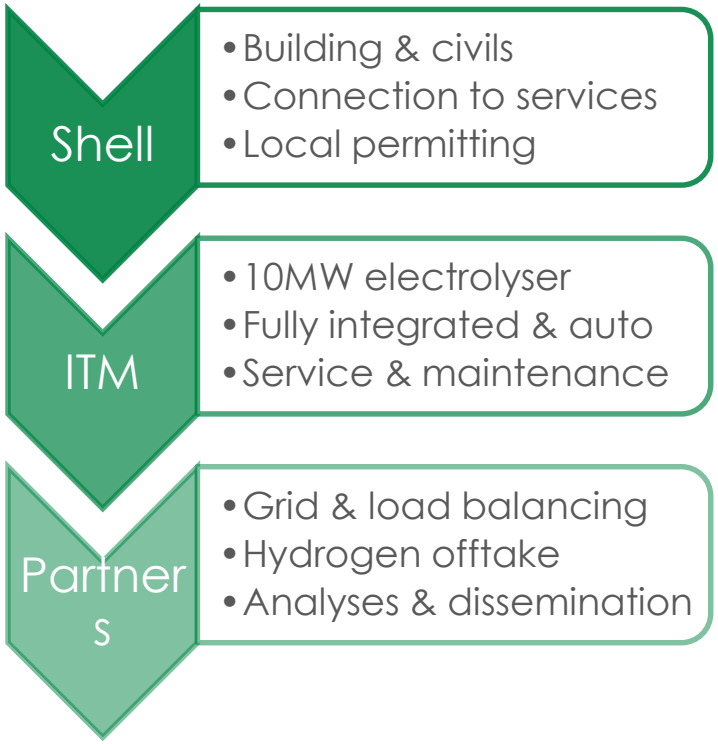
thinkstep

elementenergy

Project Overview – World's Largest PEM Electrolyser

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

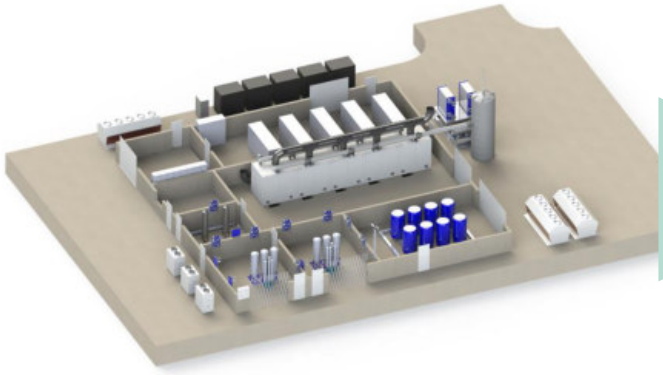
- ITM & Shell jointly developed a bid for EU funding
- Successful bid securing ~60% funding
- Requirement to undertake certain test profiles
- 5 year project
- 2 years design, build & deploy
- 3 years test operation



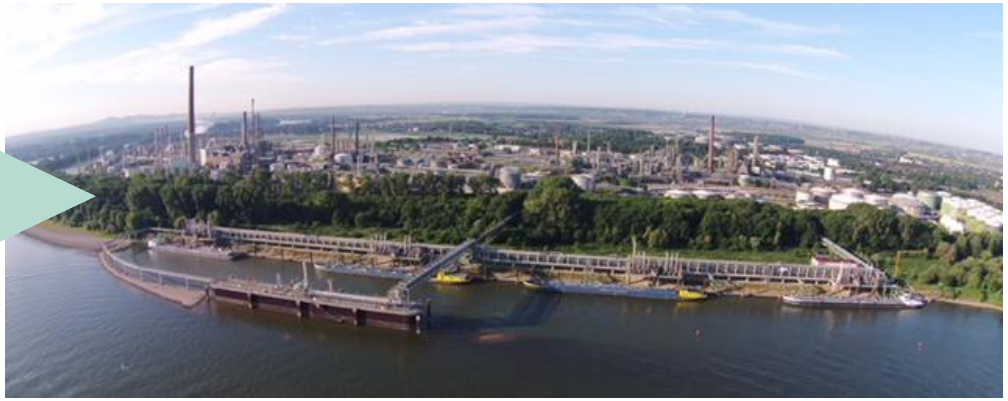
REFHYNE will deploy the world's largest PEM electrolyser

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

10 MW ITM Power Electrolyser



Rheinland Refinery (Wesseling, Germany)



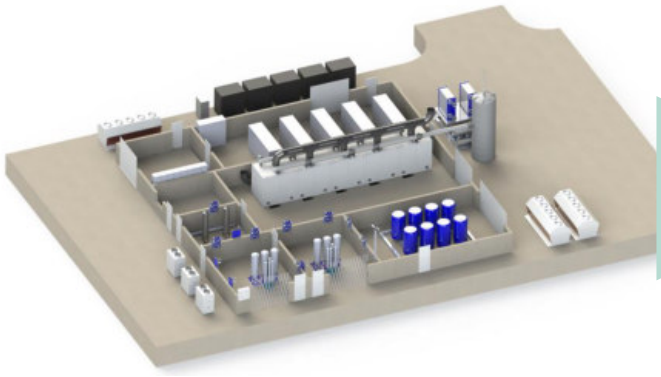
Revenue streams

- 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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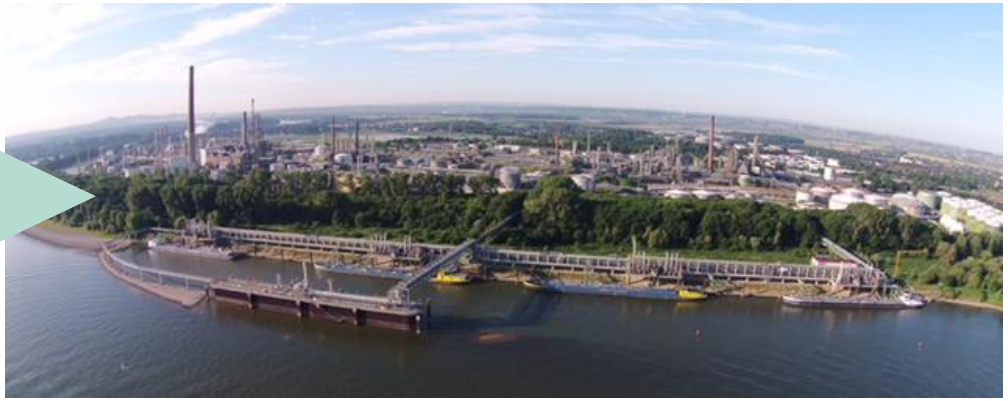

Revenue streams

- Supply to local gas network replacing steam reformed hydrogen
- Load balancing for refinery site
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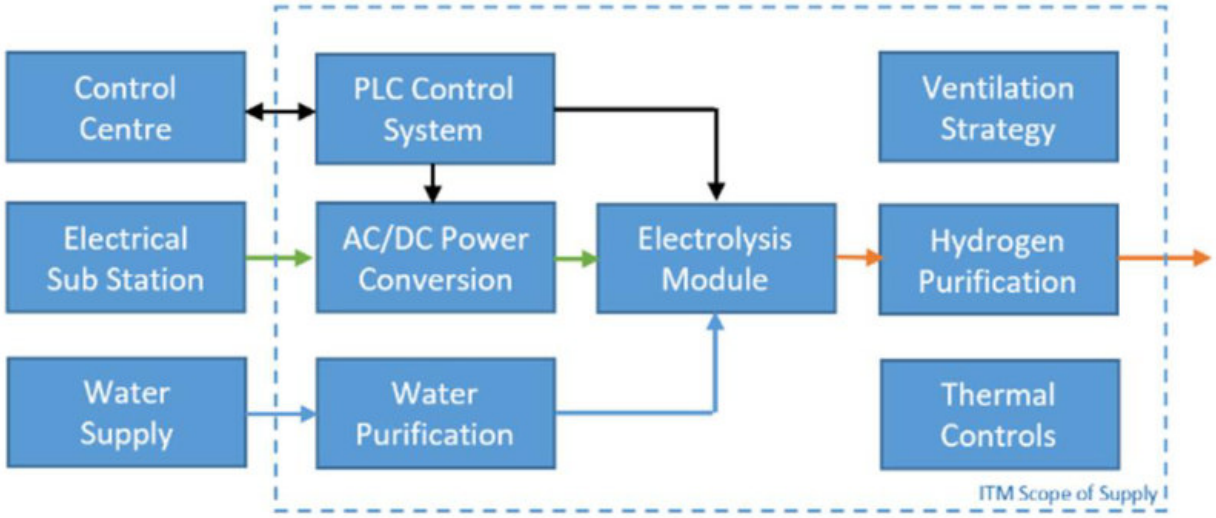
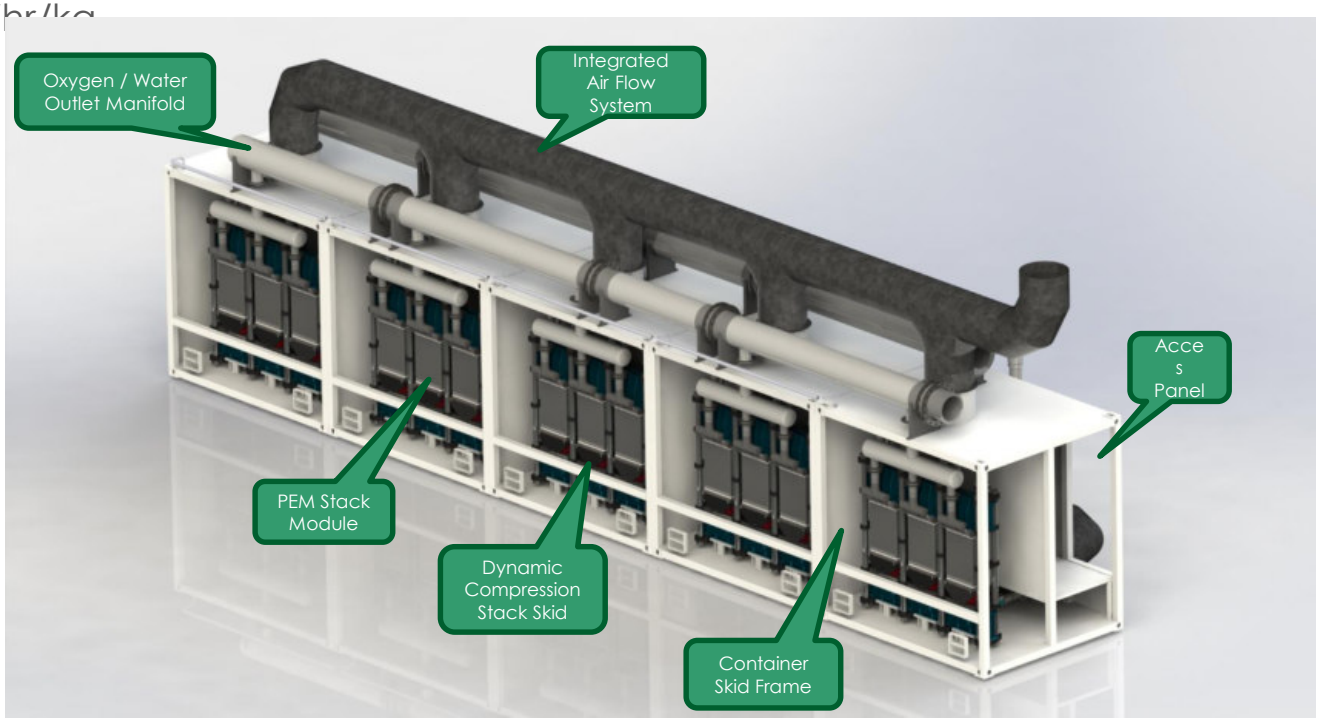
The electrolyser will enable large scale hydrogen production

- 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 the emissions required to produce hydrogen
- 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 of hydrogen per day



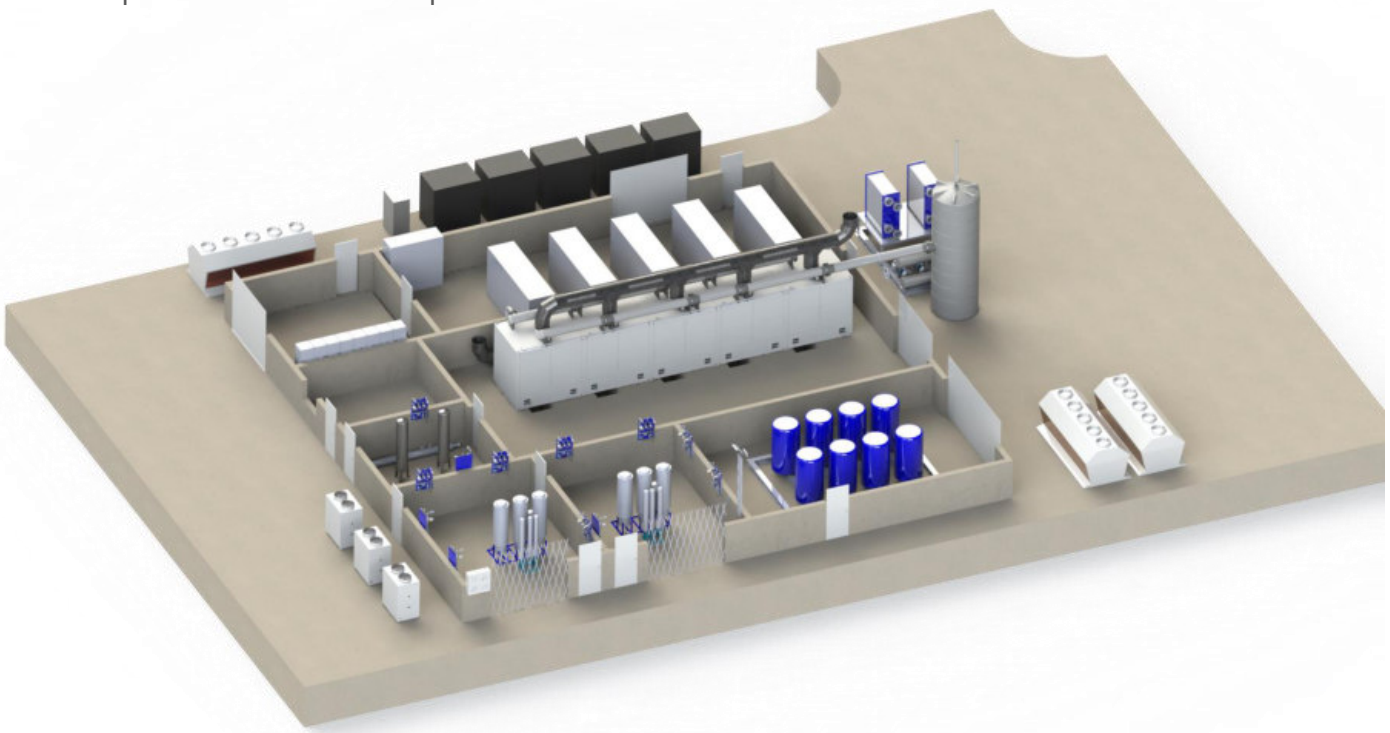
The 10 MW ITM Power Stack Skid

- The 10MW stack skid comprises 5 x 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 - 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 100MW



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