Hydrogen:
A Business Opportunity for the North East Region

Chair: Maggie McGinlay, ONE

Session 2: Hydrogen Opportunity

- **Aberdeen Hydrogen Hub** – Andrew Win, Aberdeen City Council
- **Role of H2 in Decarbonising the Dutch Economy** – Dr Jamie Frew
- **The Opportunity which H2 presents the supply chain** – Suzanne Ferguson, Wood
- **Hydrogen in the UK and Internationally**- Sarah Kimpton, DNV GL

Aberdeen Hydrogen Hub

Speaker: Andrew Win, Aberdeen City Council

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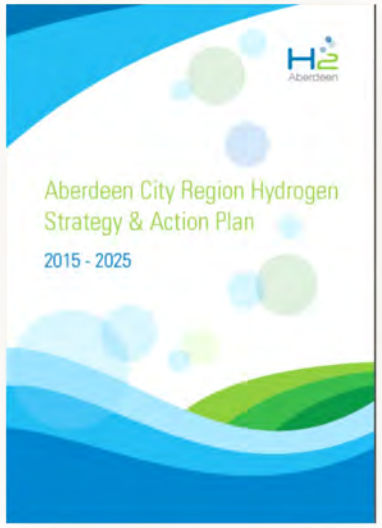
Aberdeen Hydrogen Hub

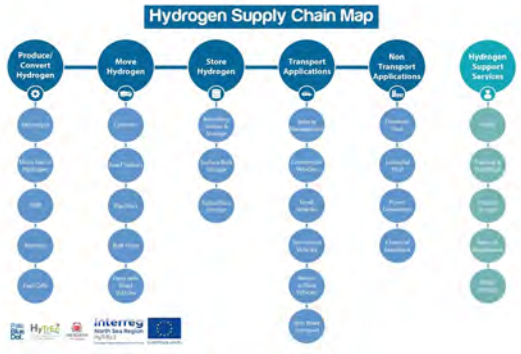
Andrew Win

Aberdeen City Council

H2 Aberdeen


Aberdeen City Region Hydrogen
Strategy & Action Plan
2015 - 2025


HYDROGENICS


Hydrogen Supply Chain Map
Produce/ Convert Hydrogen
Move Hydrogen
Store Hydrogen
Transport Applications
Non Transport Applications
Hydrogen Support Services

Vehicle Deployments

Promote vehicle deployments by a range of stakeholders in the region:

Refueling Infrastructure

Develop hydrogen refuelling infrastructure:

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Market Constraints

- Vehicle Price
- Component and Servicing Costs
- Servicing Supply Chain
- Maintenance & Technicians
- Hydrogen production & infrastructure costs

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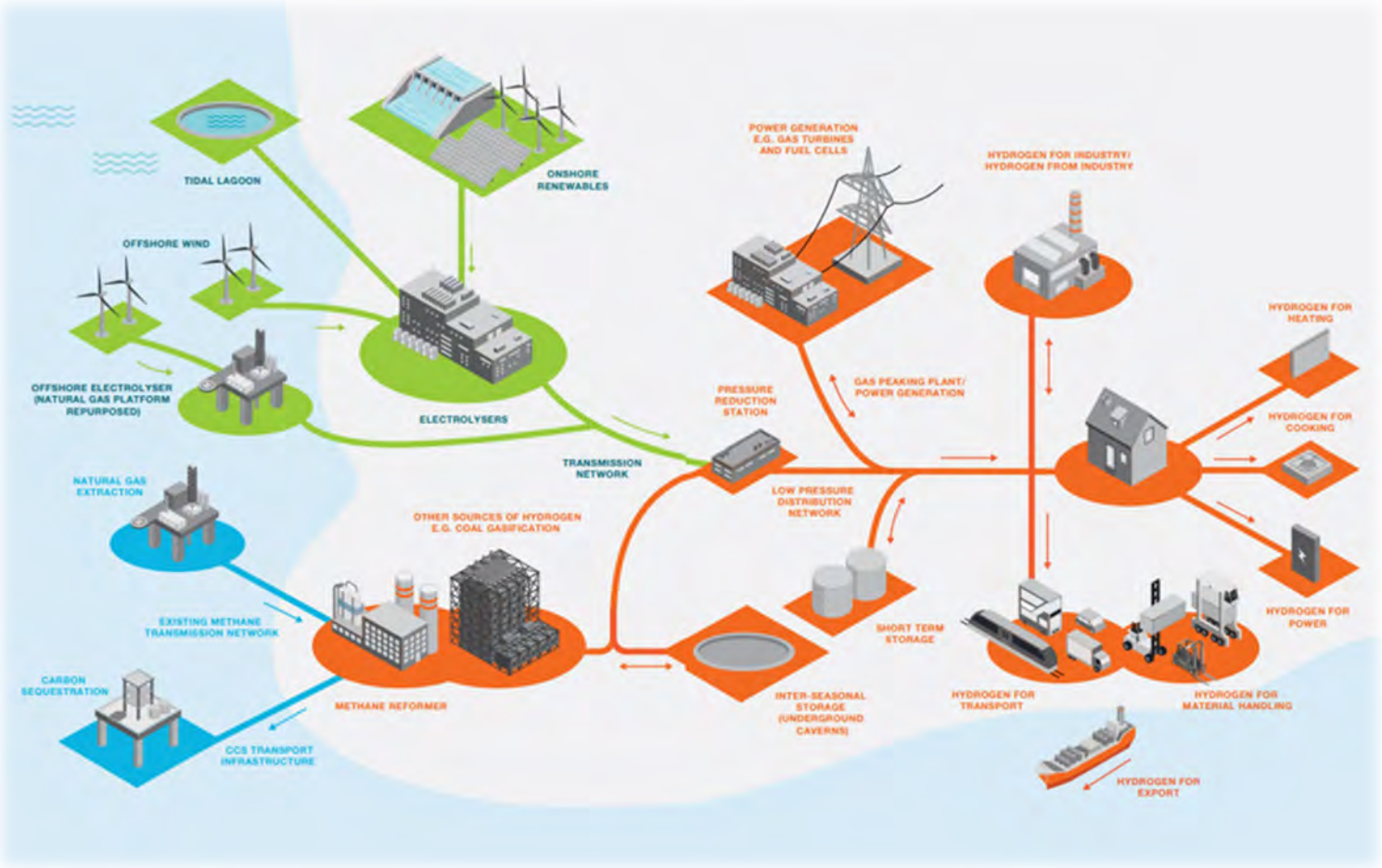
Hydrogen in an Integrated Energy System



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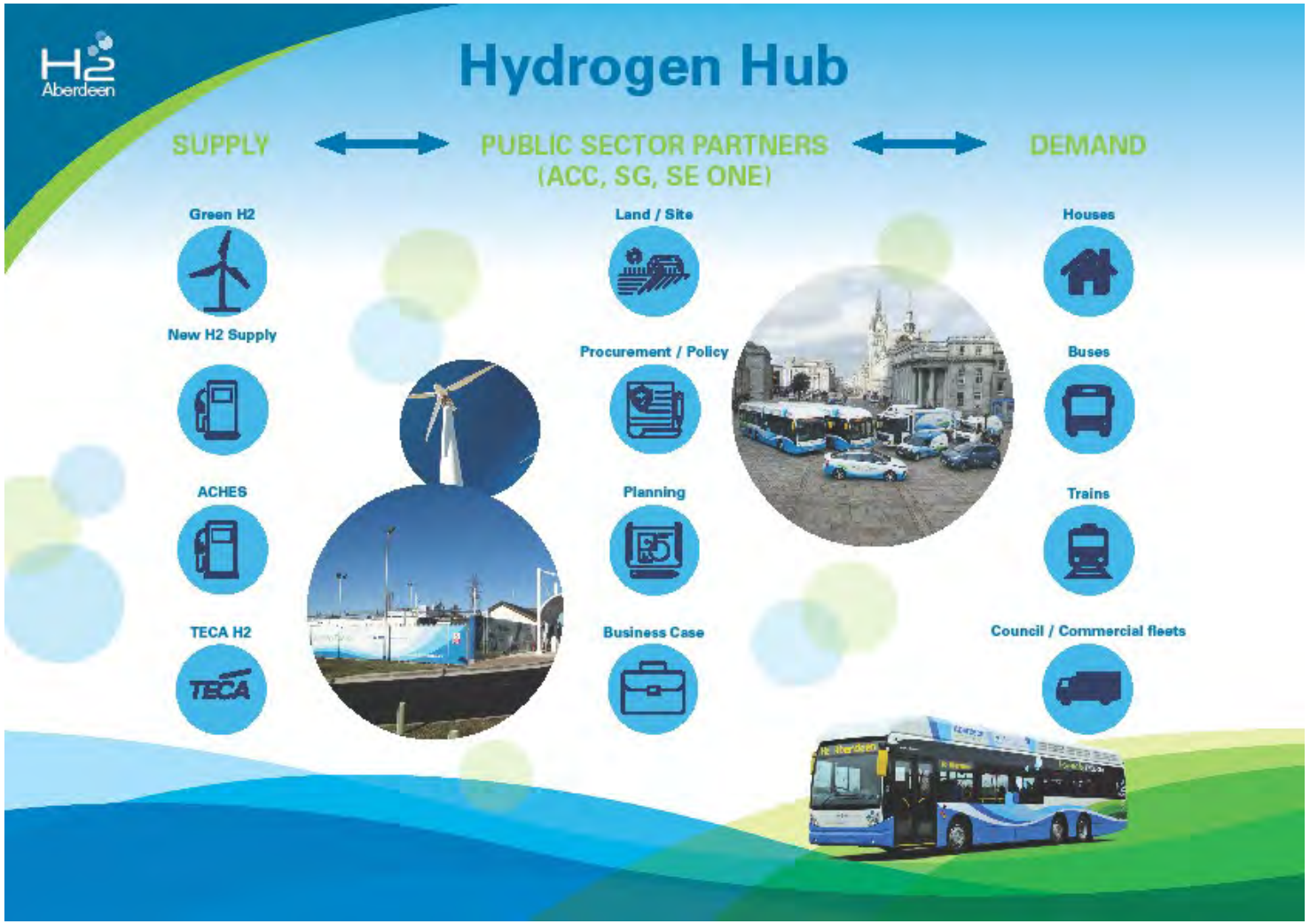
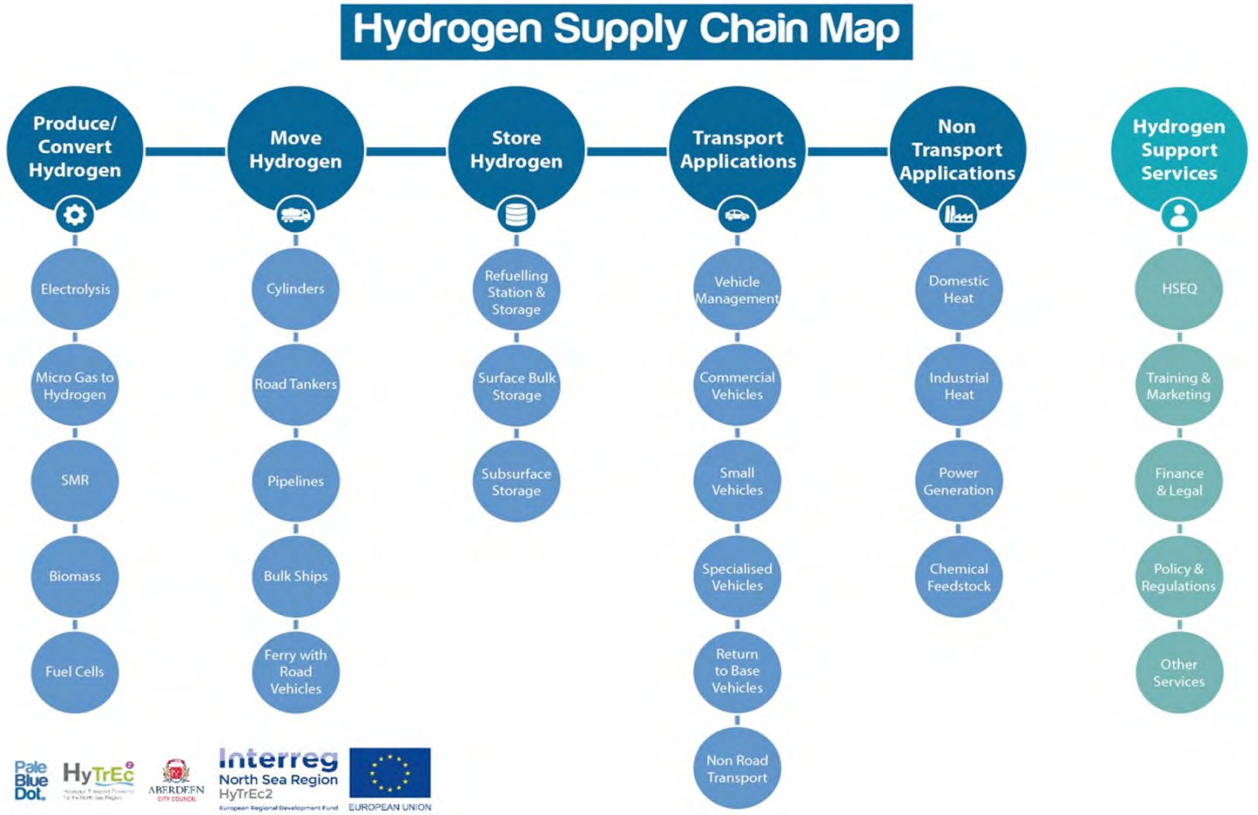
Aberdeen Hydrogen Hub



H2 Supply Chain

Encourage the development of the hydrogen economy's supply chain, seeking opportunities for the region's existing energy expertise to diversify and benefit from this growing industry:



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Role of Hydrogen in Decarbonising the Dutch Economy

Speaker: Jamie Frew, PhD, MBA

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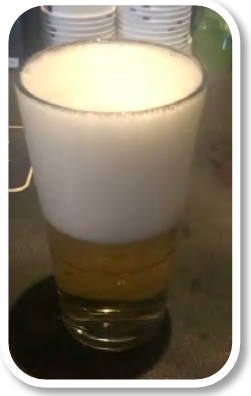
ROLE OF HYDROGEN IN DECARBONISING THE DUTCH ECONOMY

JAMIE FREW PhD MBA

IMPORTANT DIFFERENCES



IMPORTANT SIMILARITIES

COMPARISON – Economy

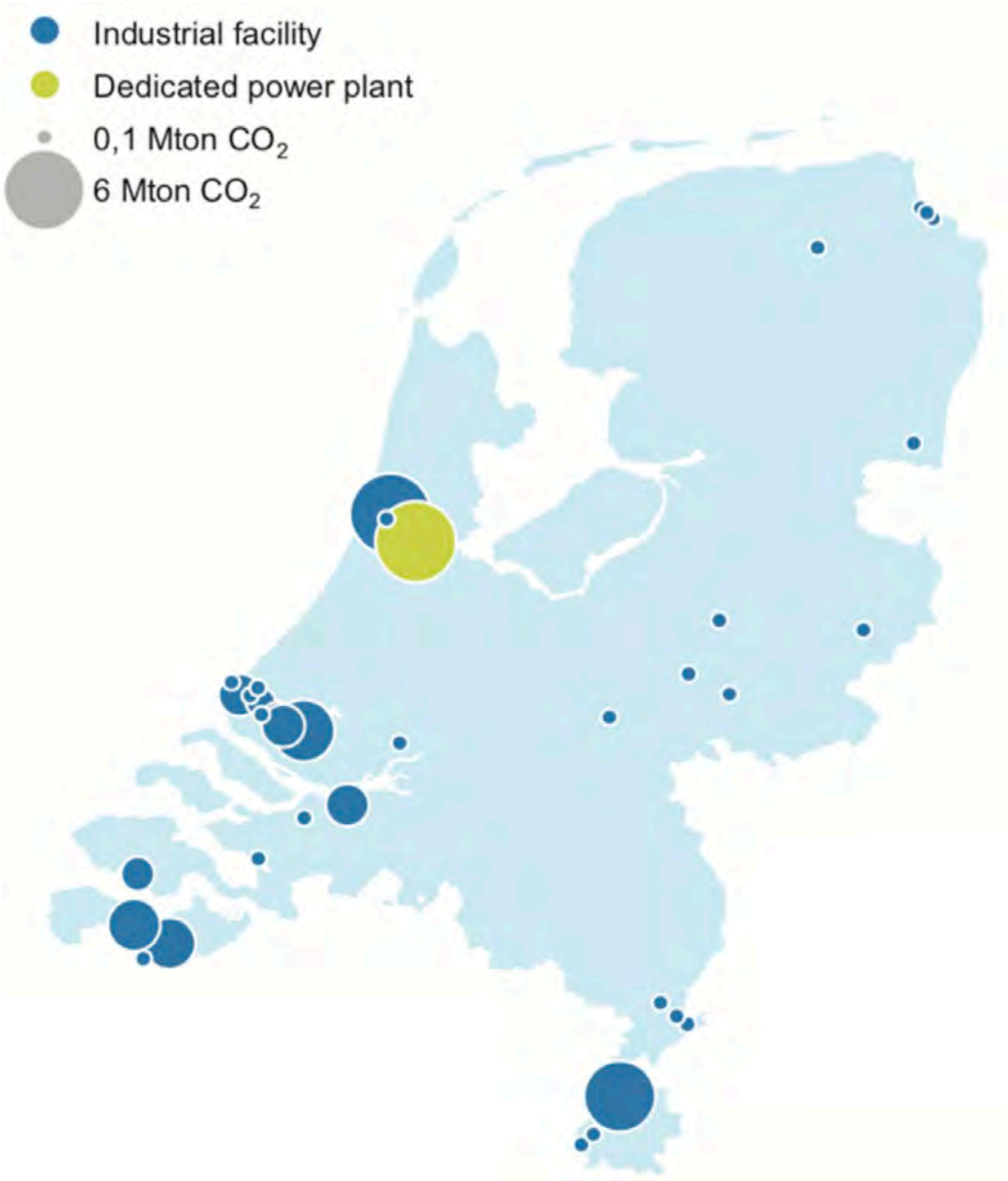
		
GDP per capita $	53	42
Debt (%GDP)	52%	86%
Innovation Ranking	2nd	4th
vehicles/1,000 people	553	584

COMPARISON – Carbon

		
GDP per capita $	53	42
Debt (%GDP)	52%	86%
Innovation Ranking	2nd	4th
vehicles/1,000 people	553	584
CO2 Tons per capita (2017)	**10.26**	**5.73**
Imports % of GDP (2018)	74%	32%
Exports % of GDP (2018)	82%	31%

COMPARISON – Trade Balance

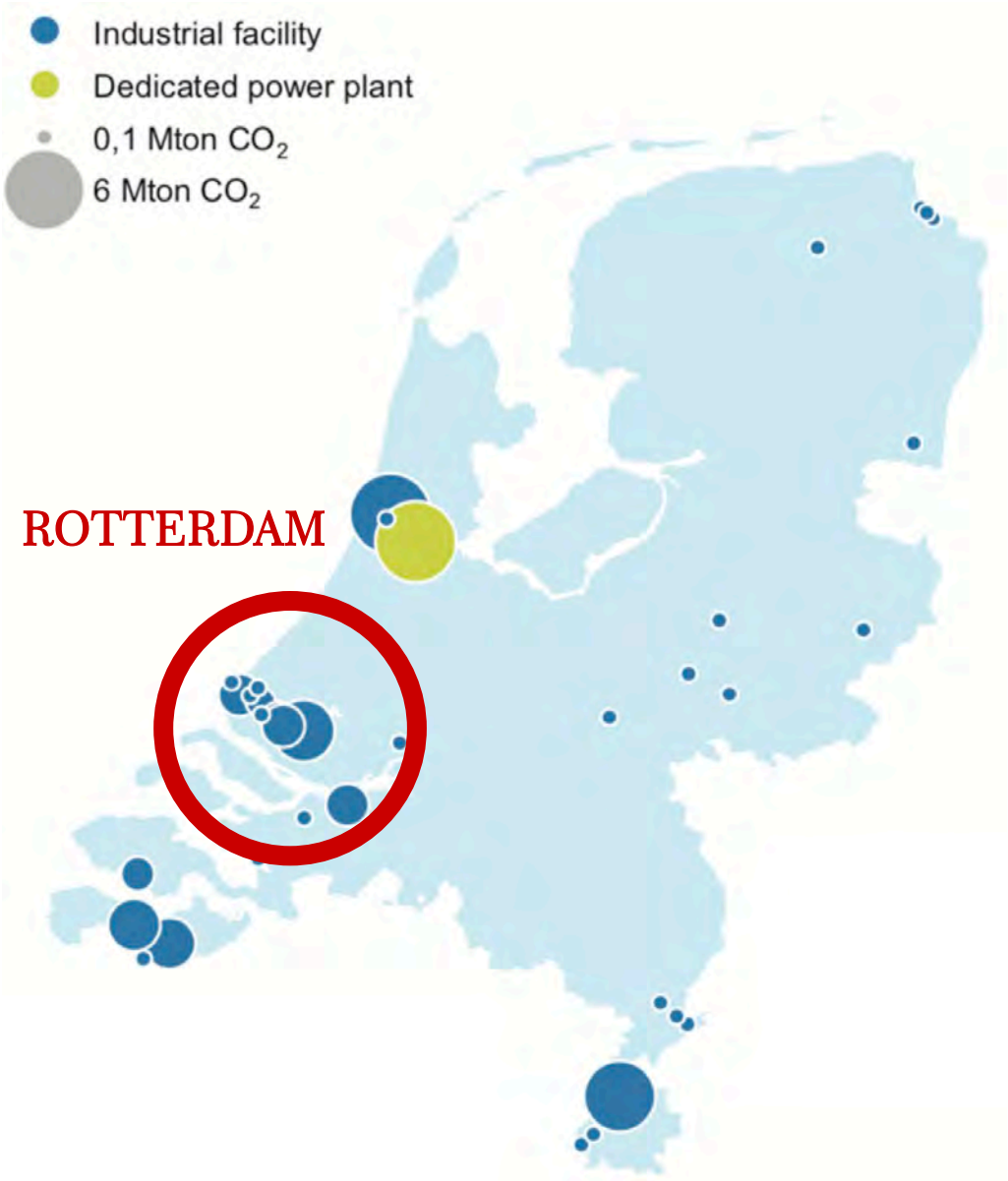
		
GDP per capita $	53	42
Debt (%GDP)	52%	86%
Innovation Ranking	2nd	4th
vehicles/1,000 people	553	584
CO2 Tons per capita (2017)	10.26	5.73
Imports % of GDP (2018)	70%	24%
Exports % of GDP (2018)	79%	17%



A CARBON INTENSIVE TRADE

INDUSTRIAL EMISSIONS (Mton)

Netherlands	Emissions (Mton)	
Total	158	
Industrial Sector	67	>40%



A CARBON INTENSIVE TRADE

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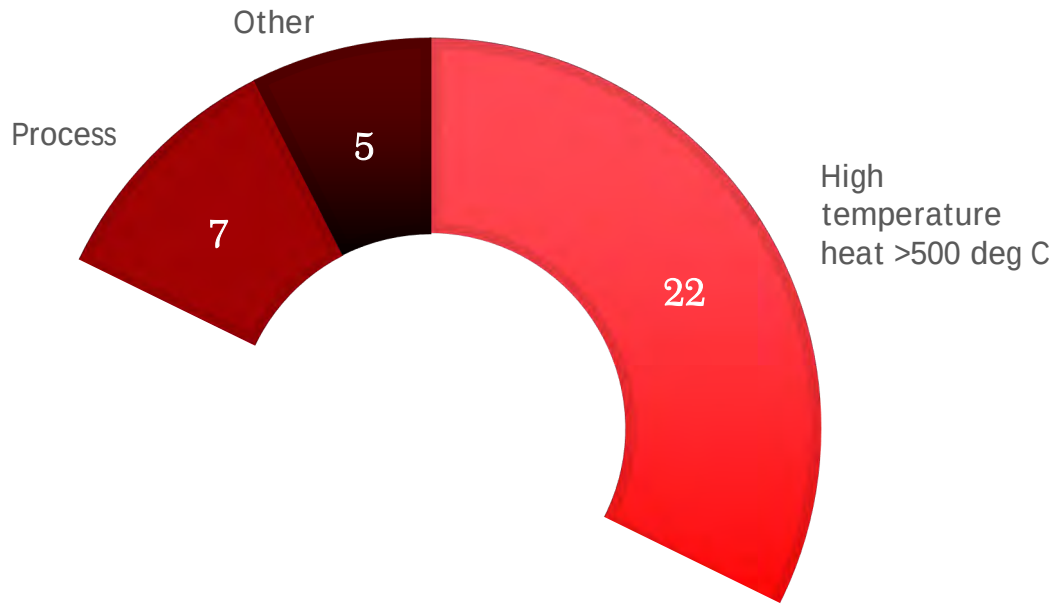

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Vision of decarbonised industry - 2050

- Thriving, globally leading industry
- Virtually zero emissions
- Demonstrate that complex system changes are **possible + profitable**

Key points

- 59% CO2 reduction (2030 vs 1990)
- National CO2 tax for industry, rising up to €120-150 per **excess** ton emitted
- Multi-billion euro support for emissions reducing technologies; specific support for **Waterstof**

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12 TO ZERO

WHAT IS THIS STUFF? WATERSTOF

WATERSTOF | WATER-DUST

WATERSTOF | WATER-DUST | HYDROGEN

1 Nm3 = 0.08988 kg = 38 scft = 10.8 Mj

Hydrogen -Let's all speak the same language!

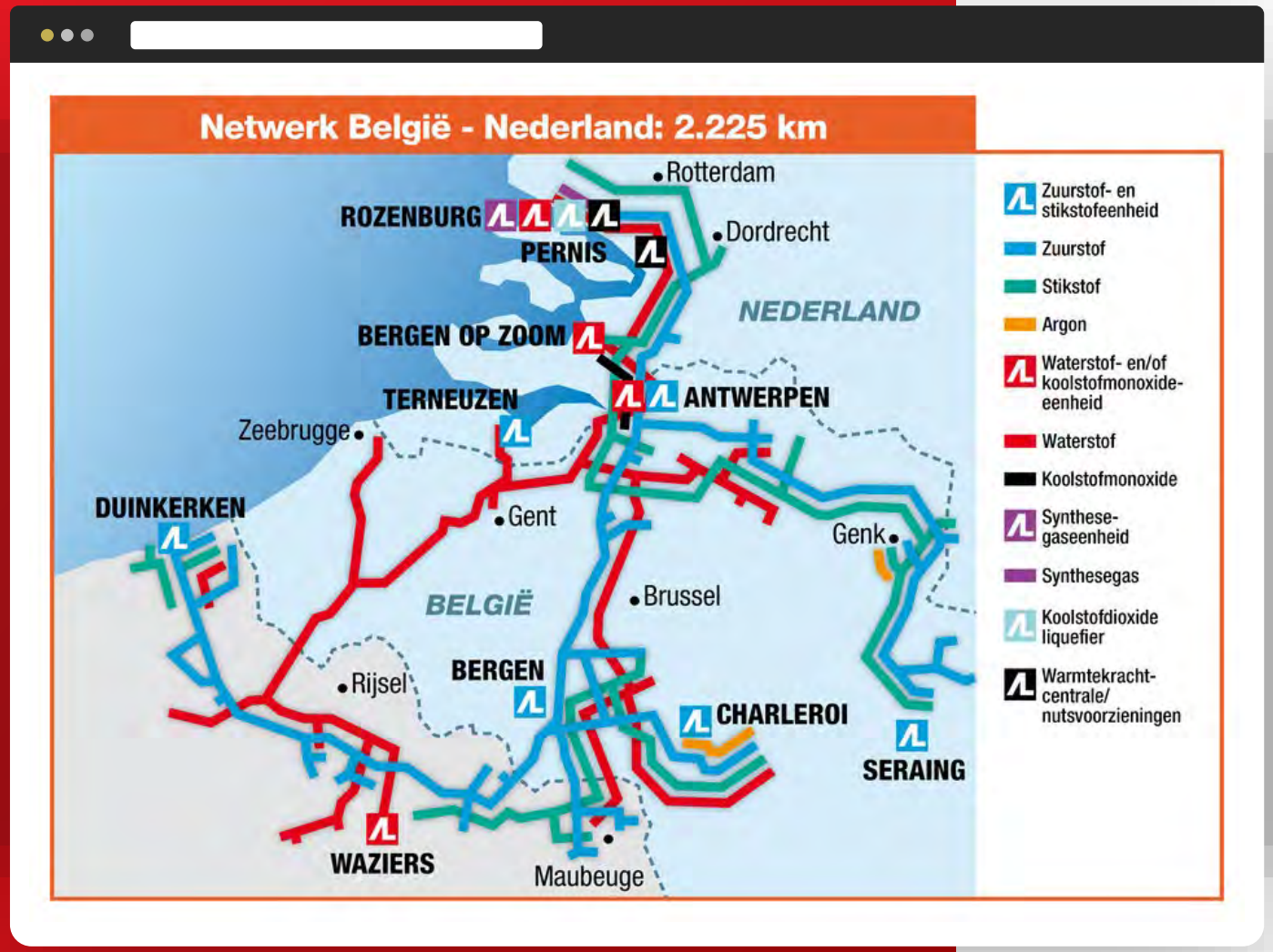
= 10 KM per 1 KG H2

= 50 000 KM => 5 MT H2 per year

VISION OF A HYDROGEN ECONOMY

- National H2 network –stimulate expansion
- Based on soon to be retired Groningen-Gas Network
- Part of greater European Network

500 k



AIR LIQUIDE BENELUX NETWORK

- Europe's largest hydrogen network
- World Scale production sites feeding industry in 3 countries
- High Availability, Reliability and Flexibility
- No fundamental barrier to large scale hydrogen networks

CURRENT APPLICATIONS OF HYDROGEN IN NL

Feedstock for chemicals

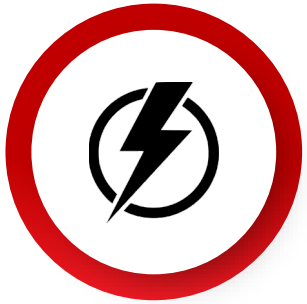
- Fertilizers
- Fuel refining
- Plastics

200 k

THE MANY USES OF HYDROGEN

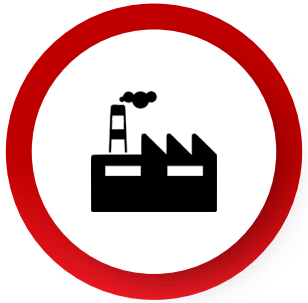
FUEL FOR

Transport



Power

HEAT FOR

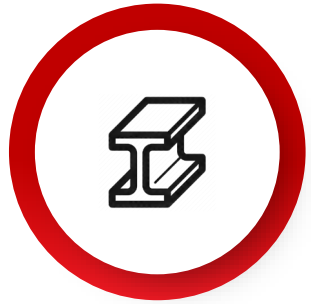


Industry

Buildings

FEEDSTOCK FOR

Chemical



Products

What colour is your hydrogen?

GREY HYDROGEN

Split natural gas into CO_2 & hydrogen

Est. 10 kg CO_2 per kg H_2

CO_2 EMITTED IN THE ATMOSPHERE

BLUE HYDROGEN

Split natural gas into CO_2 & hydrogen

Est. 1 kg CO_2 per kg H_2

CO_2 STORED OR RE - USED

GREEN HYDROGEN

Split water into hydrogen by electrolysis powered by wind & sun

Est. 0 kg CO_2 per kg H_2

NO CO_2 EMITTED

BP ROTTERDAM - GREY HYDROGEN

- Hydrocracker Investment of greater than €1 Billion
- World Scale Hydrogen Production Unit.
- Project delayed due to uncertainty about impact of climate legislation
- Huge disruption in Grey Hydrogen Market
- BP now pursuing Green Hydrogen

20 k

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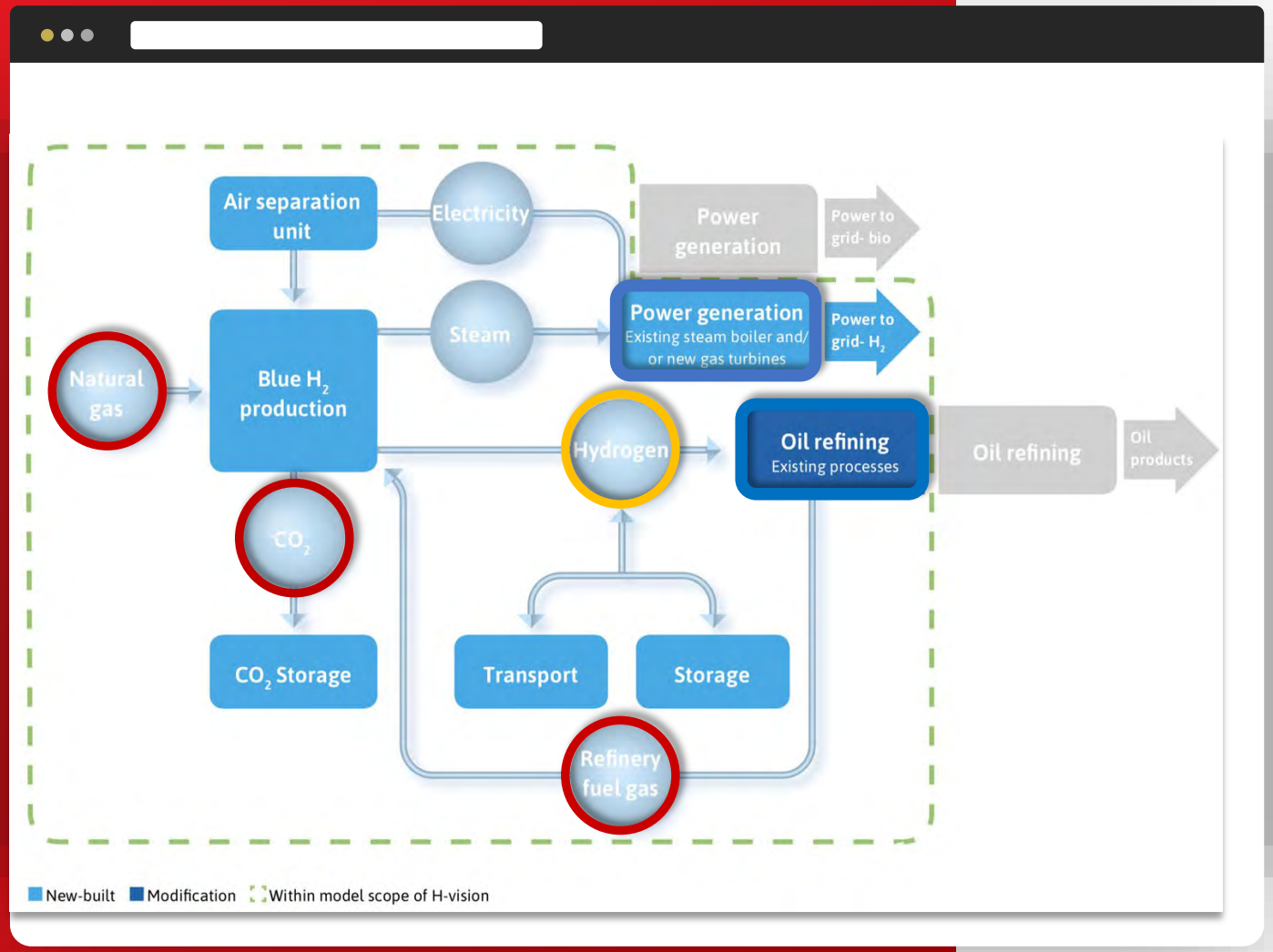
20 k

- BLUE HYDROGEN



- Solution for decarbonizing refineries and other high temperature heat applications
- Hydrogen for power generation when required
- Accelerator for large scale hydrogen deployment

250 k

North sea as a CO_2 sink

- CO_2 storage in Dutch sector is not unlimited
- H-vision type projects and other carbon capture technologies across Europe could greatly increase CO_2 volumes
- CO_2 exports to well understood geological sinks may be crucial

NORTH SEA WIND ISLANDS - GREEN HYDROGEN

- **180 gigawatts** wind capacity required in 2050 to achieve the Paris climate targets for the North Sea countries.
- **Massive offshore development**: At 8 megawatts per windmill, 22,500 mills required, covering 5% of the North Sea
- **Netherlands Ports as European Energy gateway** for renewable North Sea exports.

NORTH SEA WIND ISLANDS - GREEN HYDROGEN

	BRITNED Cable	BBL Gas Pipeline
Capacity	1 GW	15 GW
Length	276 km	225 Km
Construction Costs	£500 Million	£500 Million
Annual Volume	8 TWh	120 TWh

- Electrical transport lines **10-15x cost** of pipeline
- Hydrogen can be stored in large quantities in **geologic storage at reasonable cost**
- Large scale hydrogen storage can **balance variable renewable energy** generation

2050

Netherlands could consume **14 Mt** Hydrogen | Scale up of **15X** from current level

2.8 Mn

SOURCES

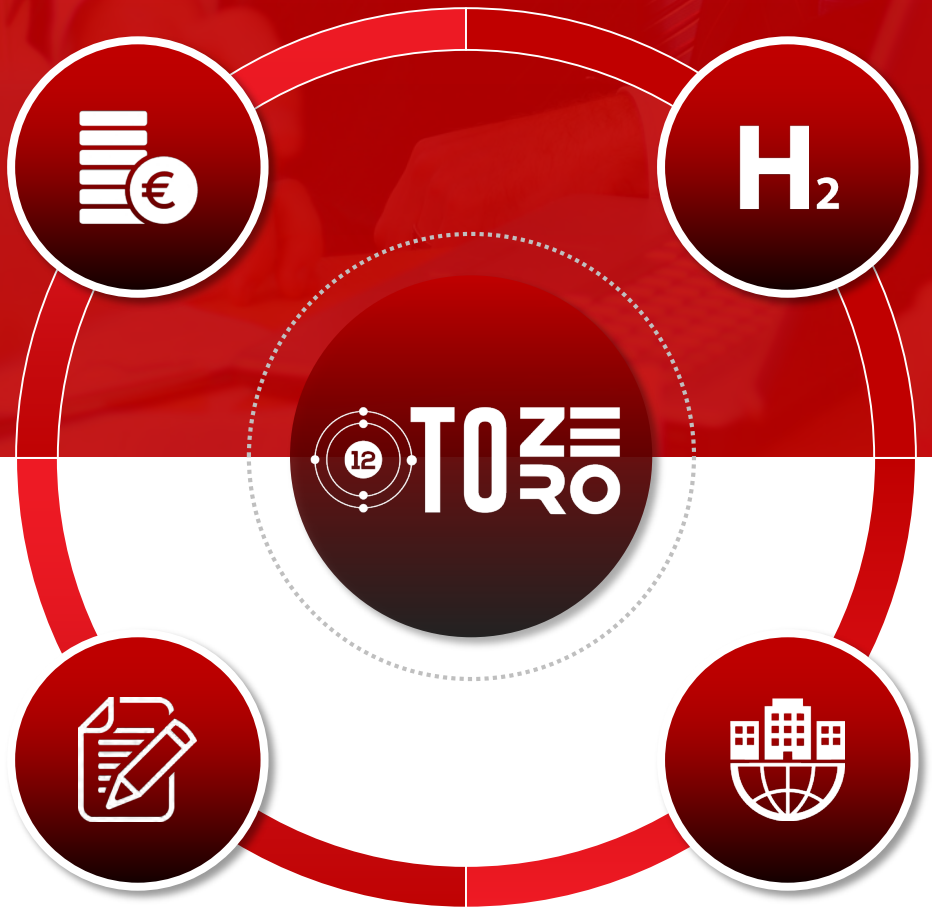
Sources and more information about the role of hydrogen in decarbonizing the Dutch economy

1. https://countryeconomy.com/countries/compare/netherlands/uk
2. https://www.mckinsey.com/business-functions/sustainability/our-insights/energy-transition-mission-impossible-for-industry
3. Source: RCI, 'Port of Rotterdam CO 2 hub: crucial stepping stone towards sustainable economic growth'
4. https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/national-climate-agreement-the-netherlands
5. https://www.tennet.eu/our-key-tasks/innovations/north-sea-wind-power-hub/
6. Technical Report Hydrogen - the key to the energy transition
7. https://www.vno-ncw.nl/sites/default/files/the_dutch_hydrogen_economy_in_2050_march_2019.pdf
8. https://www.topsectorenergie.nl/sites/default/files/uploads/Wind%20op%20Zee/Documenten/WindDays%202018/20180613_Opening_Sessie_Tennet_Mel_Kroon.pdf

NORTH OF NETHERLANDS - INVESTMENT ROADMAP

2.8 Billion Euros of investment

Green and Blue Hydrogen proposed



13 production projects proposed

New infrastructure and applications also planned

40 K

The Opportunity Hydrogen Presents For The Supply Chain

Speaker: Suzanne Ferguson, Wood

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The Opportunity which Hydrogen Presents for the Supply Chain

1st October, 2019

Suzanne Ferguson

Suzanne.Ferguson@woodplc.com

woodplc.com

Agenda

No.	Description
01	Introduction to Wood
02	Conventional Hydrogen Production
03	Hydrogen Production with Carbon Capture
04	Other Routes to Hydrogen
05	Overall Hydrogen Supply Chain
06	Conclusions

Introduction to Wood

Our global footprint

160+
Year history

$11bn+
Revenue

60,000
Employees

60+
Countries

400+
Offices

- We’re accelerating and expanding in new sectors and geographies
- Unlocking our technology across an incredible sector spread

Our global footprint

Clean Energy

Chemical

Refining

Environment and Infrastructure

Manufacturing

Marine and Defence

Mining and Minerals

Nuclear, Power and Process

Oil & Gas

Extensive experience in Decarbonisation

Designing the **UK's first 100% hydrogen** local distribution network

Asset Performance Support for one of the **World's largest CO_2 injection facilities** to ensure system integrity using Wood's Virtuoso simulator

Galion Lidar and O&M services **World's first** commercial floating wind farm

Wood pioneered the high pressure Steam Methane Reformer, designed and built **over 120 hydrogen plants**

CO_2 capture cost study for **national carbon emissions reduction** for an EU country.

Wood designed and constructed key parts of the **CO_2 pipeline network** now operational in UAE

Wood has performed **60+ CCS studies** since the mid-1990s

High efficiency Steel Manufacturing for reduced energy use and CO_2 footprint

Full-Chain CCS Capability

CO_2 Capture and Compression

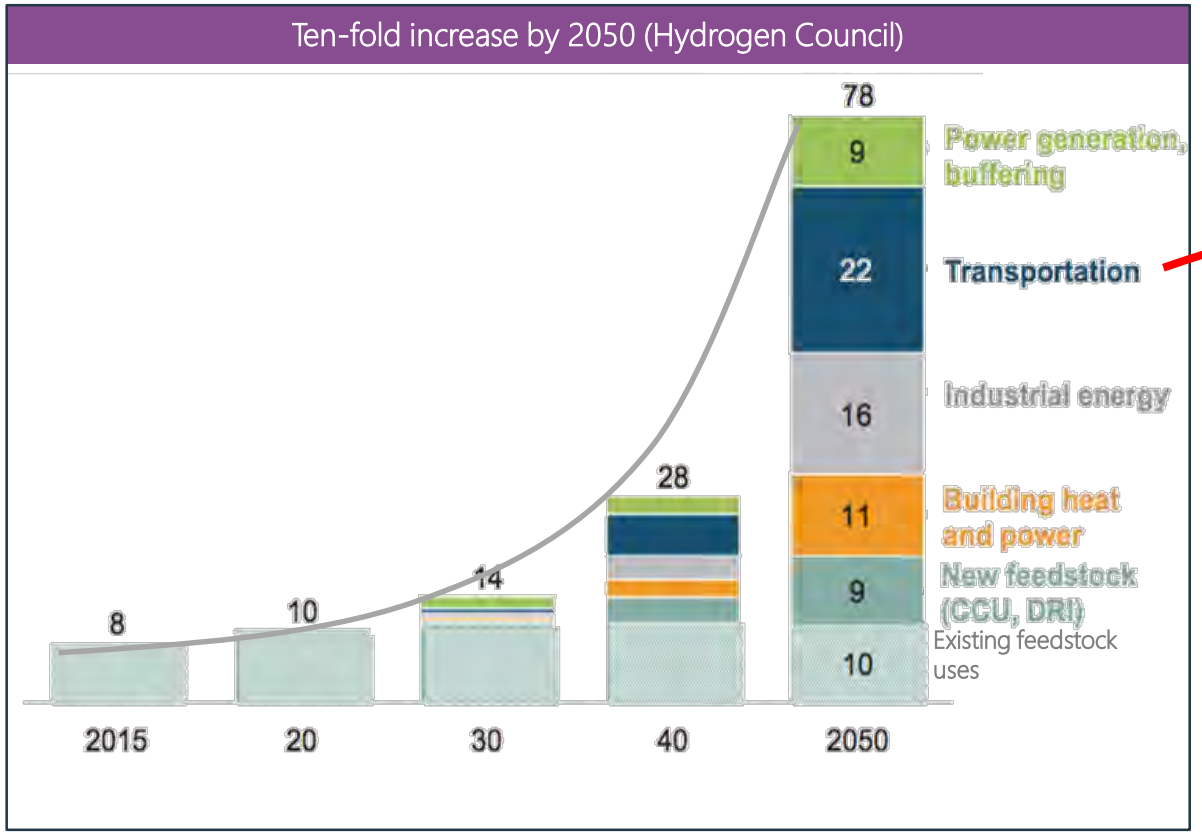
CO_2 onshore and offshore pipelines

Offshore Topside Modifications

Onshore permitting and DCO

Conventional Hydrogen Production

Decarbonisation will drive rapid growth in hydrogen



- Quarter of the global CO_2 reduction by 2050 (Hydrogen Council)
- Investment of $2.5tr with large capital projects already emerging, e.g. HyNet £920m

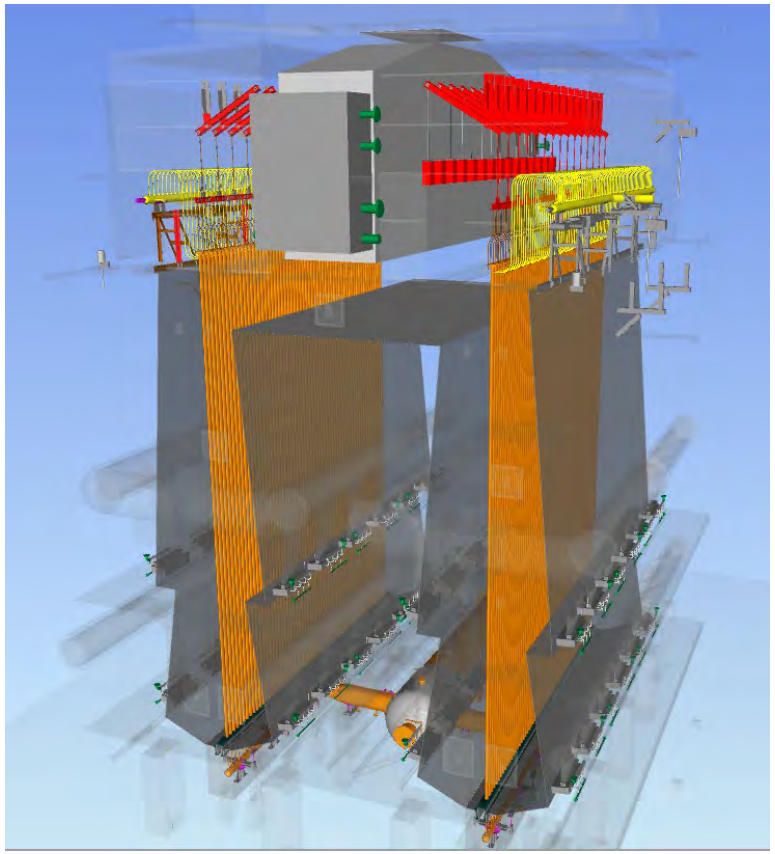
Conventional Hydrogen Production

Reforming of natural gas is an established technology at large scale

- Wide production capacity range (from 8,000 Nm^3/h to 180,000 Nm^3/h single train)
- Dedicated product line for small modular unit (from 3,000 Nm^3/h to 8,000 Nm^3/h)
- Suitable for a wide range of feedstocks from NG to LPG and Light Naphtha's.
- Converts light hydrocarbons to H_2, CO and CO_2 with addition of water (steam).
- But, approximately 10 tonnes of CO_2 are emitted for every tonne of hydrogen produced.

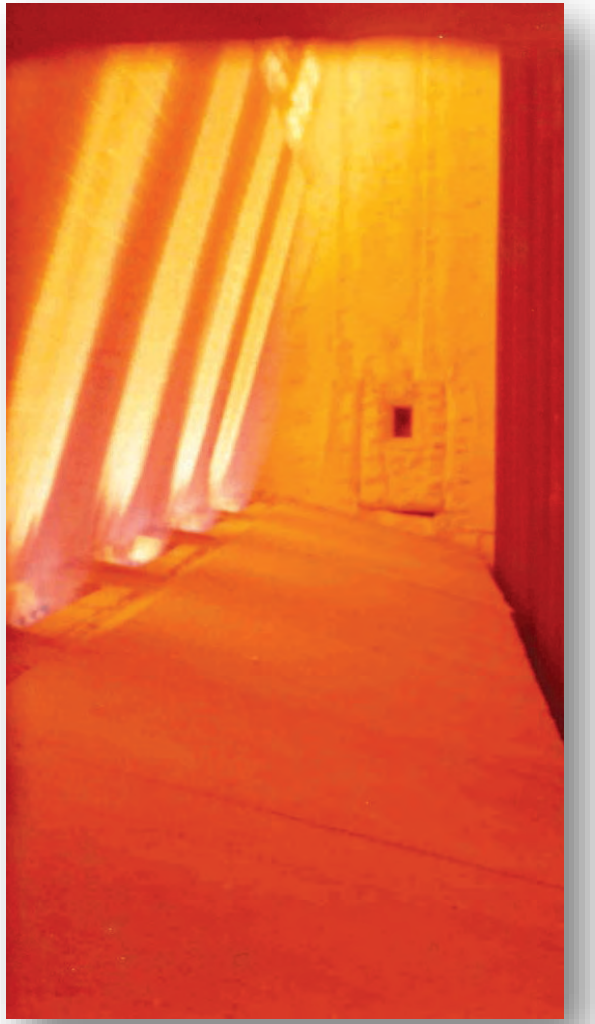
Conventional Hydrogen Production

Terrace Wall™ Steam Reforming Furnace

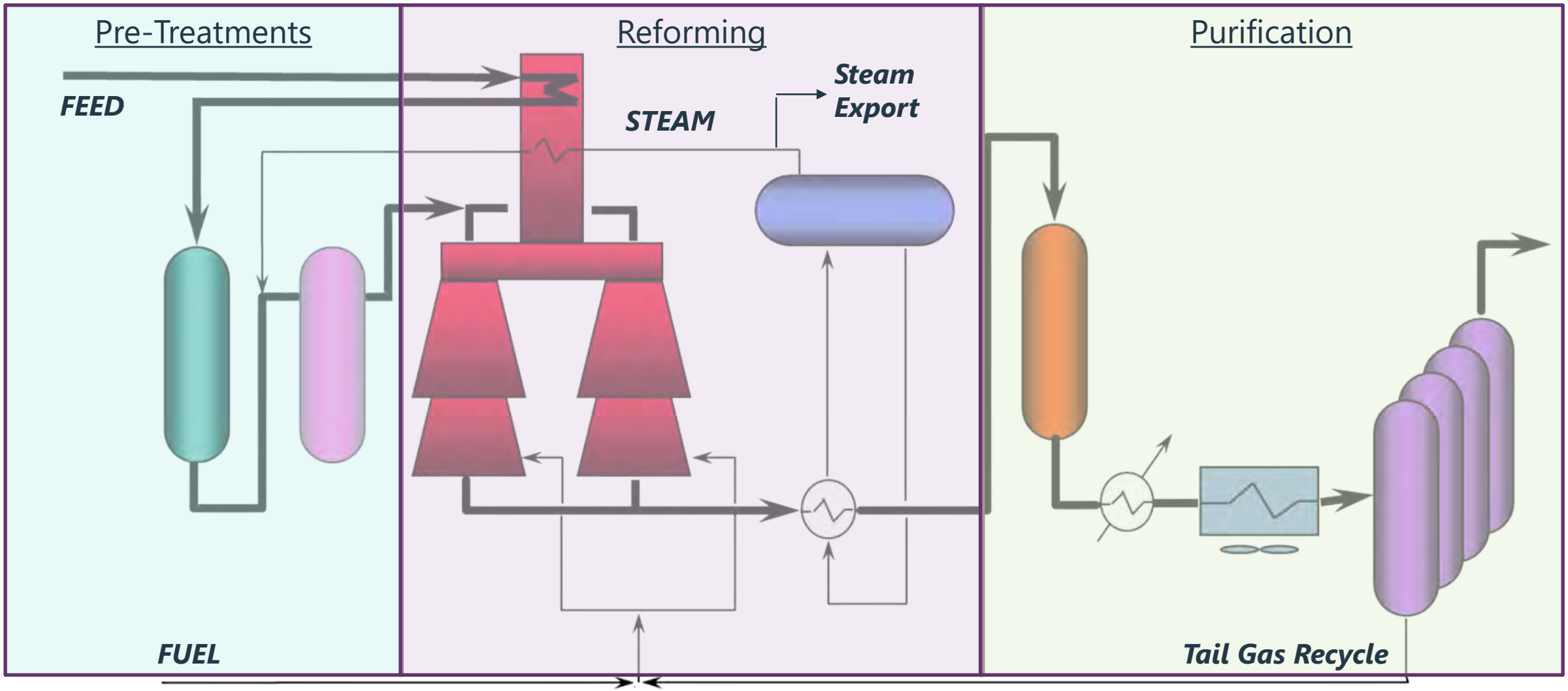


The heart of our Hydrogen Units

- High Performance
- Flexibility
- Reliability
- Simplicity



Conventional Hydrogen Production

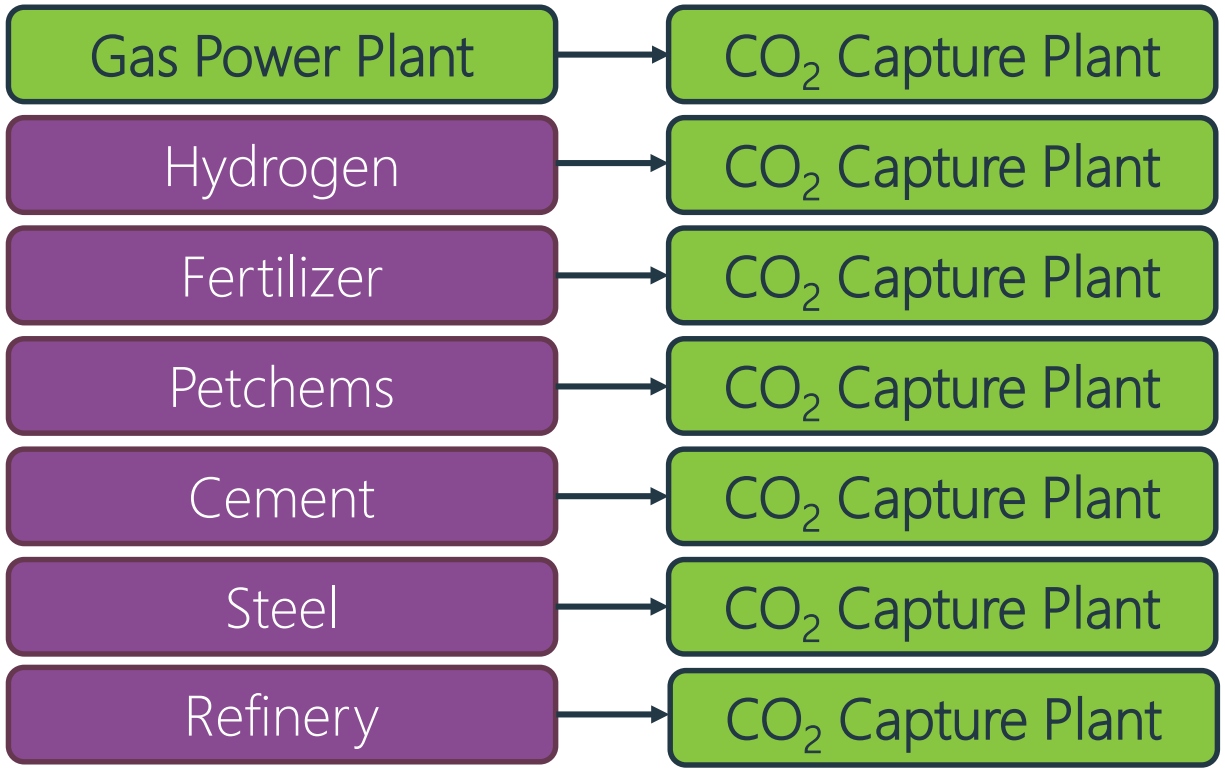


Hydrogen Production with Carbon Capture

OGCI Climate Investments

Concept Design & Pre-FEED

Objective - designing the optimised and state-of-the-art carbon capture facilities for 7 main industries representing key emitters with high impact on climate change



Gas Power + Capture

- Power plant & CO_2 capture technology ranking / selection (techno-economic analysis)
- Power / Capture optimisation
- Power / Capture pre-FEED deliverables

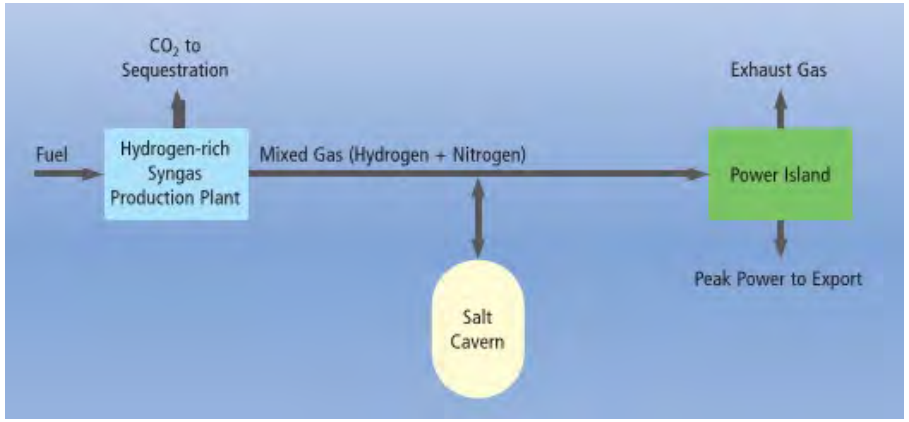
Industrial Capture x 6

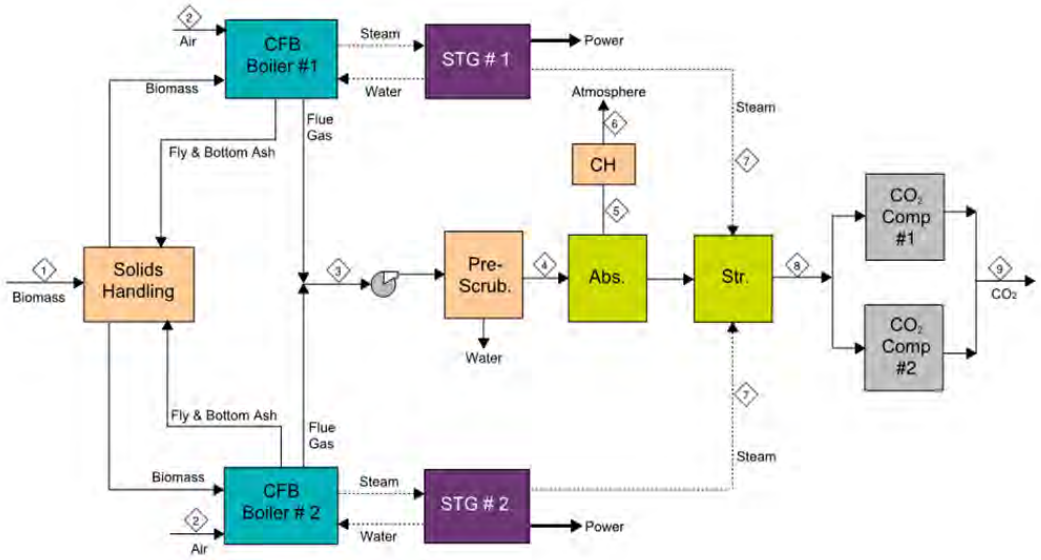
- Industrial process CO_2 capture optioneering
- Technology screening (down selection)
- Technology selection (techno-economic analysis)
- Industrial capture plant pre-FEED deliverables

Involvement in key global CCS Projects

- Post- and pre-combustion CO_2 capture evaluations for BP and IEAGHG
- Concept development, Pre-FEED and FEED contractor for Peterhead DF-1, pre-combustion capture plant
- FEED Contractor for MASDAR Hydrogen Power Abu Dhabi, pre-combustion capture plant
- FEED Contractor for E.ON Kingsnorth post combustion CO_2 capture from coal power plant
- FEED Contractor for Don Valley IGCC pre-combustion coal power plant

Involvement in key global CCS Projects

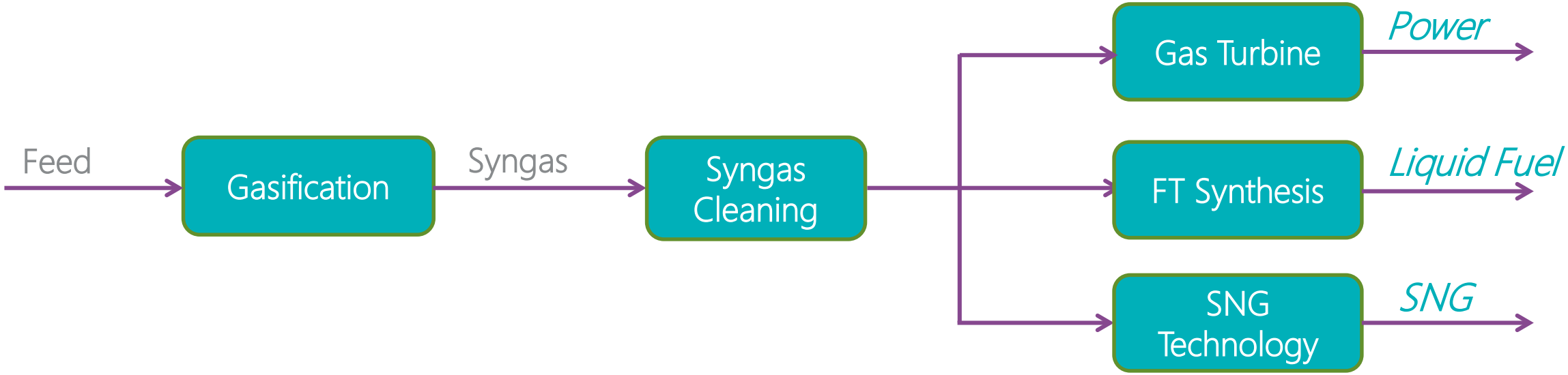




- Design and cost support to the ETI EMSE model development and analysis of novel technologies, including hydrogen turbines and salt cavern storage.
- Contributor to Teesside Collective Blueprint for Industrial CCS, followed by H21 Hydrogen study.
- BEIS 2017 Refresh of CO_2 capture Benchmarks with new state of the art cost and performance and evaluation of novel technologies
- BEIS CCUD Phase 1 - matching CO_2 capture technologies to CCU demonstration sites
  - Glass Manufacture, Brewing, Energy from Waste, Oil Refining, Biomass Power Plant
- CO_2 capture from 2 oil refineries in the Middle East for EOR
- CO_2 concept development cost study for national CO_2 emissions reduction, including CO_2 shipping to Norway

Other Routes to Hydrogen

Waste Gasification to Product Scheme



Key Features

- Waste material – Biomass (wood chips, Wood pellet, Torrified wood etc), Refuse Derived Fuel (RDF)
- Waste gasification using sub-stoichiometric O_2 into H_2 & CO ("Syngas")
- Higher value products generated

Waste-to-Hydrogen Study

Confidential, UK

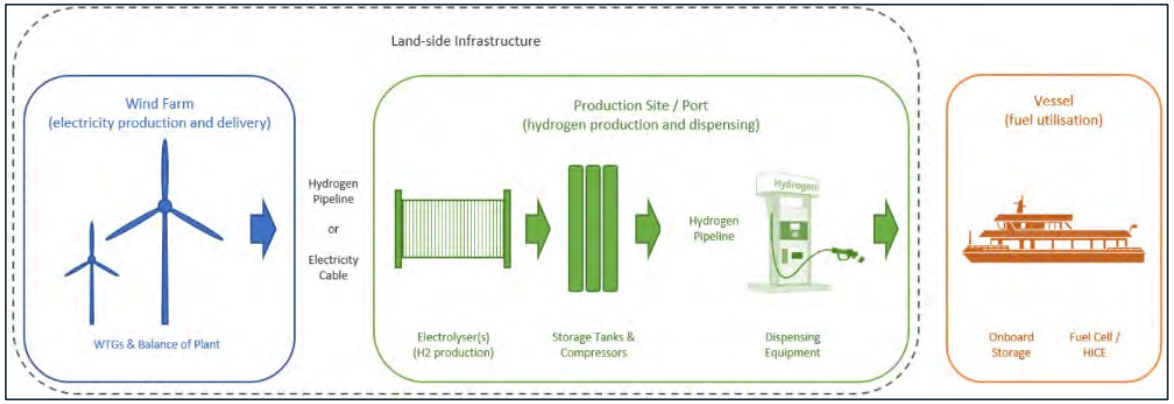
Study for a 25 TPD end-of-life plastics waste-to-hydrogen plant.

- Plant can be configured for power generation only or Hydrogen product plus power (internal use).
- Process designed to handle plastics including black plastics.
- Purpose designed proprietary gasifier to convert feed to gas followed by clean-up
- Hydrogen separation by PSA to 99.999% purity.
- Gas engines for power when plant in generation mode.
- MP Hydrogen for passenger vehicle supply.

Green Hydrogen Example – SWIFTH2 Project

Overview

- SWIFTH2 Hydrogen Ferries Feasibility Study
- Involving:
  - vessel design
  - hydrogen generation (electrolysis)
  - storage& pipe infrastructure
  - port infrastructure including dispensing
  - renewables integration (wind)
- Hydrogen priced at £3.70/kg (£2.90 with RTFO)
- First step towards decarbonising shipping sector
- Supporting Scottish Government targets



Shell Moerdijk

Summary

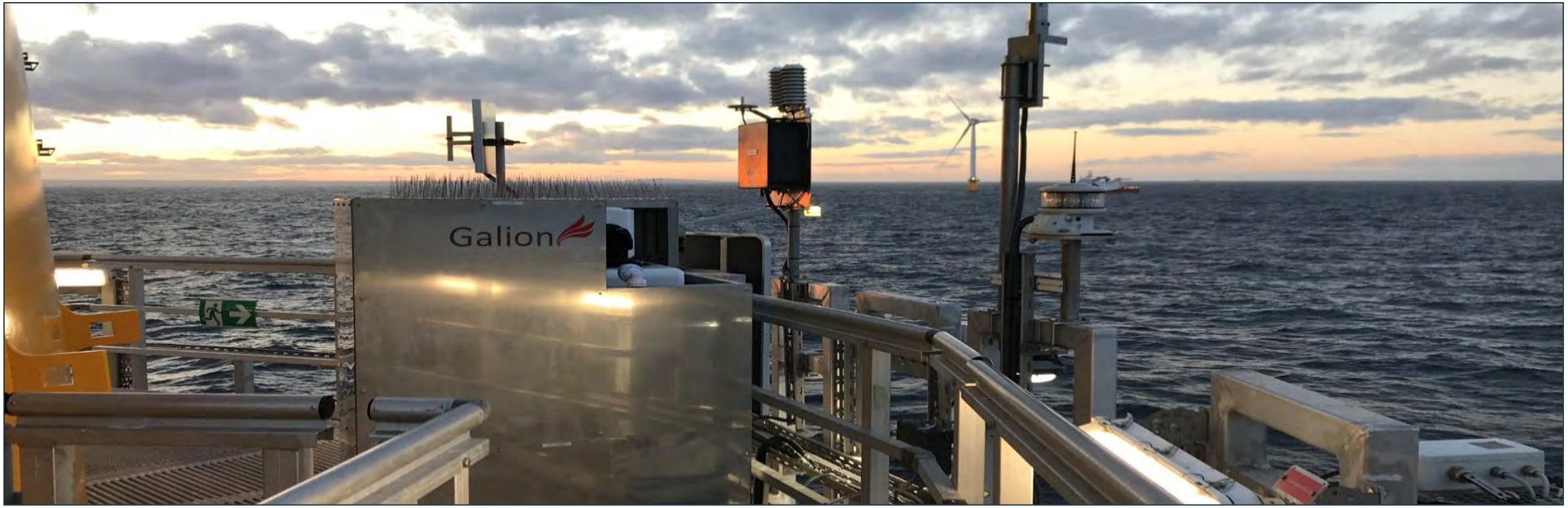
The 76,000 panel solar PV plant is one of the largest facilities of it's kind and generates enough energy to power around 9000 homes.

Scope of work

Wood acted as owner's engineer throughout the pre-construction and construction phases of the project.

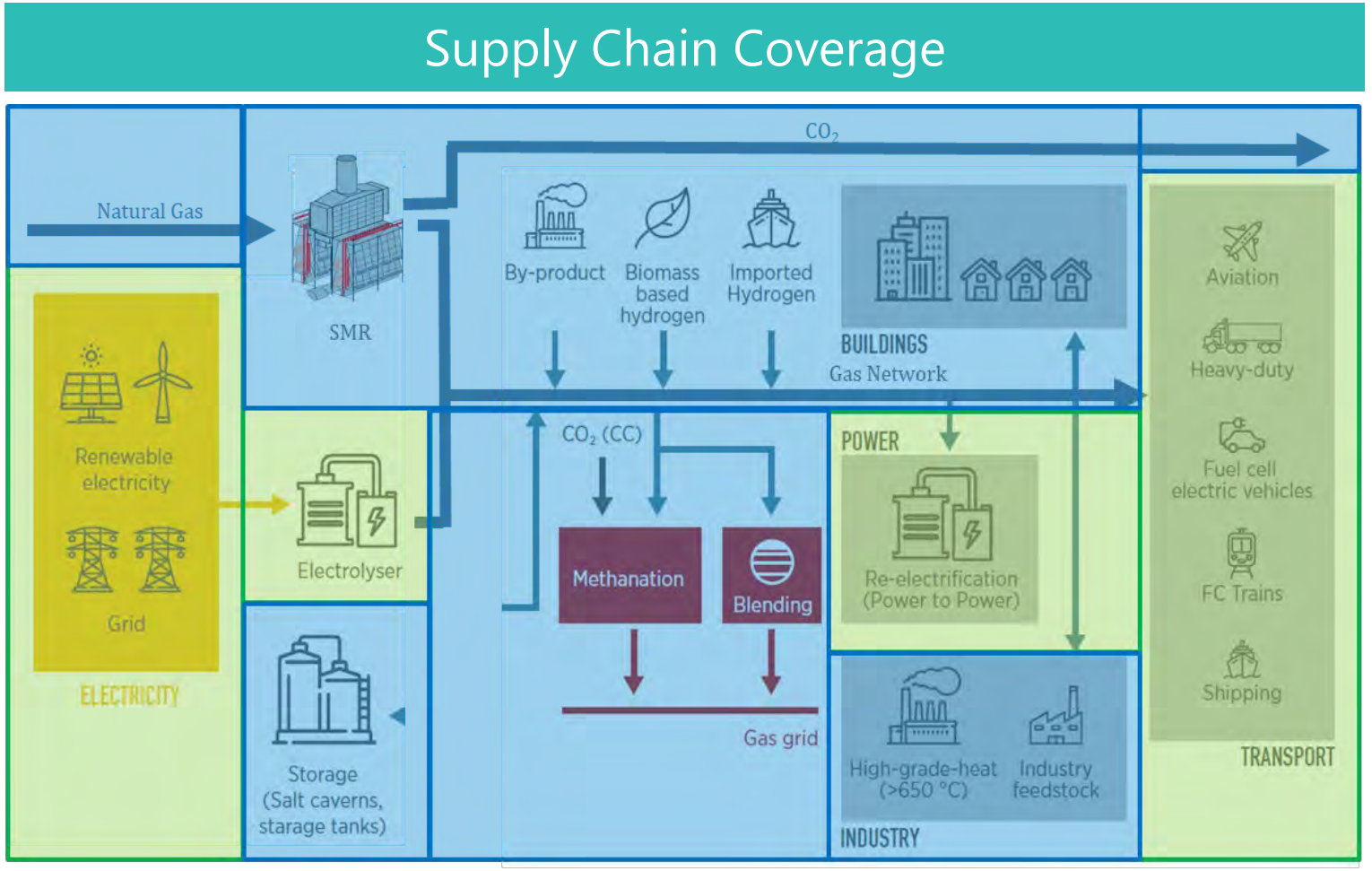
Hywind Scotland Floating Wind Farm – World First

- Investor diligence
- Lidar technology



Overall Hydrogen Supply Chain

Hydrogen for the future

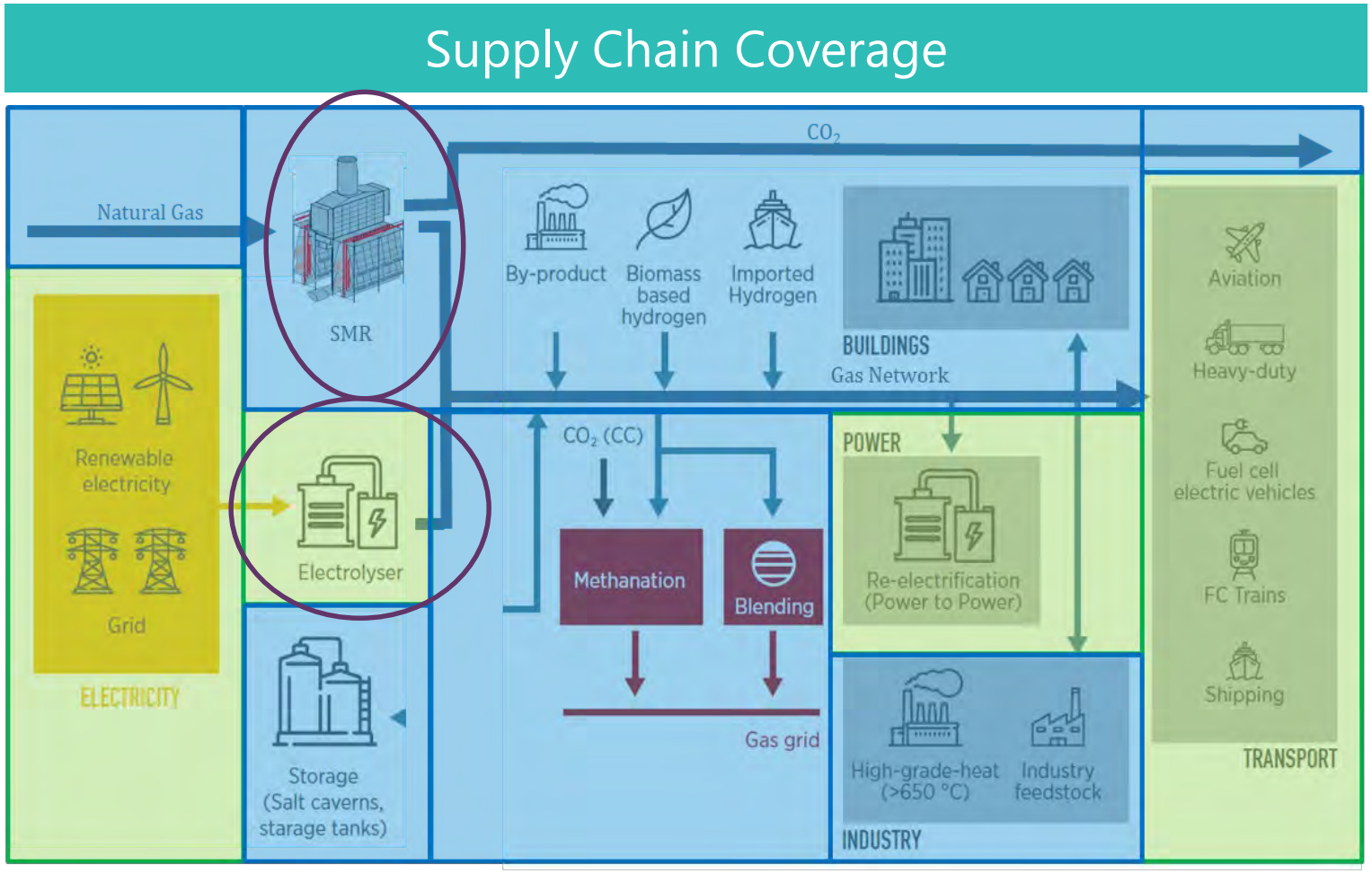


Wood provide comprehensive supply chain coverage and proprietary technology

Hydrogen for the future

Blue Hydrogen

Green Hydrogen



Wood provide comprehensive supply chain coverage and proprietary technology

Hydrogen for the future

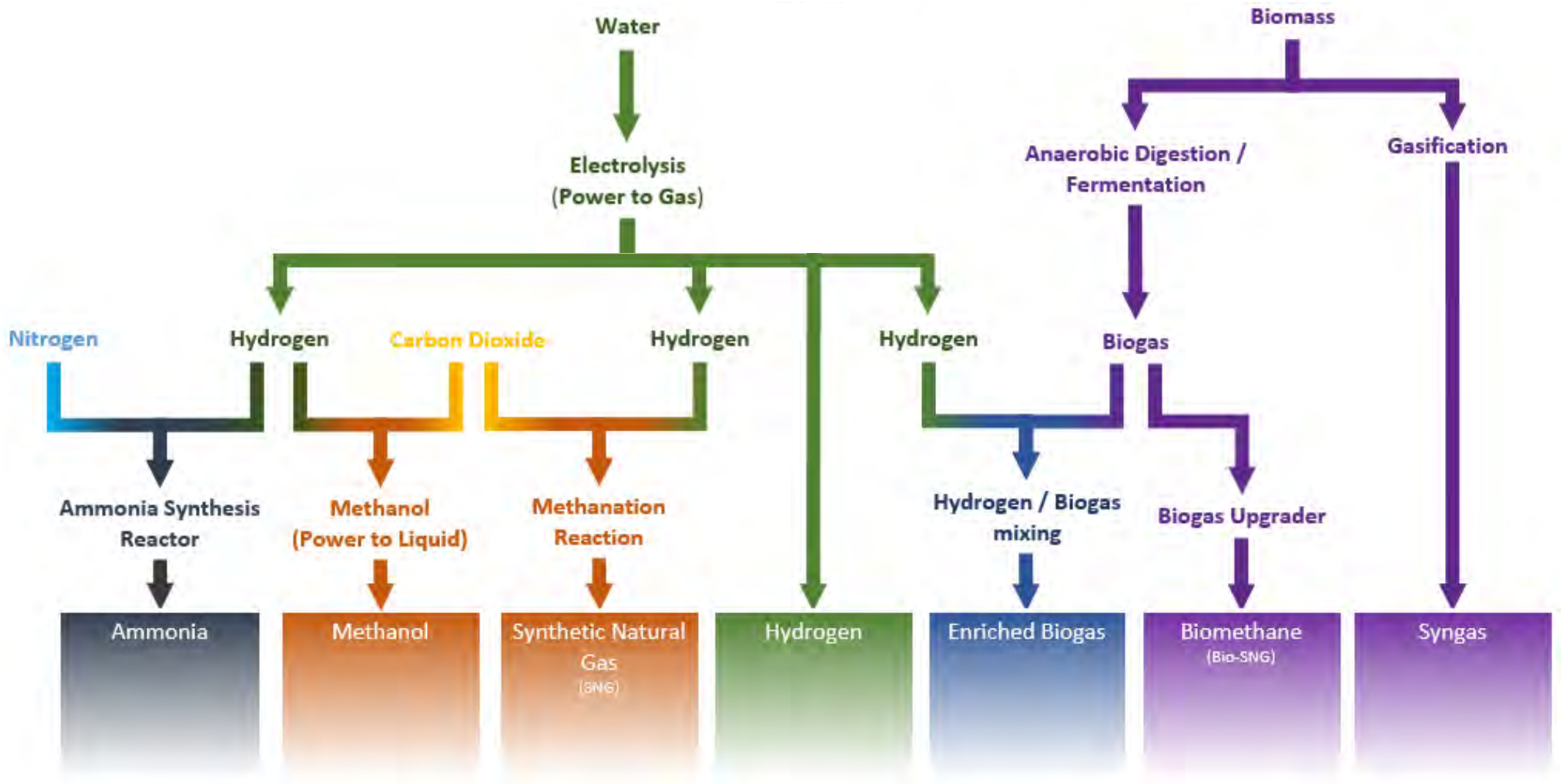
Wood works collaboratively with many other organisations

- Feasibility Studies, technology/financial/feedstock supply assessments, FEED, EPC, owner's engineer, permitting
- Renewable energy integration, grid integration & infrastructure
- Life cycle cost, carbon footprint & environmental impact assessments
- Safety assessments, performance validation, operations management
- Trading, hydrogen transportation and storage

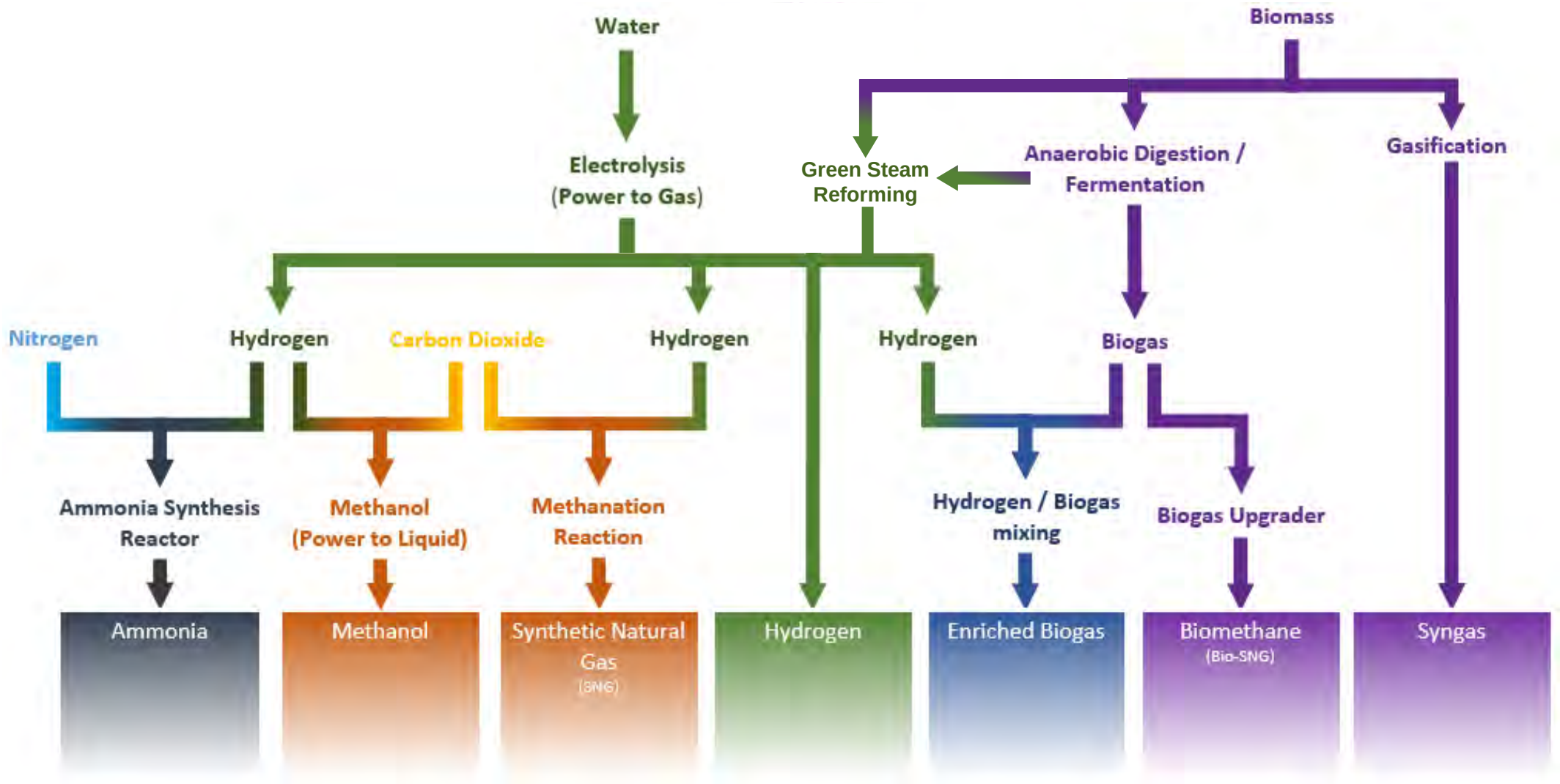
Hydrogen for the future

Wood works collaboratively with many other organisations

Green Hydrogen as an Energy Vector



Renewable Hydrogen as an Energy Vector



Conclusions

Conclusions

- Ten-fold increase in hydrogen use anticipated by 2050
  - Development of hydrogen vehicles and appliances

- Significant increase required to supply this hydrogen
  - Bulk hydrogen production
    - Natural gas reformation with CCS
    - Renewable power electrolysis
    - Other routes, such as waste to hydrogen
  - Transmission and distribution
  - Storage

- Hydrogen as an Energy Vector is interlinked with many other industries and processes

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Hydrogen in the UK and Internationally – A Perspective from DNV GL

Speaker: Sarah Kimpton,

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OIL & GAS

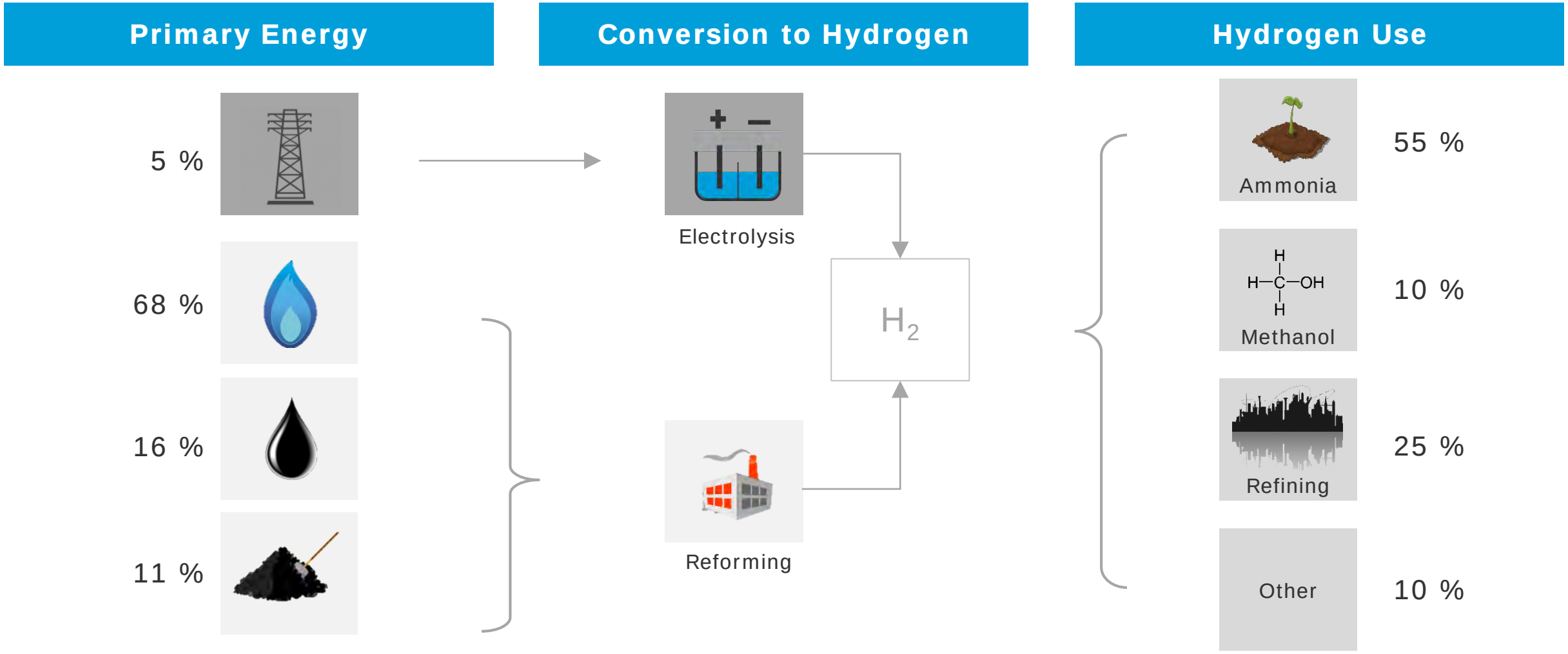
Hydrogen in the UK and Internationally

A perspective from DNV GL

Sarah Kimpton

01 October 2019

Today, Hydrogen is Primarily used as a Feedstock



Innovation - Hydrogen as an Energy Carrier

Heating (buildings)

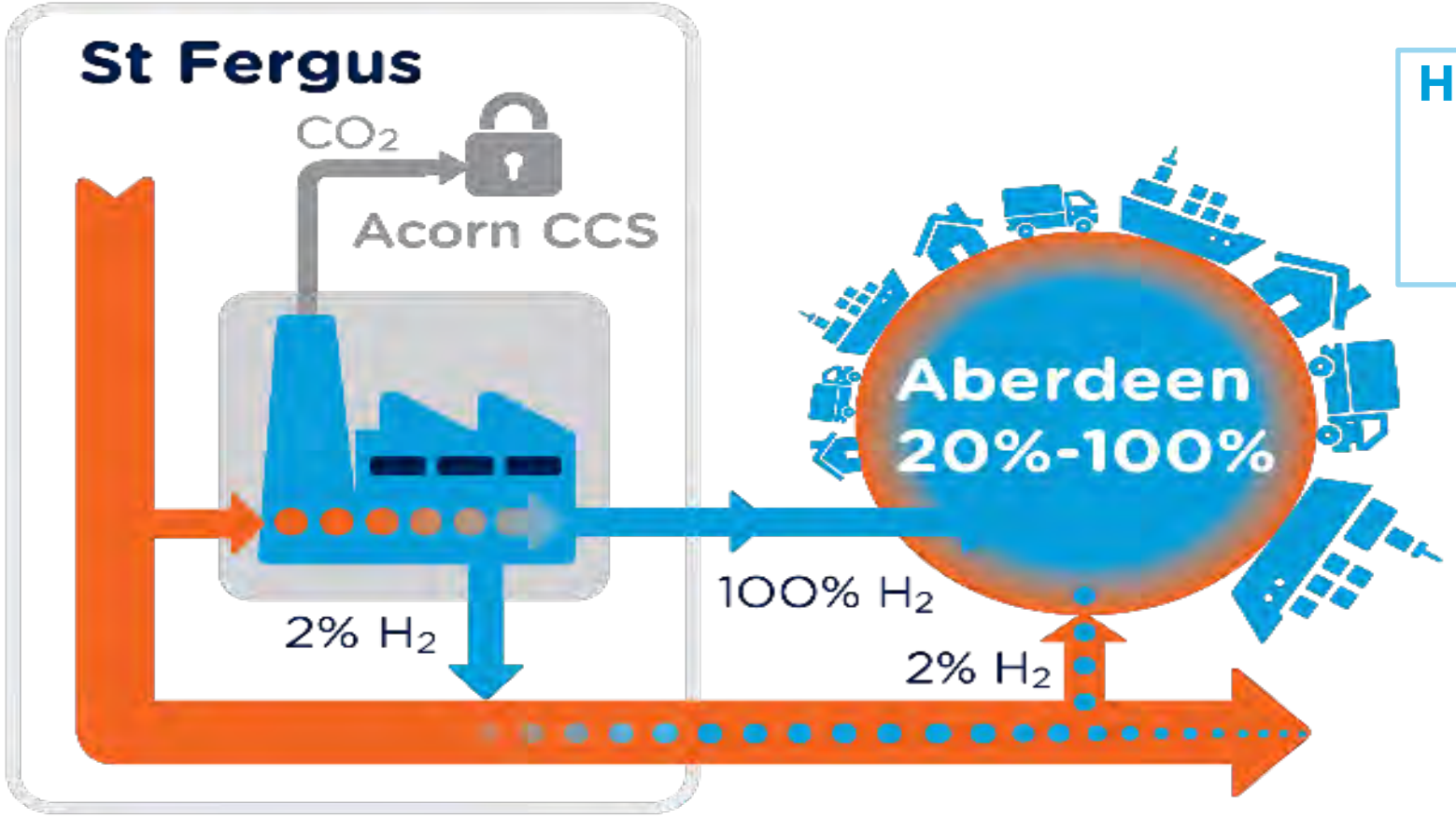
Transport

Constrained renewable power generation

Energy intensive industry

Deutsche Fotothek

UK - Aberdeen Vision Project

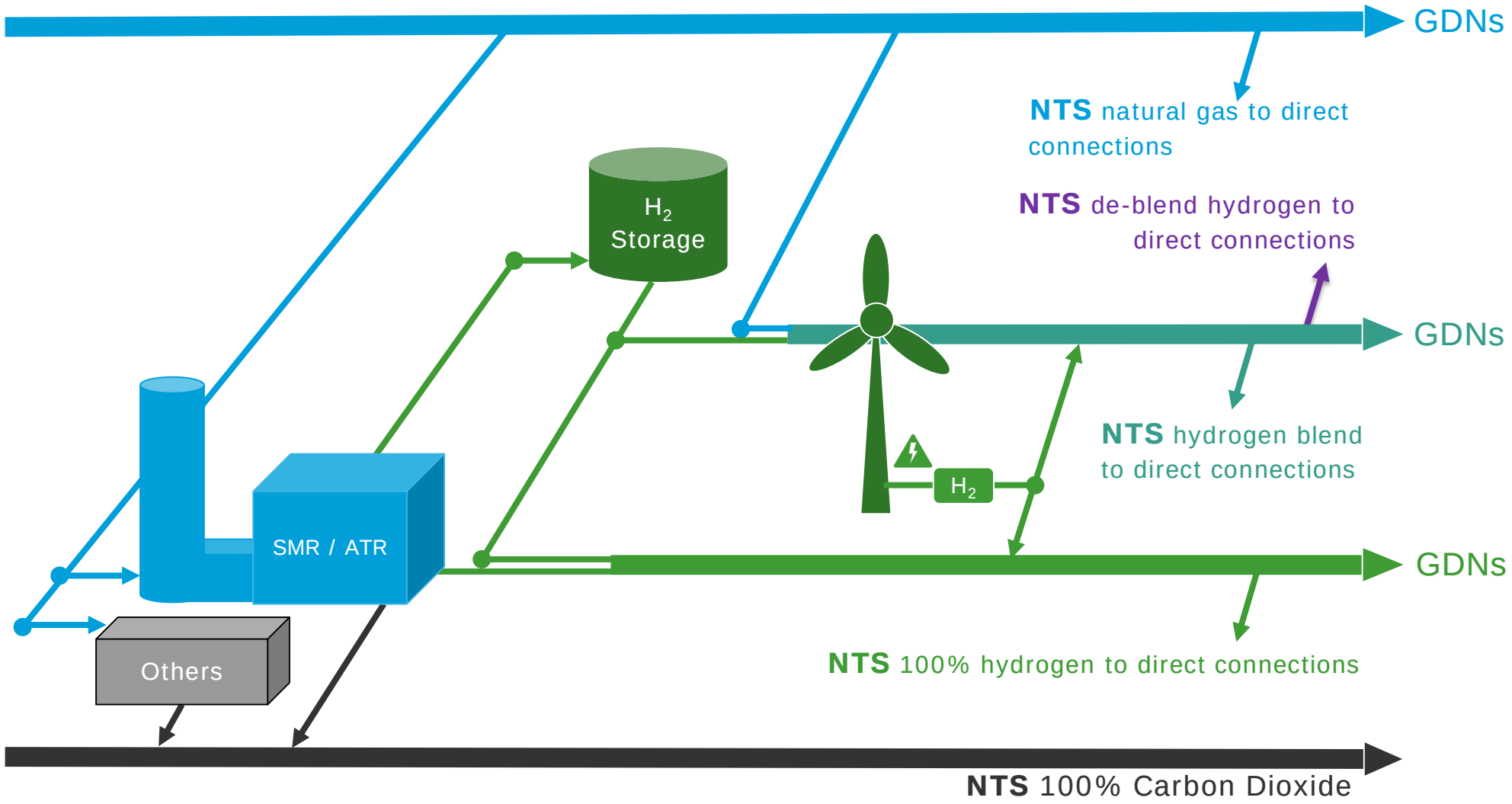


Hydrogen for

- **Heat**
- **Transport**

Pale Blue Dot + National Grid + SGN + DNV GL

UK – Hydrogen in the Gas National Transmission System



Hydrogen for

- **Heat**
- **Transport**
- **Power**
- **Industry**

Europe, Asia, Canada and US – HyReady JIP

- No current guidelines for gas transmission and distribution operators
- Output
  - Practical guidelines for hydrogen injection
  - Mitigation measures
  - Up to 30% hydrogen blend
  - Phase one - gas networks
  - Phase two - compressors and end users
- DNV GL
  - Program coordination and implementation
  - Literature review
  - Building on NaturalHy and HIPS projects

Hydrogen for

- **Heat**
- **Transport**
- **Power**
- **Industry**

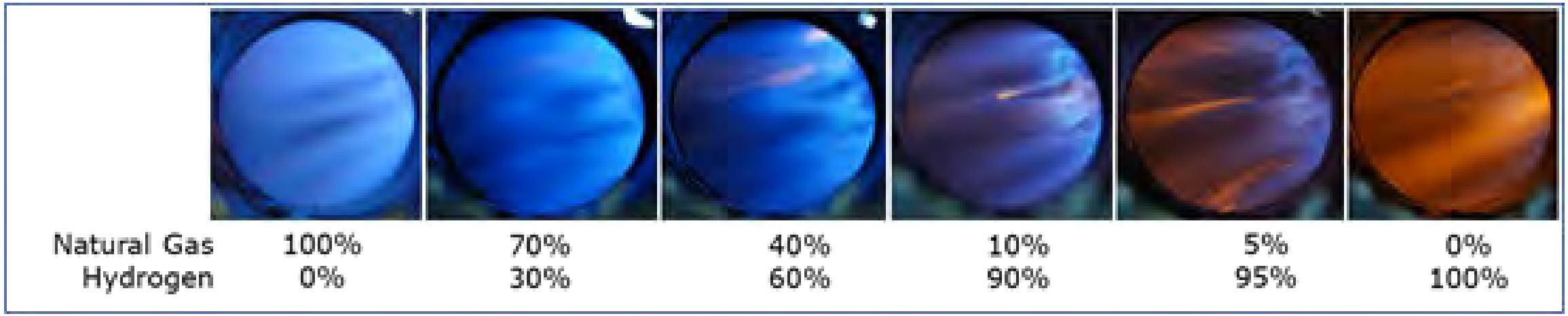
UK – BEIS Hy4Heat Programme

- Demonstrate safe delivery of 100% hydrogen to domestic consumers
- Work pack 2
  - Determine optimum purity of hydrogen
  - Necessity of adding a colourant to increase visibility of flames
  - Develop IGEM hydrogen standards
- Work pack 7
  - Experimental study to investigate how hydrogen leaks disperse in homes and streets
  - HyStreet at our Spadeadam facility

Hy4Heat

Hydrogen for Heat

Europe – Burner Control System



Full range fuel flexible burner control

Consortium of >25 companies

- Hydrogen producers
- Gas transport/distribution companies
- Manufactures
- Suppliers of burners and control systems

- Boiler and oven manufacturers
- Industrial end-users
- Government
- Trade bodies

Hydrogen for:

- **Industry**
- **Commerce**

Europe - GERG and CEN Hydrogen / H2NG Initiative

Reduce barriers to injection of hydrogen into gas grid

Literature surveys

Subject areas prioritised by CEN

Bottlenecks from hydrogen roadmap

List gaps in knowledge

Benefits and costs of removal of barriers

Priority / topic area	Expected Lead
Safety	DNV GL
Gas Quality	GRT Gaz
Underground storage	DBI
Power Generation and Engines	DNV GL
Industry	Engie
Steel Pipes	GRT Gaz
Network Equipment	DBI
End use over 20% hydrogen	DGC
Integration coordination, interfaces and transverse subject management	GERG

Hydrogen for

- **Heat**
- **Transport**
- **Power**
- **Industry**

Netherlands - Rozenburg Apartment Complex

- Dutch Government running pilot projects
- 25 homes near Rotterdam
- Synthetic natural gas to hydrogen
  - 8% of heat demand (statutory limitation)
- DNV GL:
  - Burner engineering for hydrogen boilers
  - Life cycle emissions
  - Risk assessments
  - Verification of performance

Production from green electricity → Gas grid operator Stedin → Rozenburg Boiler house → Zero-carbon comfort

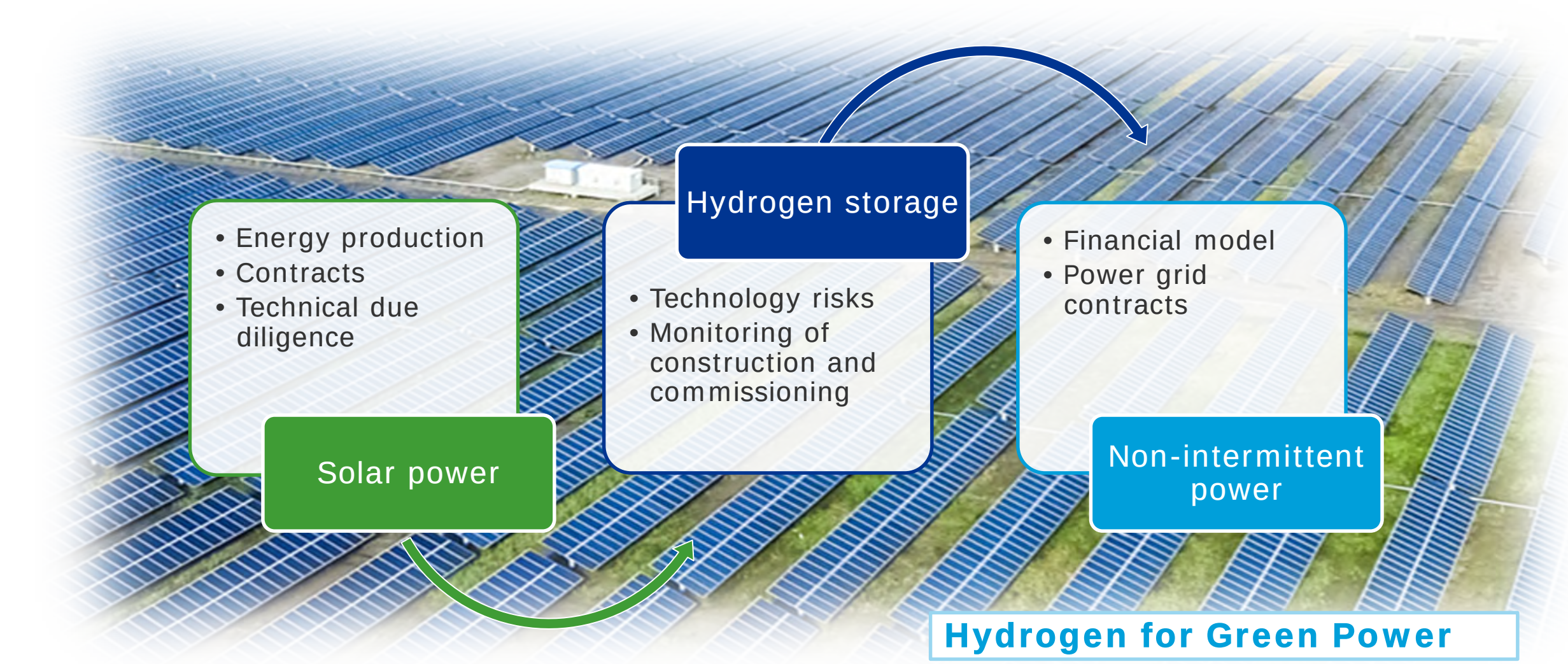
Netherlands - Energy Delivery Business Models and Investors

Decentralised generation → Electricity grid congestion → Grid Reinforcement

- Dutch start-up to build world-first integrated hydrogen wind turbine
- On-shore wind turbine supplying electrolyser
- Expanding to on- and off-shore wind turbines
- Business assurance for “green” investor
- Assessment of energy production
  - Verification of financial model and assumptions
  - Evaluation of subsidies and investments
  - Commercial analysis of business plan

Hydrogen for Green Power

South America - Combined Solar and Hydrogen Storage



Innovation - Hydrogen as an Energy Carrier

Decarbonisation of heating (buildings)

Transport applications

Adding value to surplus electricity from renewable power generation

Decarbonisation of energy intensive industry applications

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Thank you

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