



Hydrogen and Fuel Cells for Sustainable Energy Conversions

**The 'whole energy system' transition with
recent deployment projects in Scotland**

Nigel Holmes, Chief Executive, Scottish Hydrogen & Fuel Cell Association

ASLEE Conference, Glasgow, 20th March 2017

Areas we will cover

- SHFCA & our member activities
- Scotland's journey to a Low Carbon Economy
- Innovative Projects – Making Most of Renewables
 - Aberdeen & Fife: renewables into transport
 - Orkney Islands: Surf 'n' Turf & BIG HIT projects
 - Ammonia, biogas upgrades, and more
- Hydrogen as Sustainable Feedstock
- Challenges and next steps...



SHFCA & Member Activities

Key SHFCA activity areas include

- Fuel Cell distributed CHP – ultra low emissions
- Hydrogen and Fuel Cells for Sustainable Transport
- Energy Storage with Hydrogen, Small to Large scale

SHFCA Members:

- Energy companies & delivery partners
- Researchers & Developers
- Early Adopters & Project Partners

85+ SHFCA members

- The most proactive H&FC Association in Europe?



Some of our 85+ SHFCA members...



Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean



ABERDEEN
CITY COUNCIL



Micro, SMEs, Corporates, Local Authorities, Academics, & Partners

Early Pioneer Projects in Scotland

By SHFCA members:

- PURE, Unst (Shetland)
- SEED, Isle of Lewis
- The Hydrogen Office



Scotland's Progress towards Low Carbon

- Using more Local Energy & Distributed Generation
- Hydrogen for energy storage & conversions
- Hydrogen from renewables is 'Green Hydrogen'
- Scotland's electricity now almost 'carbon free'



Scotland's last coal fired power station closed in March 2016

Scotland's Ambitions for Reducing CO₂



- Reduce CO₂ emissions by 42% in 2020 (compared to 1990 baseline)

42%

(the answer to life, the universe and everything)



- Generate 100% of Scotland's power* from Renewables



- Install 1 GW of Locally Owned Renewables



* In 2015 Scotland generated over 50% of its annual electrical demand from Renewables, and the CO₂ reduction was 46%

New Climate Change Plan (RPP3)

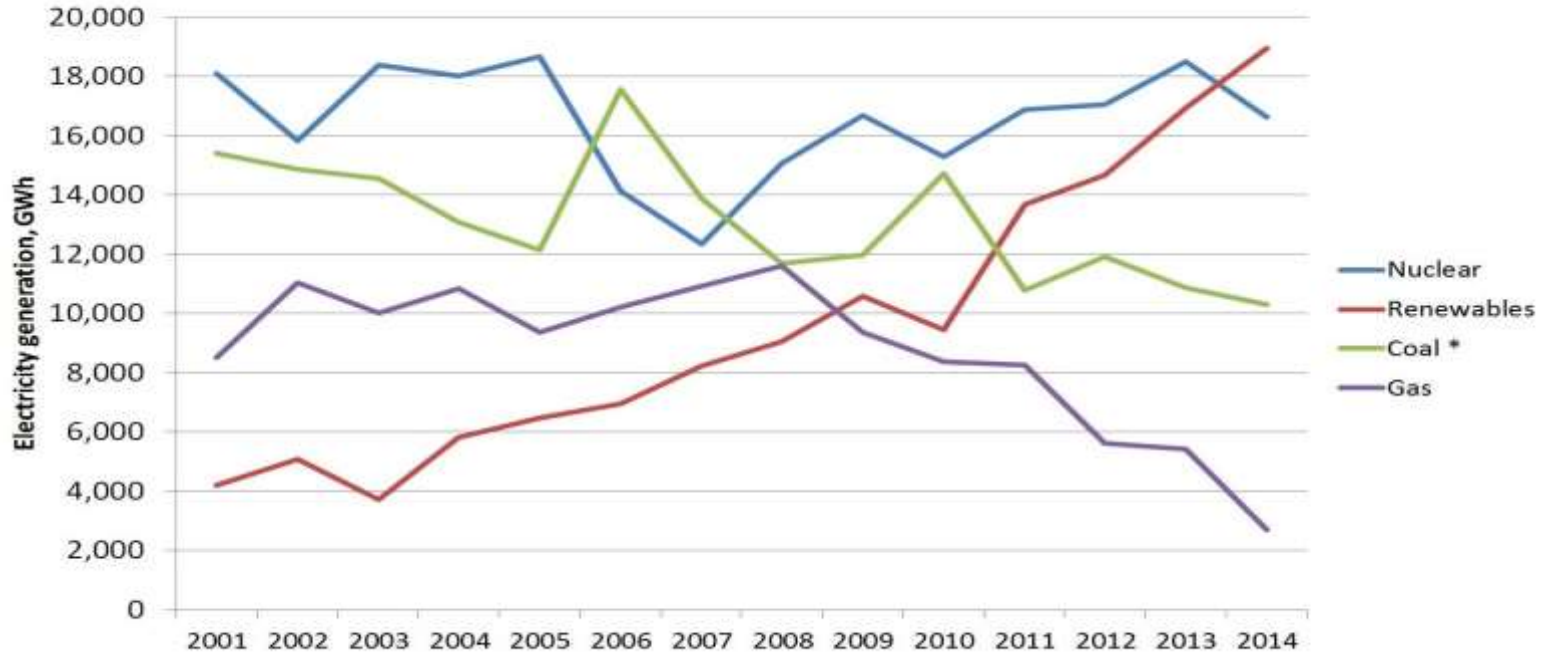
- Released 24th Jan 2017
- 2017-2032 plan
- 66% CO₂ reduction
- From 1990 baseline
- Consultation now open
- Respond by 20th April

DRAFT CLIMATE CHANGE PLAN
The draft third report on policies
and proposals 2017-2032
January 2017



Scotland's Power Generation Mix

Electricity generation mix



Source: DECC

Footnote: No coal power generation in Scotland after April 2016

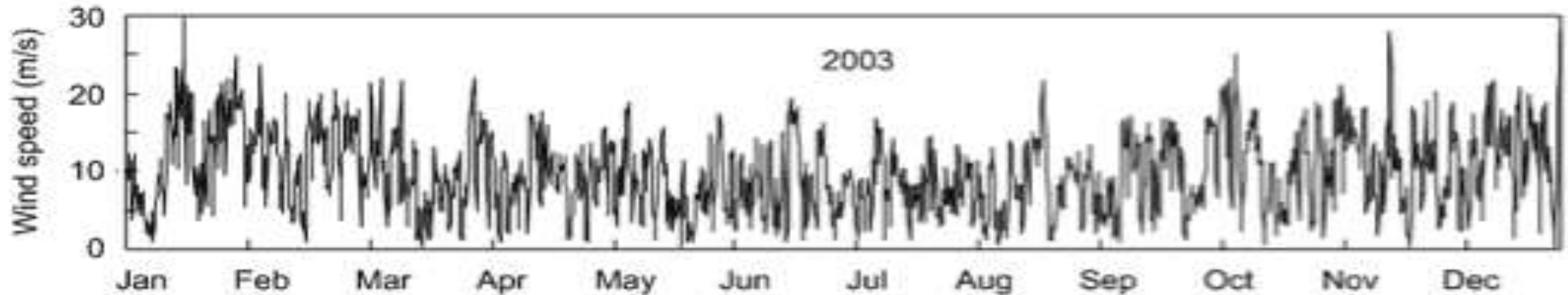
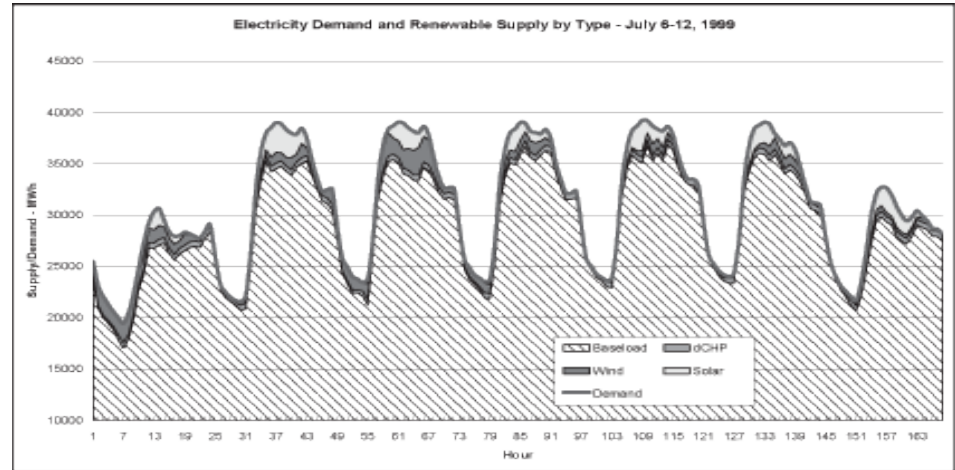
Challenge – Making most of Renewables

Match Supply to Demand

- Demand 2.5 to 7.5GW
- Reasonably predictable

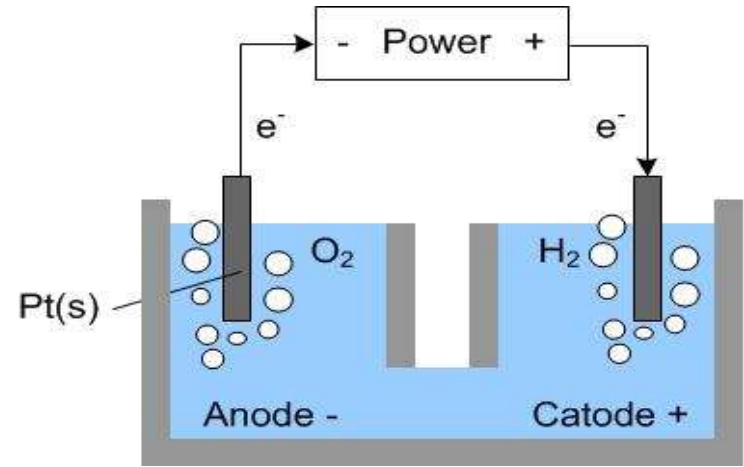
Variable Wind Generation

- Increasing renewables



Converting Surplus Power to Hydrogen

- Electrolysis of Water
- Uses Renewables
- Produce 'Green' Hydrogen
- Use in Heat & Transport



Electrolyser Schematic ↑

← Industrial Electrolyser

Convert Power to Hydrogen – Any Scale

- Very small, less than 1 Watt
- Small, few kWatt
- Medium, many kWatt
- ...Big, many MWatt



100mW for school demo



3 x 250kW for Aberdeen Buses



100MW for Ammonia process

H₂ Links Renewables with Transport

- SHFCA member Aberdeen City Council saw economic development opportunities
- Hydrogen – making the link between Renewables & Transport
- Hydrogen from electrolysis of water
- Video from All-Energy 2012:
<https://www.youtube.com/watch?v=6PDgvlVaEdk>
- What happens next...



Aberdeen's Hydrogen Buses



Europe's Largest Fleet - 10 Hydrogen Fuel Cell Buses launched in Aberdeen March 2015, EU Supported

Hydrogen produced on Site



Hydrogen is produced at Kittybrewster by electrolysis of water, with power supplied from wind farms in Aberdeenshire area.

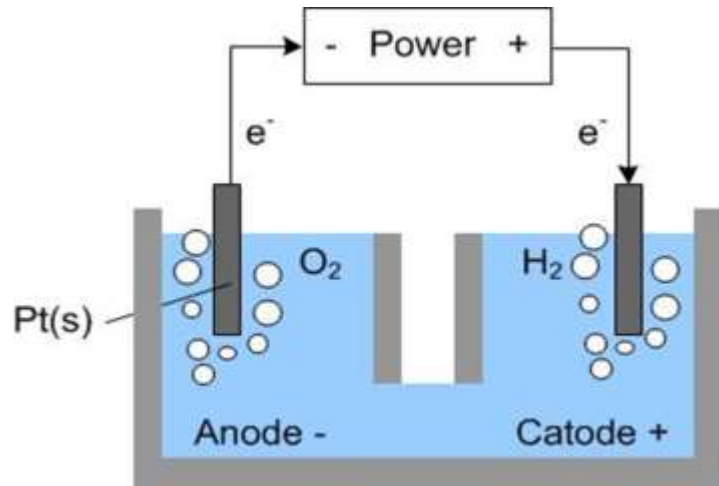
Building Aberdeen's Clean H₂ Fleet



Like many cities, the centre of Aberdeen is an Air Quality Management Area with NO_x and Particulates (mainly from Diesel) causing health issues. Hydrogen vehicles are helping to address this problem.

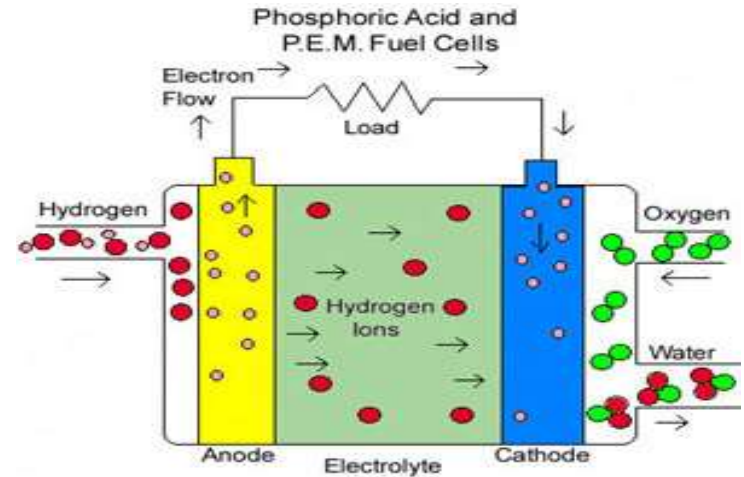
Hydrogen & Fuel Cells

- Electrolysers convert electricity to hydrogen
- Fuel Cell is the 'opposite' to electrolysis...



Water Electrolyser

Power in, Hydrogen out



Fuel Cell

Hydrogen in, Power Out

Key Features of Fuel Cell Vehicles

- Zero Emissions of harmful NO_x , SO_x , and particulates
- Zero CO_2 at tailpipe, just water
- 5kg H_2 = Range 300+ miles
- Quick refuel, under 5 mins





The Hydrogen Office in Methil

Hydrogen Office – Levenmouth Project

- Renewables: 750kW Wind
- & 160kW Photo-Voltaic
- 250kW PEM electrolyser
- 45kg Hydrogen storage
- Power from 100kW fuel cell
- Toshiba Energy Management System
- Private wire network to 9 buildings
- 2 x 24kg/day Vehicle Refuellers
- Fleet of 17 Hydrogen vehicles



Fleet of 17 Hydrogen Vehicles

- 10 Renault Kangoo electric vans, with hydrogen FC range-extender
- 5 Ford Transits (Fife Council) run on a mix of hydrogen and diesel
- 2 Refuse collection vehicles (Fife Council) running on a mix of hydrogen and diesel – these are a world-first
- All vehicles are dual-fuel, and so can operate even if hydrogen supply interrupted

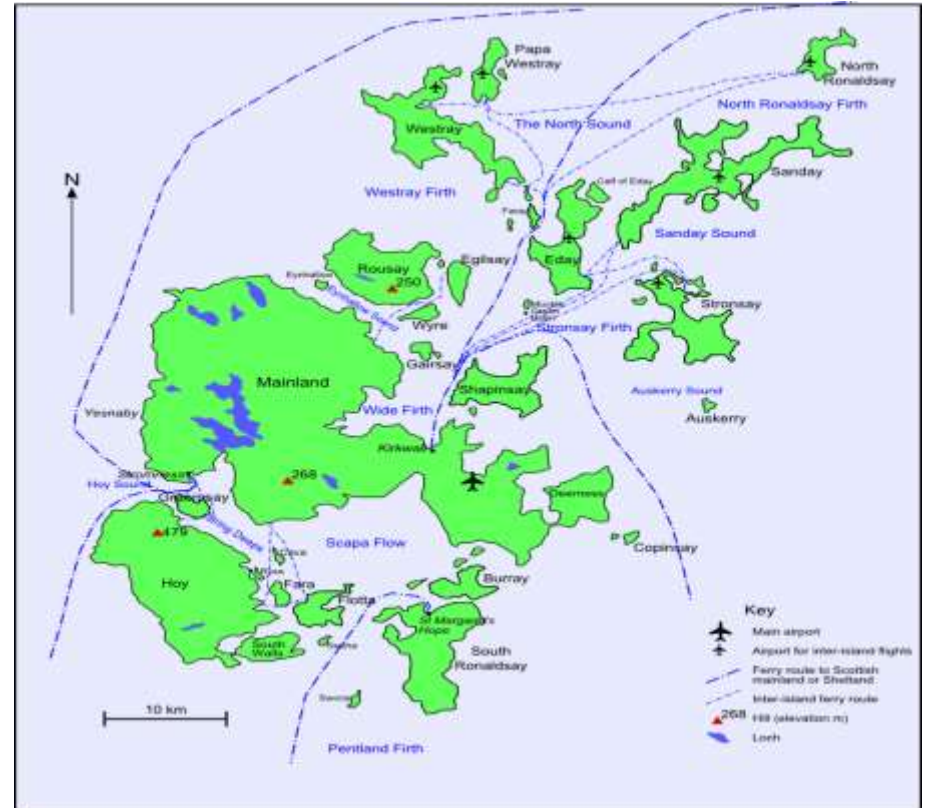
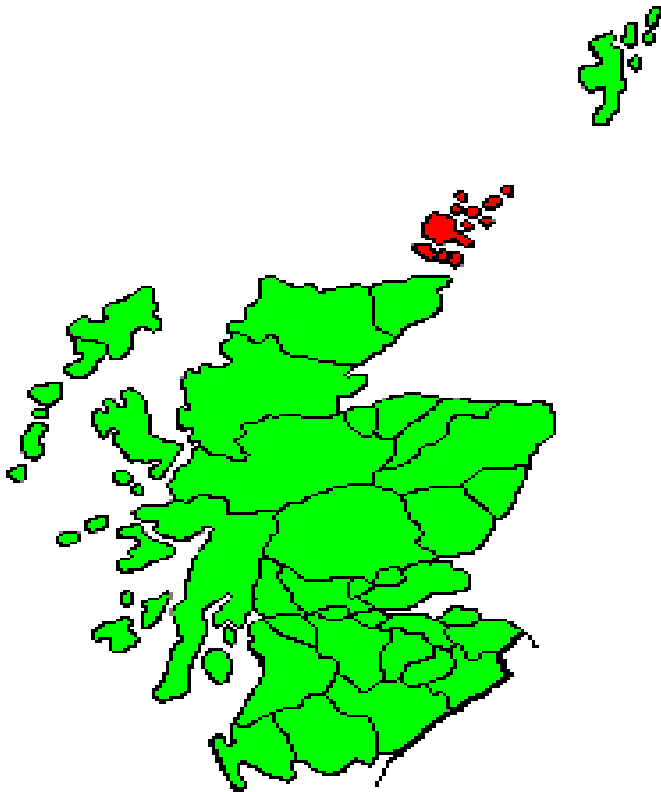


Levenmouth Fleet – with 2 RCVs

- World first H₂-ICE Refuse Collection
- Diesel-hydrogen flex fuel



Hydrogen in the Orkney Islands



Orkney Islands Achievements

- By 2014 over 100% of Orkney's power* from Renewables
- Over 50MW of installed renewable capacity
- Hosts the European Marine Energy Centre



Orkney is now generating over 120% of its annual electrical demand from Renewables, but many wind turbines are still constrained due to weak grid

Orkney Marine Renewables

- Unique tidal flow
- Good wave yields
- EMEC = European Marine Energy Centre
- Developed with Heriot-Watt University

More marine energy converters have been tested in Orkney waters than at any other single site in the world



EMEC Grid Constrained

- Weak interconnector to Orkney Mainland
- Limiting EMEC test facility potential
- Study to explore options
- Electrolyser & Hydrogen opportunity
- Highlands & Islands Enterprise support
- 0.5MW electrolyser procured in 2015
- Located on Eday

Test Facility

**STROMNESS SUB STATION
LINK TO GRID, CAPACITY
FOR 4MW PER YEAR**

**EMEC - ORKNEY OFFICE
OLD ACADEMY, STROMNESS
CENTRE ADMINISTRATION
& DATA MANAGEMENT**

**STROMNESS HARBOUR
MARINE SUPPORT
FACILITIES**

**SCAPA FLOW
SHELTERED
ANCHORAGE**

**COASTGUARD
LOOKOUT POST
OBSERVATION
EQUIPMENT**

**BILLIACROO CABLE
LANDFALL SWITCHGEAR
BUILDING**

**SUBSEA CABLE
& FIBRE OPTIC
LINK**



EMEC 0.5MW Electrolyser

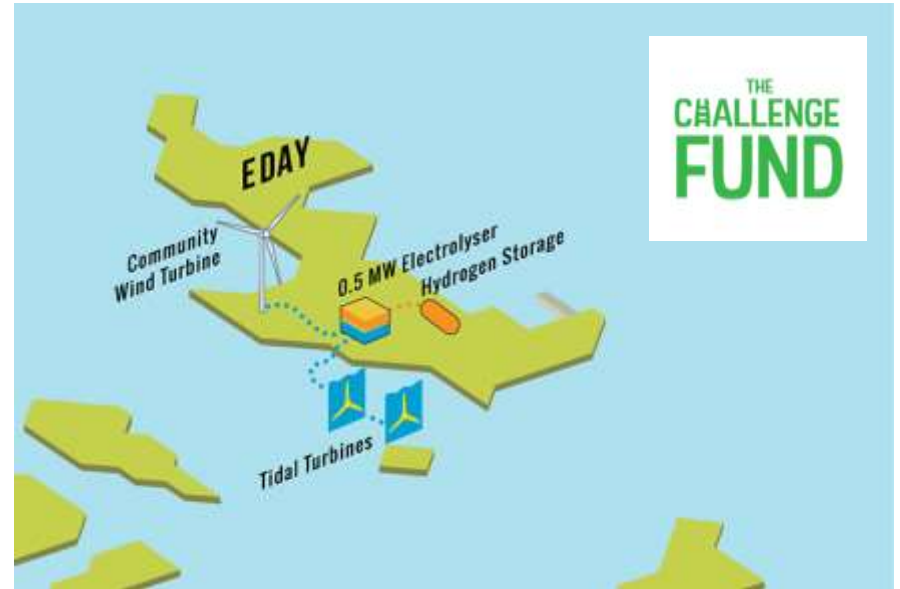


High pressure PEM electrolyser supplied by ITM Power

Surf 'n' Turf : Meeting the Challenge

Surf 'n' Turf is one of the first 5 LECF supported innovative community renewables projects.

It aims to generate hydrogen from wind and tidal, and use that hydrogen to avoid grid limitations and develop local demand for hydrogen.



Eday : the Facilities at EMEC

Surf 'n' Turf Project – Partners

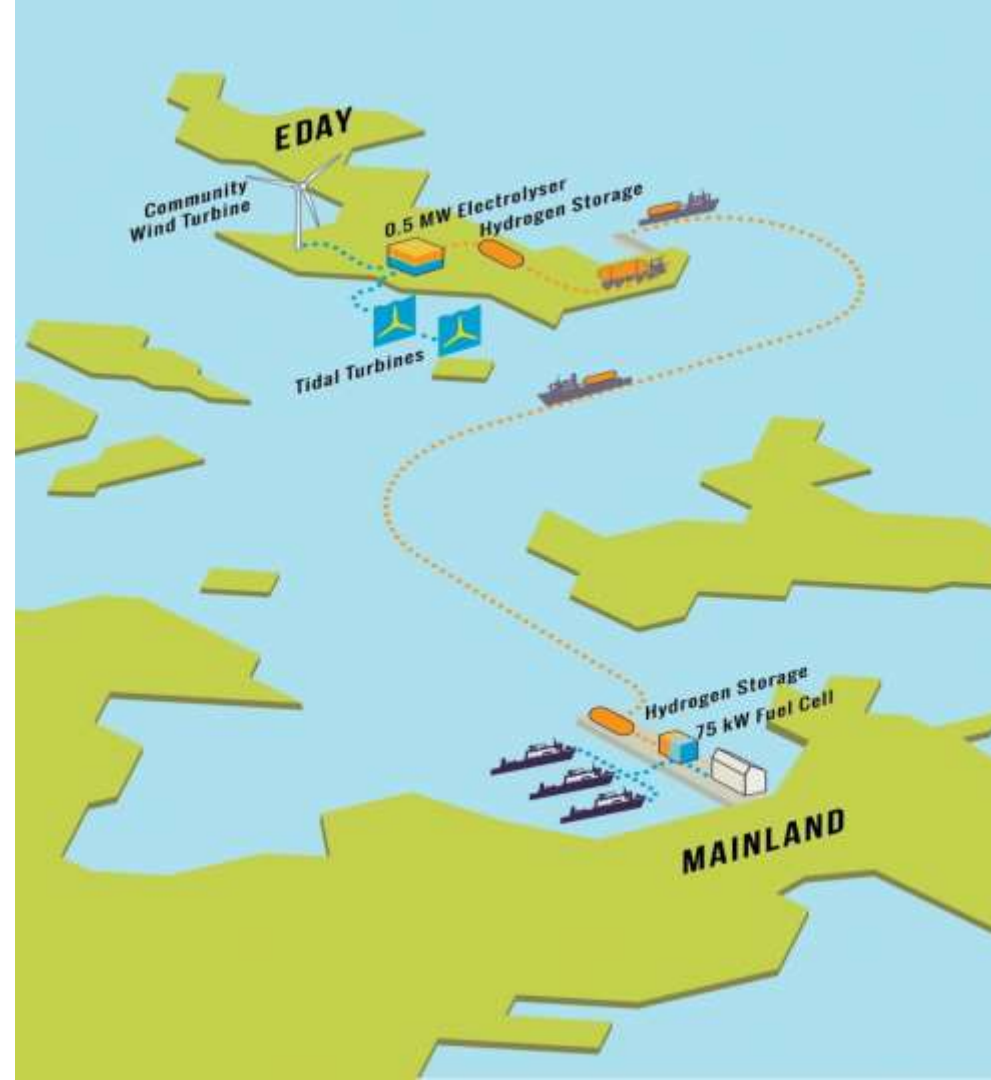


Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean



Surf 'n' Turf : Moving Energy

- Hydrogen produced on Eday
- Moved by tube trailer
- Destination Kirkwall
- Use for clean power at dockside



Lightweight Tube Trailers



Announced May 2016 : BIG HIT



Shapinsay's 0.9MW local wind turbine

Announced in May 2016, using hydrogen made from renewable electricity and 1MW electrolyser to supply heat and transport and help overcome local grid constraints in Orkney. €5m EU grant support for the BIG HIT project, funded by FCH 2 JU.



1MW balancing electrolyser

BIG HIT Project – 12 Partners + Supporters from Europe



Symbio FCell



ORKNEY
ISLANDS COUNCIL



BIG HIT
Grant agreement no.: 700092

Hydrogen Moved by Tube Trailer

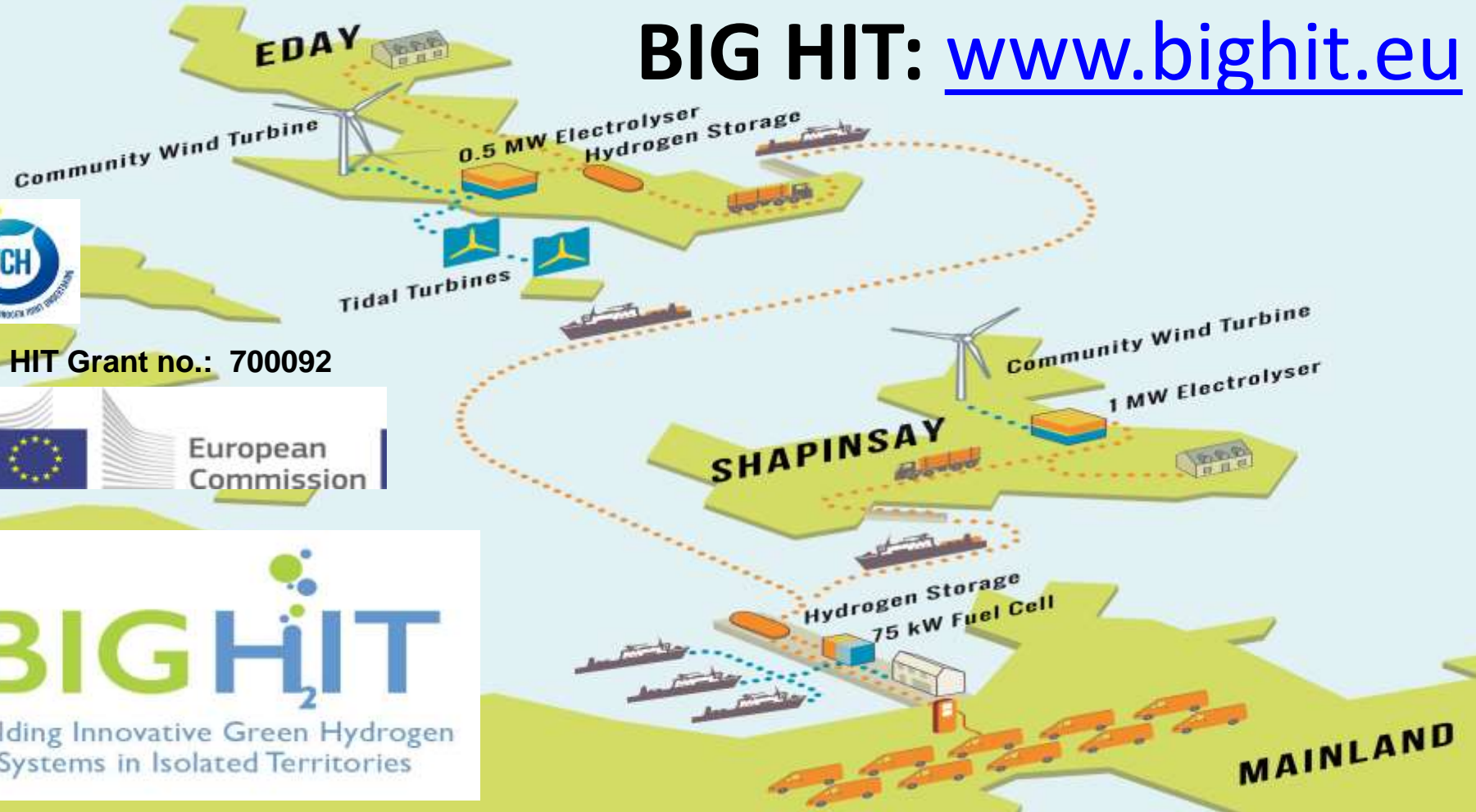
- Hydrogen produced from renewable energy
- Wind, wave, and tidal
- On Eday & Shapinsay
- Store in tube-trailer
- Move to Kirkwall
- Used for transport
- Also heat and power



BIG HIT: www.bighit.eu



BIG HIT Grant no.: 700092

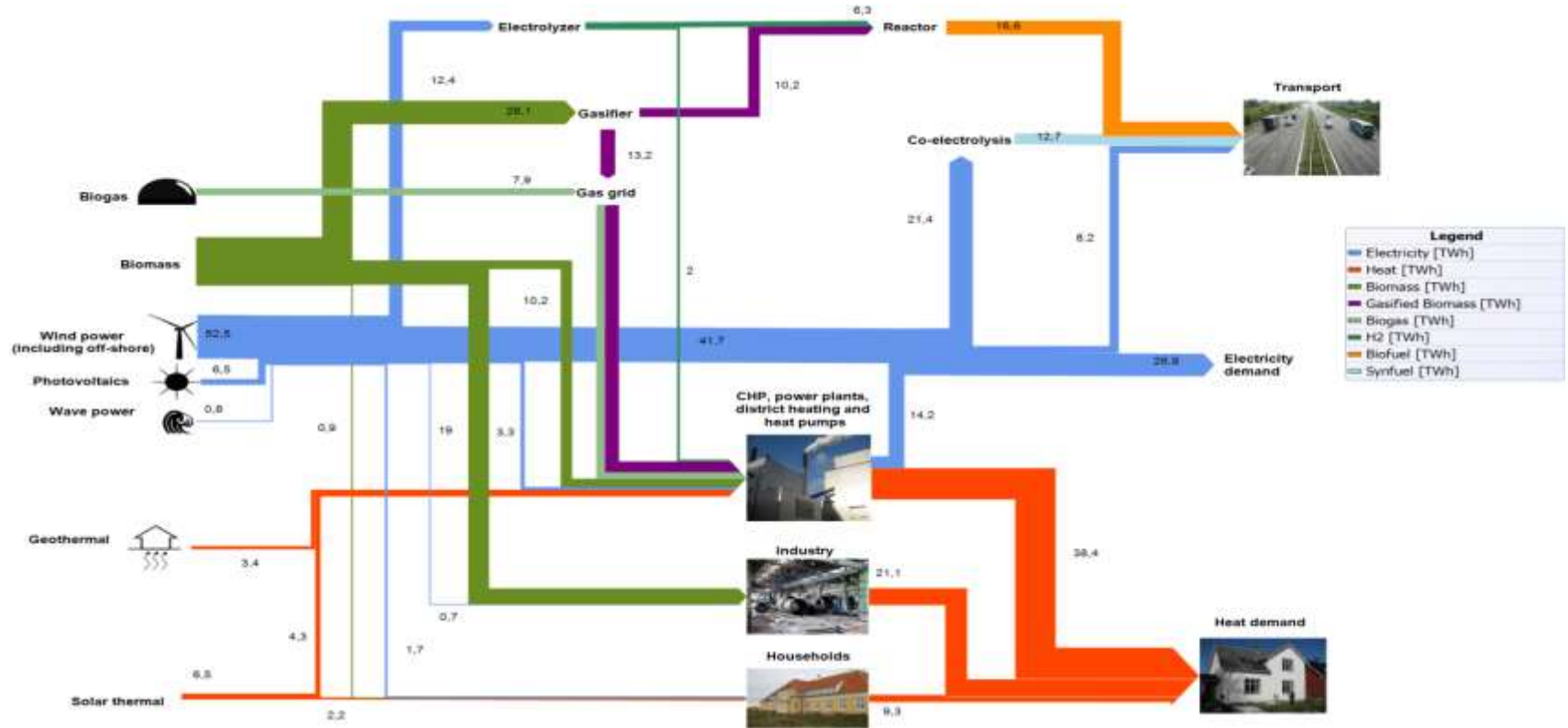


BIG HIT Launch 27-28 Sept 2017



Opening event takes place in Kirkwall, Orkney Islands
To register your interest send email to info@bighit.eu


Denmark: 100% Renewable Energy System by 2050



Sankey diagram of the CEESA 2050 100% renewable energy scenario

Agri-Renewables with Hydrogen



 Turbine Location

- 20kW wind turbine
- 48kW photo-voltaic
- Hydrogen production & storage
- Hydrogen boiler
- Hydrogen fuel cell



 New Trial Site Plant Room

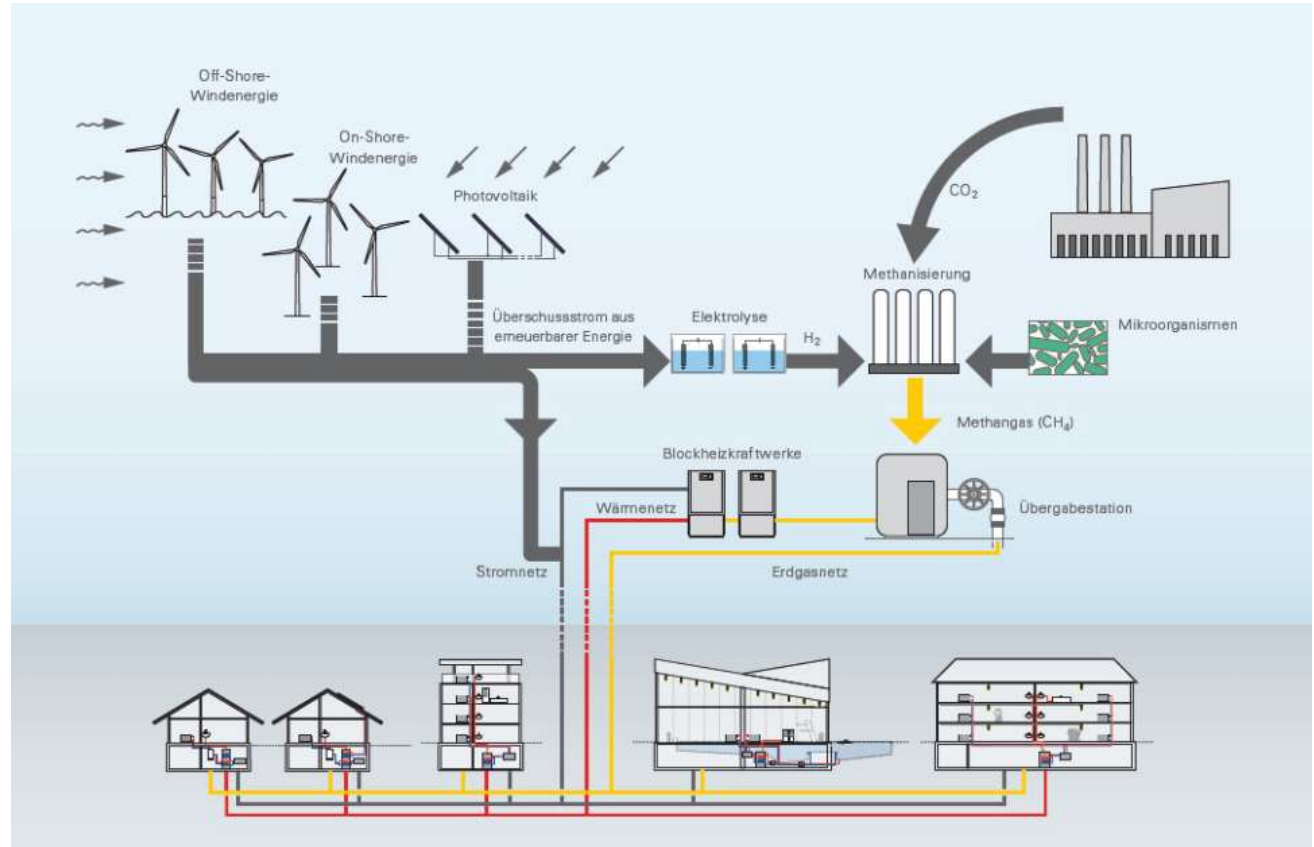
Convert H₂ into Sustainable Chemicals

- Sustainable Methanol production
- CO₂ & power from geothermal vents
- Hydrogen by electrolysis of water
- Avoids 'Food vs Fuel' Dilemma



CO₂ Conversions with Hydrogen

- Extensive
- Scalable
- Proven chemistry



Global Use of Hydrogen as Feedstock

Current Global use of Hydrogen

- 60 million tonnes per year
- 50% for Ammonia (fertiliser) manufacture
- 45% for oil refining (fuels)

But... over 98% of this Hydrogen is produced from fossil fuels (coal/methane) using reformation.

Opportunity for Hydrogen from Renewables

Multi-MW scale 'Green' Hydrogen

- Hydrogen by Electrolysis
 - MW scale since 1928 in Norway
 - 100MW electrolyzers proven
- Use with Renewables
 - System Balancing
 - Optimise on-site & local use of energy
 - Overcome grid constraints
- Store, Distribute, & Use 'Green' Hydrogen
 - Can be used in gas networks for low carbon heat
 - As feedstock for chemical conversions, fertiliser etc
 - Route to sustainable chemicals using bioconversions

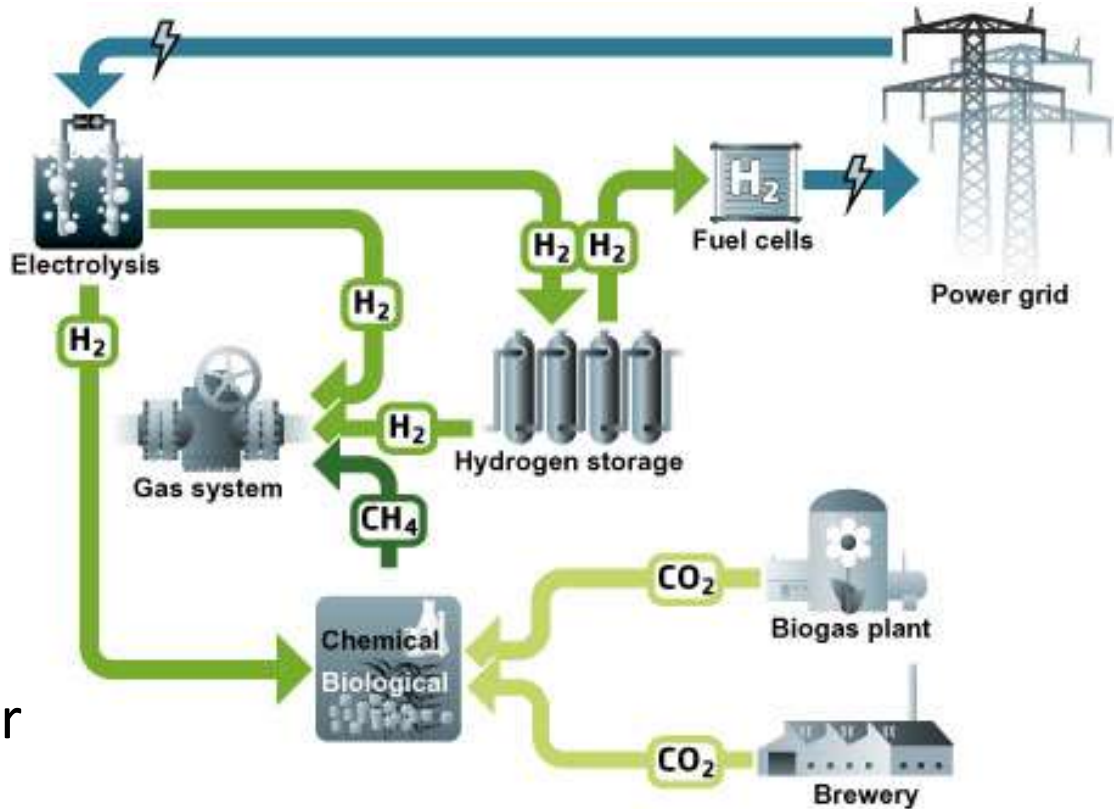


21'000 Nm³/h H₂ electrolysis plant

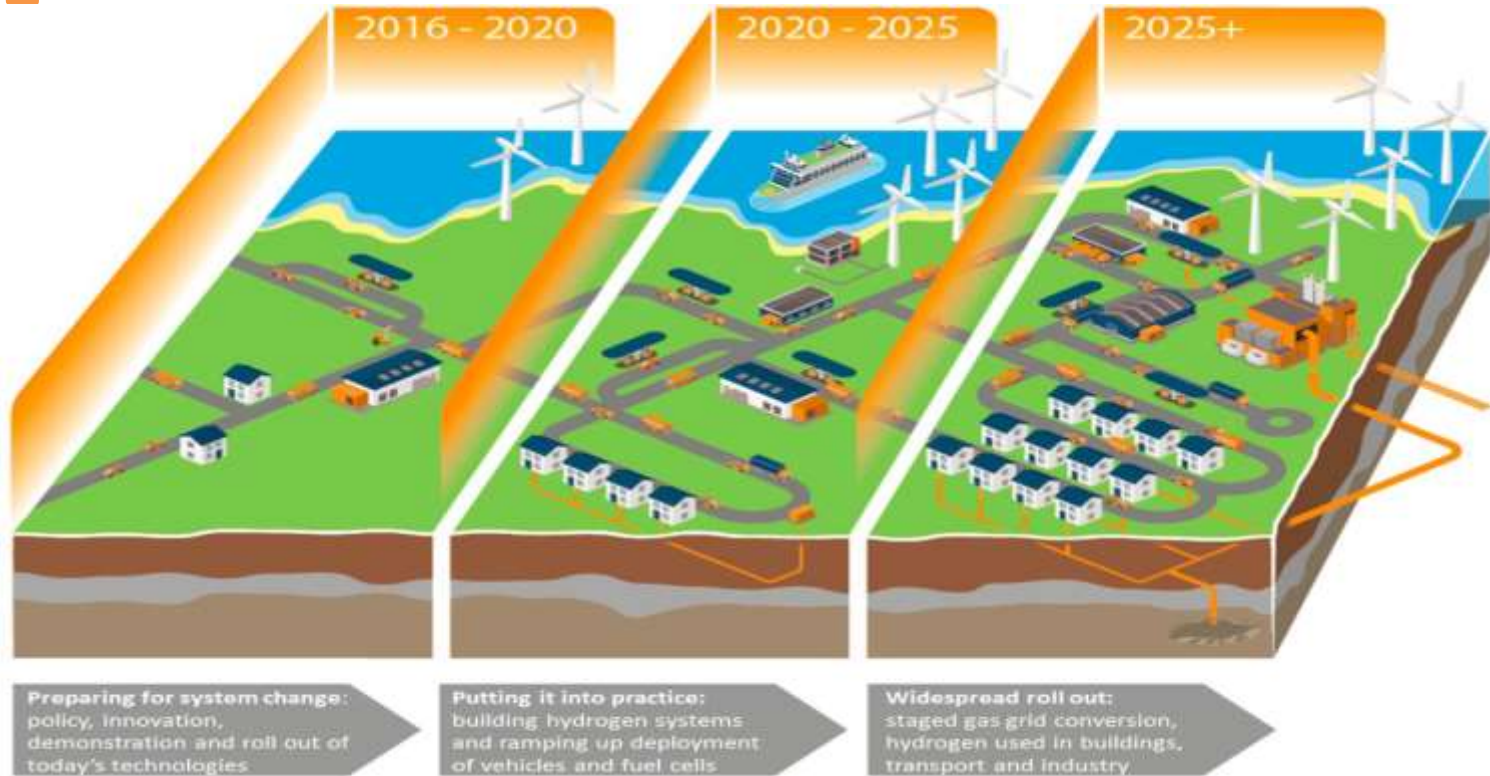
100MW Electrolyser used in Zimbabwe
from 1975 –2009 for fertiliser manufacture

Adding flexibility with Hydrogen

- Use hydrogen as a clean energy vector
- Also as feedstock for chemical conversions
- Make 'commodity' products
- Storable & Transportable
- Fuels, Chemicals, Fertiliser

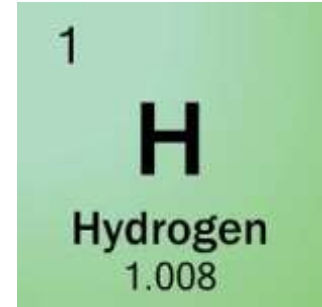


H₂ & Fuel Cells in the Energy System



Closing Comments

- Hydrogen – the link with renewable energy
- Can be used as a chemical feedstock
- Basis for sustainable conversions & products
- Opportunity for innovative bio-conversions
- Adding value, making sustainable products



H₂ and Fuel Cells for Sustainable Energy Conversions

Thanks for Listening - Any Questions?

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ASLEE conference, Glasgow, 20th March 2017

