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Helen Melone

Senior Policy Manager

Scottish Renewables

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Scotland's Hydrogen Potential: The Experts' View

Chaired by Clare Lavelle,

Associate Director, Energy Consultancy Leader – North, ARUP

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Stuart McKay

Head of Hydrogen Policy

Scottish Government

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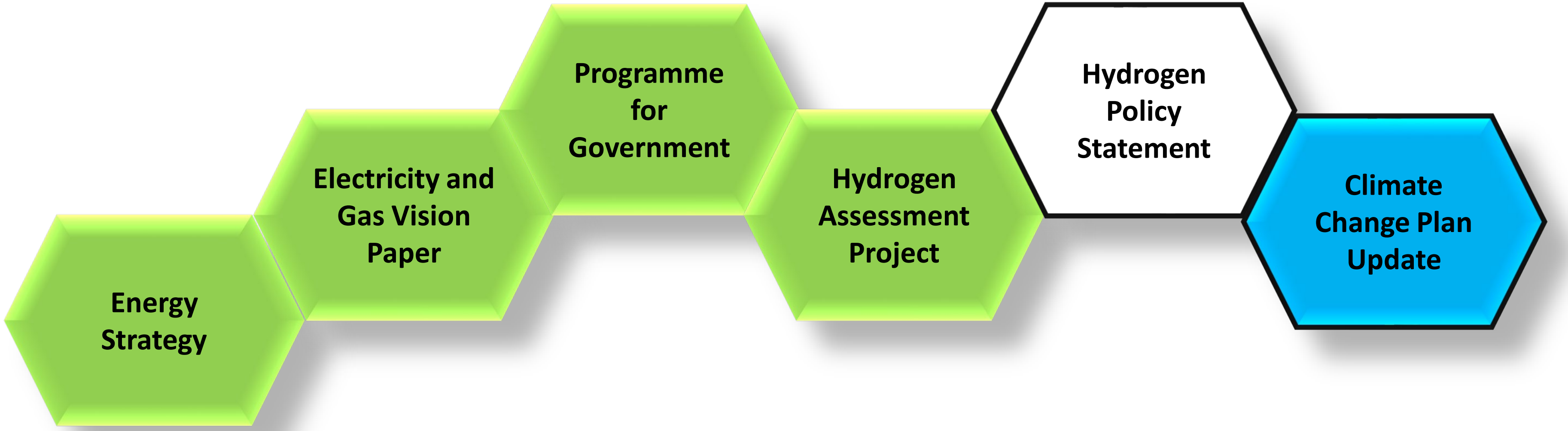
Scottish Government : Hydrogen Policy Arc



Hydrogen Assessment – Key Messages

Scotland could grow a strong hydrogen economy supporting jobs and GVA growth – Value can be captured through investing in innovative technology and commitment to infrastructure.

Co-ordination of efforts across industry and government – Better co-ordination will enable an efficient transition and ensure economic opportunities are maximised.

Clear strategy with proposed ambitions – There is significant focus globally on the opportunities that can be realised from developing an indigenous hydrogen economy, that aligns with the needs of a global market.

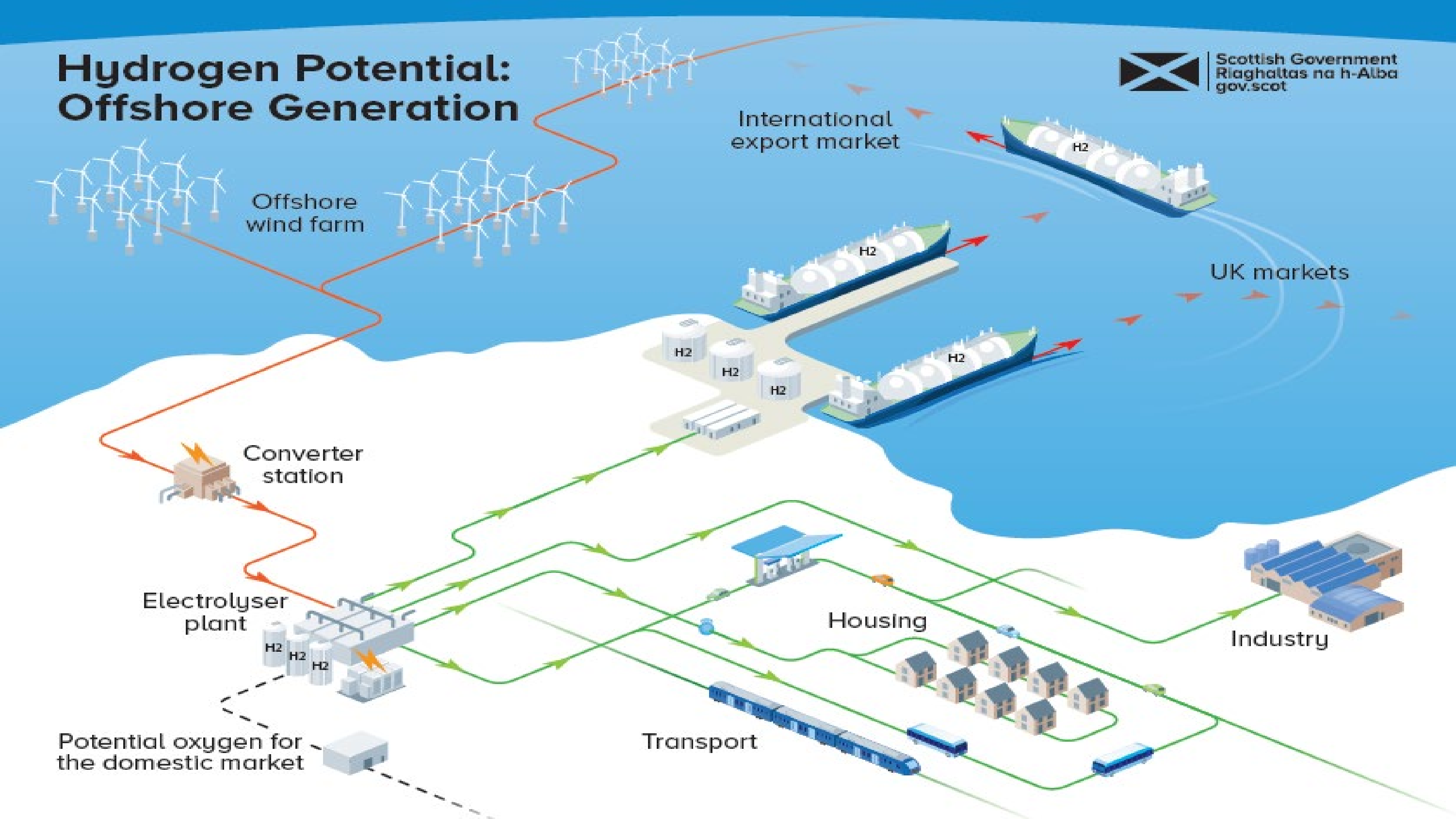
Going beyond the pilot project stage and into commercial scale projects – The next important step is to move beyond the small pilot stage and into large scale commercial projects.

Maintaining flexibility – Hydrogen is still in the early stages of commercialisation as an energy vector and could develop in several different ways. Ruling out options now would be premature, in the context of seeking net-zero 2045 solutions.

Hydrogen needs to be seen within a whole energy system context –Hydrogen will complement increasing electrification, by improving system flexibility and resilience. Some of its benefits will only be understood when looking at the wider system context.

Speed of deployment – If Scotland wants to capture more of the economic value from hydrogen activities it needs to act quickly and decisively.

Hydrogen Potential: Offshore Generation



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Nigel Holmes
CEO
Scottish Hydrogen and Fuel Cell Association

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David Wallace

Senior Strategy Manager

ORE Catapult

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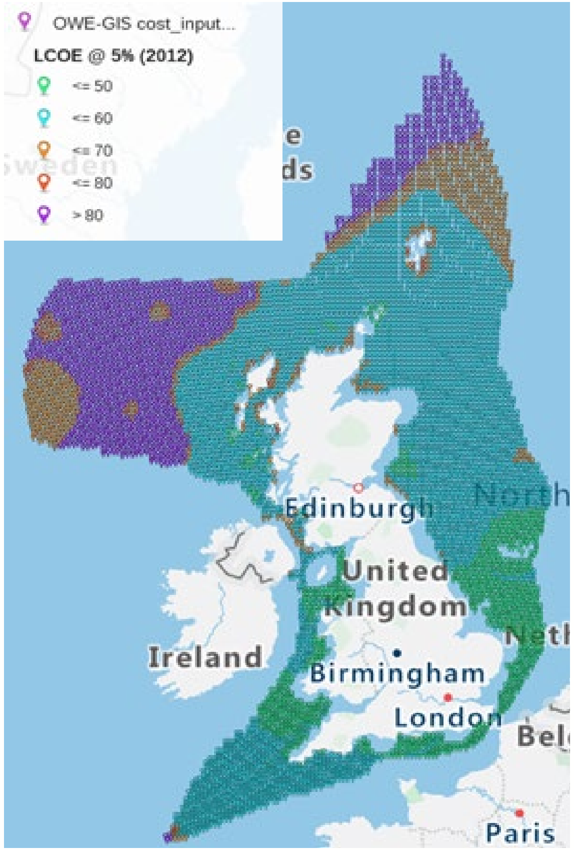
Offshore wind and hydrogen
Solving the Integration Challenge

10 December 2020 | david.Wallace@ore.catapult.org.uk

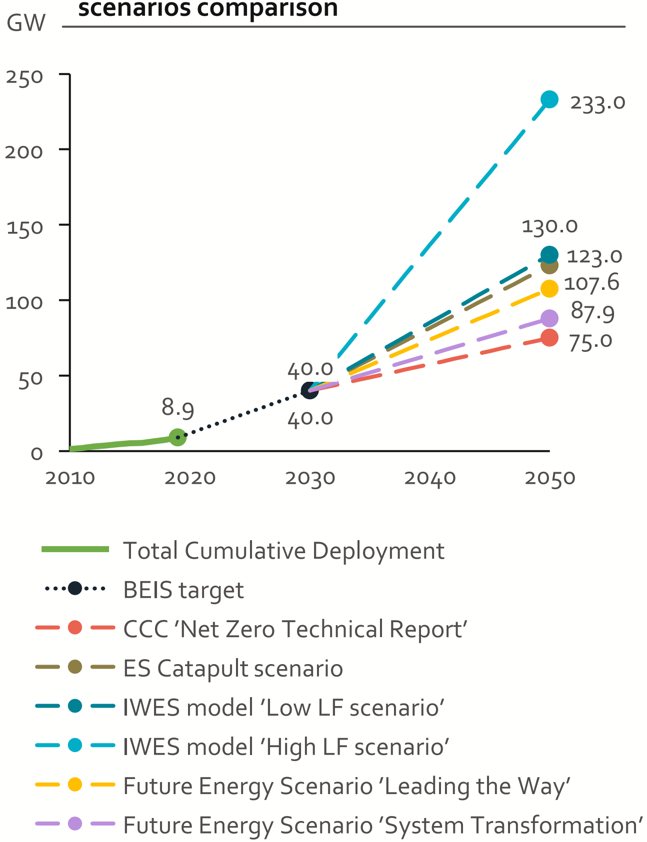
CATAPULT
Offshore Renewable Energy

Context – Sufficient OSW available for UK needs and exports

Modelled LCOE estimates for UK waters
(£ /MWh)



Total installed capacity in the UK - scenarios comparison



- Affordable OSW is sufficient for UK energy needs, PLUS
- Substantial global exports

  e.g. 200TWh-1,200TWh green-H2 demand in Northern Europe in 2050

  CAVEAT: assumes floating wind is commercialised from 2030

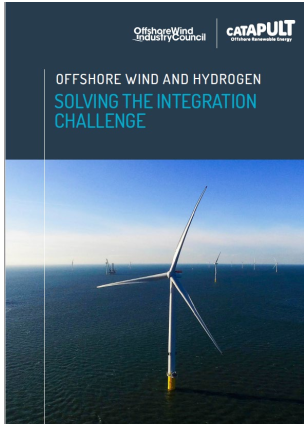
- Need to coordinate infrastructure, markets, with neighbours in Europe, to enable full UK potential

Scottish waters ~735 GW capacity @ < £40/MWhr

Our cost modelling used our supply curve for OSW

OWIC & OREC OSW-H2 study

Background and objectives



- Report delivered as part of Sector Deal Task Group to 'Solve the Integration Challenge'
- Goal - identifying opportunities to strengthen offshore wind's role in delivering innovative solutions to system integration
- Related study, WSA: ESC applied whole energy system modelling to provide insights into the potential scale of OSW, and the scale and role of H2 in system balancing.

Key findings

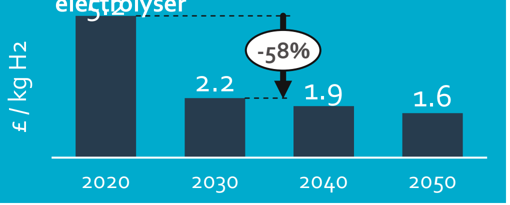
ENERGY SYSTEM

The UK energy system requires 130TWhr to over 200TWhr hydrogen in 2050, to integrate 75GW, or more of offshore wind.

① COST REDUCTION

Most of the cost reduction for green hydrogen from offshore wind occurs by 2030, by which point it can meet a significant part of energy demand.

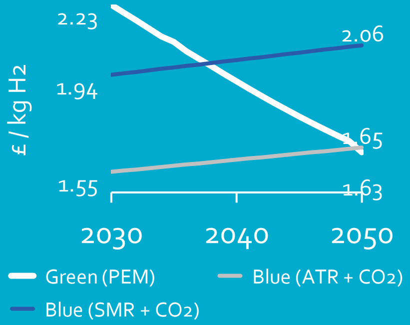
LCOH projection for PEM electrolyser



② GREEN AND BLUE HYDROGEN

Green hydrogen from OSW costs less than blue hydrogen by 2050*, although factors including more rapid adoption of electrolysers, swings in natural gas prices, leakage of natural gas, or cheaper blue hydrogen generation technologies, could change this picture.

*Hydrogen production from natural gas with CCS might not be a necessary part of a net-zero UK energy economy in 2050.



Key findings (2)

There are signs in the marketplace that green hydrogen will take off faster than we assumed, cutting costs by 2030 by more than we have estimated.

Driving deployment of electrolysers is essential for reducing their cost – the UK has done this before, with offshore wind.

Technology acceleration is an essential means of reducing electrolysis costs – the UK has strong leadership in academia, and industry, to build on.

POTENTIAL BENEFITS

③

£320BN

Cumilative GVA in 2050 (electrolysers and UK OSW enabled by H2) of which £250bn is exports

120,000 JOBS

Sustaining up to 120,000 new jobs, many in manufacturing, mainly outside London & SE

£48BN P.A.

Additional potential in green hydrogen exports to Europe, using up to 240GW of dedicated offshore wind

A wide range of UK companies will benefit from growth of the green hydrogen industry

Next steps – Roadmap track 1 - Core R&D programme

CATAPULT Offshore Renewable Energy

R&D programme objectives

Example challenges.

Full list of challenges available in the report

CAPEX reduction

Reducing the use of high-cost materials; simplifying design to reduce labour and increase automation.

Unit scale-up

Pressure management across larger stacks.

Improve efficiency

Improved surface reaction characteristics; improved designs and greater design integration across balance-of-plant; new power electronics solutions.

Increase reliability

Materials aging challenges, especially high temperature for SOEC; hydrogen embrittlement management.

Flexible operation

Improved integration across components; optimised electrochemistry; materials for a wider range of operating conditions.

Increase manufacturability

Electrolysers are currently not manufactured in scale. Continuous serial production methodologies have to be established

Better marine environment tolerance

Decreasing OPEX and tackling O&M challenges. Developing more resistant materials.

Non-electrolysis technologies (maximum 5% of funding)

Potentially to include direct cracking of methane to H_2; photo-catalytic H_2 production.

To avoid lost opportunities, our roadmap of research, projects and supporting actions to 2030 should be adopted as soon as possible

- The roadmap for the UK is set out as three essential tracks: The first is the R&D track for the Core R&D programme.
- The R&D programme, and in particular the theme relating to the cell stack component, will draw upon world-leading capabilities that already exist within UK academia
- This R&D programme could be delivered through a hub programme structure and would consolidate and build on existing research and industrial capabilities in the UK. It would include both short-term upscaling of lower risk current technology and disruptive, higher risk projects.

Roadmap track 2 – Demonstrations at scale

Production	• At least three demonstration projects by 2025 proving the integration of electrolysis with wind turbines and farms offshore. This should include the development, demonstration and optimisation of integrated solutions with OSW (considering decentralised, centralised, ongrid and offgrid approaches).
Mobility	• At least two hydrogen transportation hub conversion projects coordinated with existing programmes to promote refuelling infrastructure and fuel cell vehicles. This requires immediate implementation. • Multiple project phases can provide a smooth pathway for demonstration of scale up of PEM electrolysers. A focus on FCEV buses is necessary to promote an affordable mode of transport that is suitable for urban locations and to support the existing technological lead of several UK companies.
Gas network	• Six demonstrations of 10,000 homes using 100% green hydrogen for heat, at each of the six major Industrial Decarbonisation zones, if local demographics are suitable - by 2030.
Industry	• Minimum of two electrolyser-based hydrogen demonstrations at >100MW H2 production - by 2025 to create investor confidence in developing manufacturing capabilities. • Ensure UKRI funding for the roadmapping phase of the Industrial Decarbonisation clusters includes large-scale electrolysis to green hydrogen. • Ammonia and methanol production switched to green hydrogen use at selected three sites – by 2035.

- Track 2 is a set of key demonstrations of critical technologies and integrated systems and markets, at scale.
- Demonstration projects will also contribute to the 2.6GW of electrolyser deployment, or multiples thereof, that we have recommended as a target for 2030. Demonstration projects should be at the right scale, to match the maturity, and the volume manufacturing plans, of electrolyser suppliers.
- H100 Levenmouth, Fife. World-first 100% residential hydrogen, with offshore wind

Roadmap track 3 - Enabling actions and policies

For OSW-H2 technology

- More flexible funding sources for demonstrations
- Facility to validate emerging technology, develop bulk production of low-carbon, low-cost, resilient hydrogen including piping, large-scale ORE storage demonstration facility and a 'living laboratory' for energy storage integration and local generation systems.
- A revenue support mechanism for production of green hydrogen
- **Make regulatory sandpits easy to access and multi-agency; lessons should be learned from the integrated approach to innovation of the OGA**
- Certification of hydrogen-ready boilers as zero-carbon compliant heating technologies.
- Establishing a cross-departmental Hydrogen Strategy within the UK Government
- Guarantee a collaboration mechanism to build on existing links between UK researchers, companies and European counterparts.

For cluster development

- Creation of multi-market hydrogen hubs around industrial clusters with existing hydrogen infrastructure.
- Development of refuelling hubs around hydrogen hubs. Rollout of 1,100 refuelling stations by 2030
- Set out a public transport strategy that will ensure all new buses are emission-free from 2025 onwards.
- Planning support and guidance for new buildings around hydrogen hubs to use hydrogen for heat. To support LCOH reduction, a scheme similar to the Renewable Heat Incentive should be established.
- **Mechanisms for Ofgem to approve investments by gas distribution network operators in 100% hydrogen network infrastructure around hydrogen hubs**
- Critical infrastructure funding to enable the gas import ports to develop roadmaps and begin the transition to hydrogen imports, exports and storage.
- Adaptation of climate related charges in the industrial sector, to allow offsets against investment in green hydrogen production.

For market development

- Develop readiness for internationally-traded bulk hydrogen at key UK ports
- **Engage with, and shape, European initiatives to develop North Sea hydrogen infrastructure for OSW farms.**
- Development of strategic heat decarbonisation policy
- **Amend Gas Safety Management Regulations to support hydrogen blending into the gas grid.**
- Consider mandating that new boilers sold after 2025 are hydrogen ready
- Support for FCEV cars and buses fleet build up around hydrogen hubs
- Promote carbon accounting of embodied carbon, internationally

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Potential into reality: future technology today

Chaired by Morag Watson,

Director of Policy, Scottish Renewables

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Adam Frew

Renewable Energy Consultant

Wood

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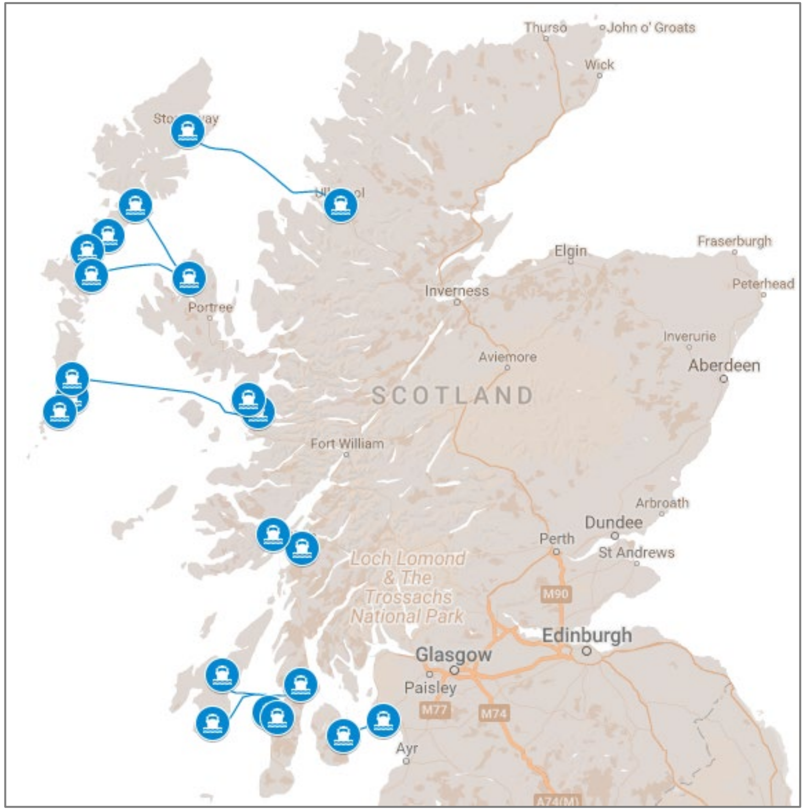
Scottish Western Isles Ferry Transport using Hydrogen

SWIFTH_2

Adam Frew

Project Partners

Study Area



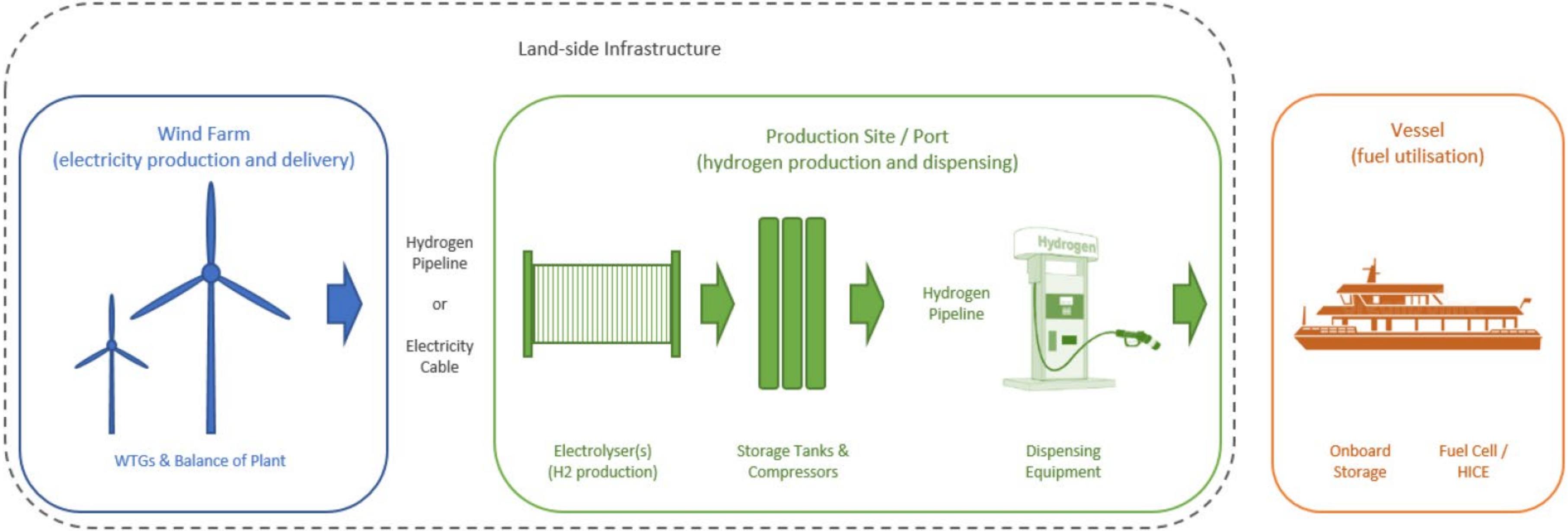
- CMAL owned vessels operated by CalMac
- 12 islands evaluated
- 9 ferry routes assessed:
  - Ullapool - Stornoway
  - Uig - Tarbert - Lochmaddy
  - Kennacraig - Ports Askaig / Ellen
  - Mallaig - Lochboisdale - Armadale
  - Ardrossan - Brodick
  - Craignure - Oban
  - Leverburgh - Berneray
  - Barra - Eriskay
  - Gigha - Tayinloan

Opportunity

- Abundant renewable energy resources
- Extensive community wind farm development
- Weak local power grid in areas
- High degree of fuel poverty in areas

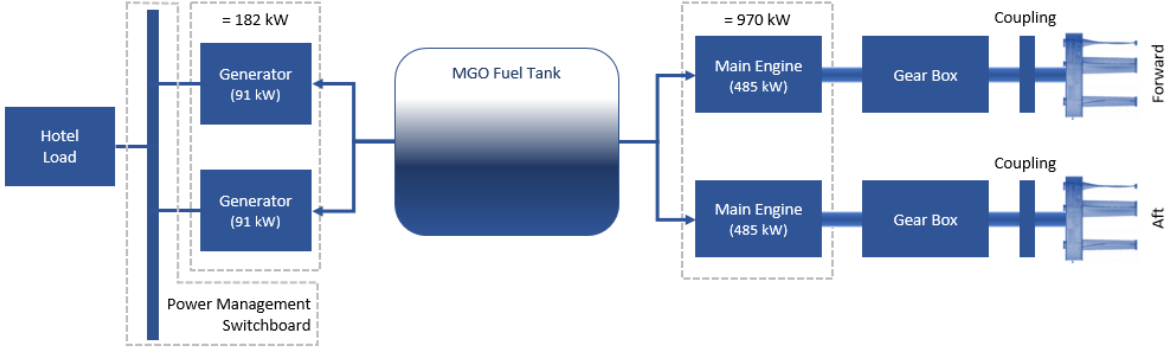
- Large user of transport fuel operating in the area
    - Need to decarbonise the Scottish Ferry fleet

Proposed Solution - Overview

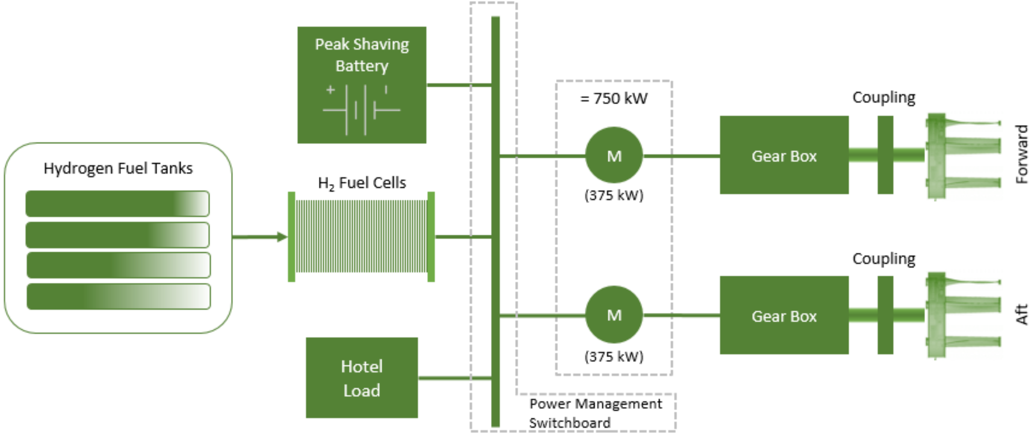


Proposed Solution – Vessel Powertrain

Existing MGO fuel powertrain



Proposed H2 fuel powertrain

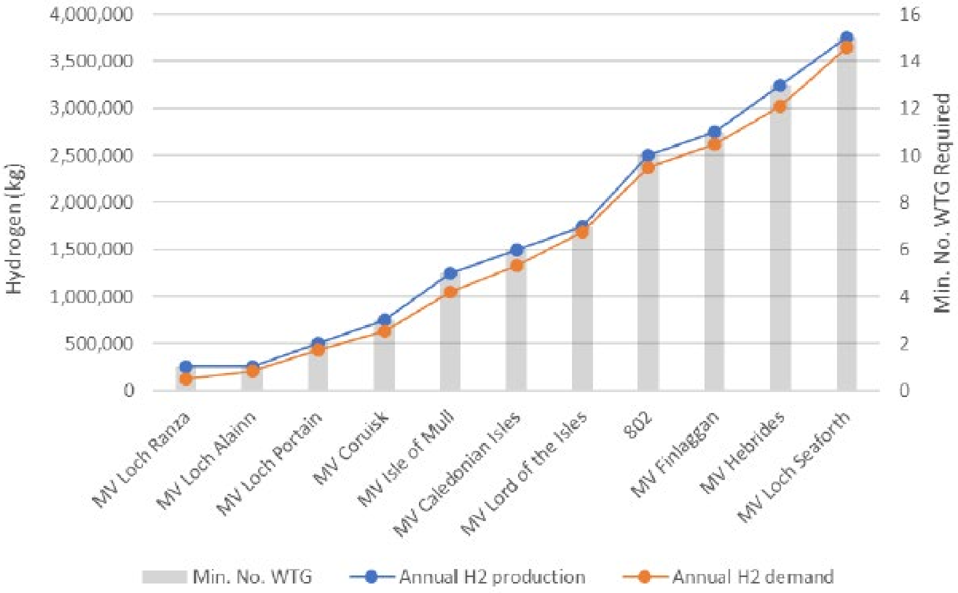


Feasibility Study Methodology

Activities undertaken as part of the feasibility study:

- Modelling of existing fleet energy demand profiles
- Sizing and specification of equivalent hydrogen power-train
- Assessment of islands to determine suitability based on:
    - Vessel hydrogen fuel and equipment weights and volumes
    - The size of hydrogen production plant required at onshore
    - Wind resource and energy yield assessment
    - Wind farm land-use and planning review
    - Wind farm accessibility
    - Solar resource assessment

Modelling - Wind Farm Size



Wood's energy modelling, in collaboration with CMAL and Siemens-Gamesa, has determined the size of wind farm required to produce enough hydrogen for each ship operating the ferry routes (SWT-DD-130 4.3 MW).

Shortlisted Location - Isle of Lewis

- 19,620.5 MWh annual wind resource
- 1,797.9 MWh annual solar resource
- MV Loch Seaforth
- Daily energy consumption of ~110 MWh per day
- Equal to 10,063 kg hydrogen per day
- Emissions savings of 21,815 CO_2e per year
- ~52 MW wind farm (12 x SWT-DD-130 WTG)
- ~25 MW electrolyser (7,250 m^2 footprint)
- Minimal access restrictions

Island	Score	Weighted Score	Ferry Route
Eriskay	19	88	Barra - Eriskay
Lewis & Harris (S-U)	17	78	Stornoway - Ullapool
Skye (U-T-L)	16	78	Uig - Tarbert - Lochmaddy
Lewis & Harris (U-T-L)	17	76	Uig - Tarbert - Lochmaddy
Barra	18	75	Barra - Eriskay
Gigha	17	75	Gigha - Tayinloan
Lewis & Harris (L-B)	17	74	Leverburgh - Berneray
North Uist	15	74	Uig - Tarbert - Lochmaddy
Skye (M-L-A)	15	73	Mallaig - Lochboisdale - Armadale
Berneray	15	72	Leverburgh - Berneray
South Uist	15	70	Mallaig - Lochboisdale - Armadale
Mull	15	69	Oban - Craignure
Islay	14	60	Kennacraig - Port Askaig / Port Ellen
Arran	13	52	Ardrossan - Brodick

Next Phase – Proposed Scope of Works

- Detailed feasibility phase:
  - Island(s) and ferry route(s) now selected
  - The Arnish community wind farm site is now earmarked as the power producer
  - CMAL have confirmed their interest in building a ship
  - CalMac have been contacted to secure their commitment as the hydrogen off-taker

- Pre-FEED:
  - Determine hydrogen demand and redundancy
  - Design and specify the chain of components for the green hydrogen system
  - Optimise the system to drive down the cost of green hydrogen (parity with LNG targeted)
  - Produce a business case
  - Undertake technical HSE activities

wood.

woodplc.com

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Hydrogen Projects Manager

European Marine Energy Centre

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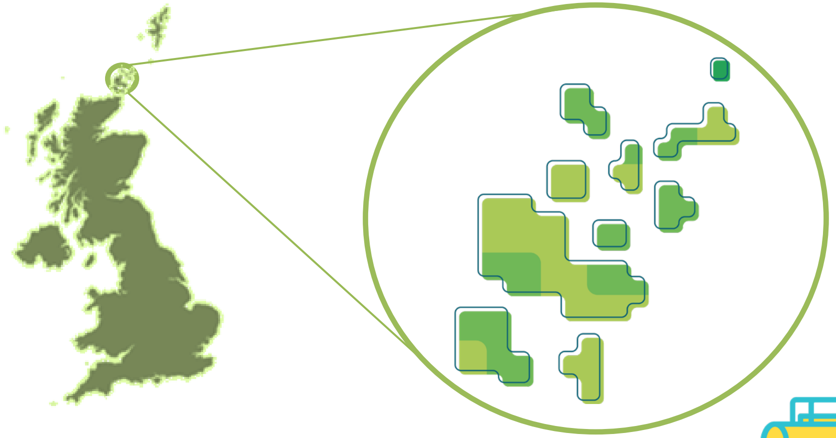
The Hydrogen Islands

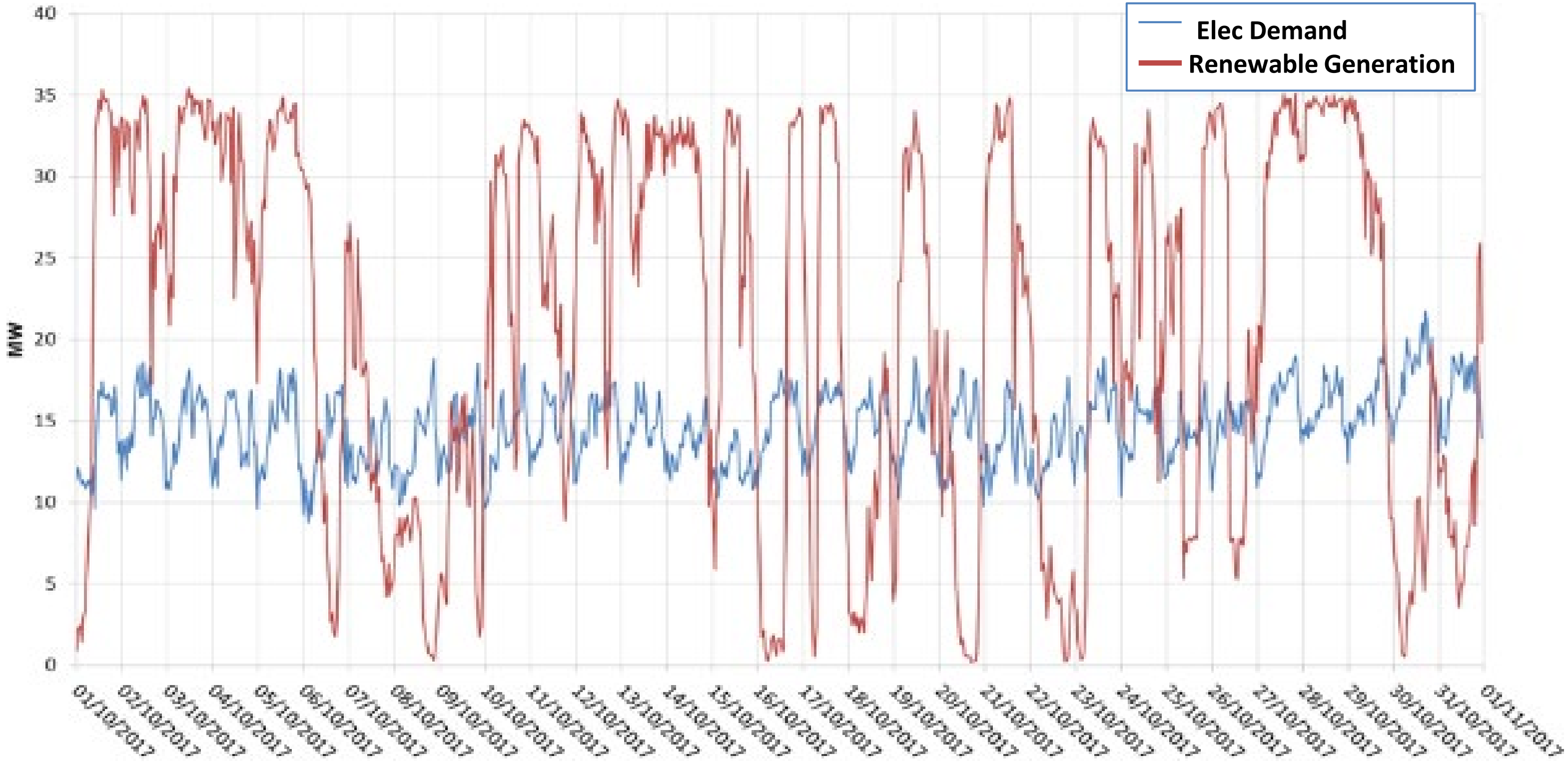
Adele Lidderdale
Hydrogen Project Manager

Orkney Energy

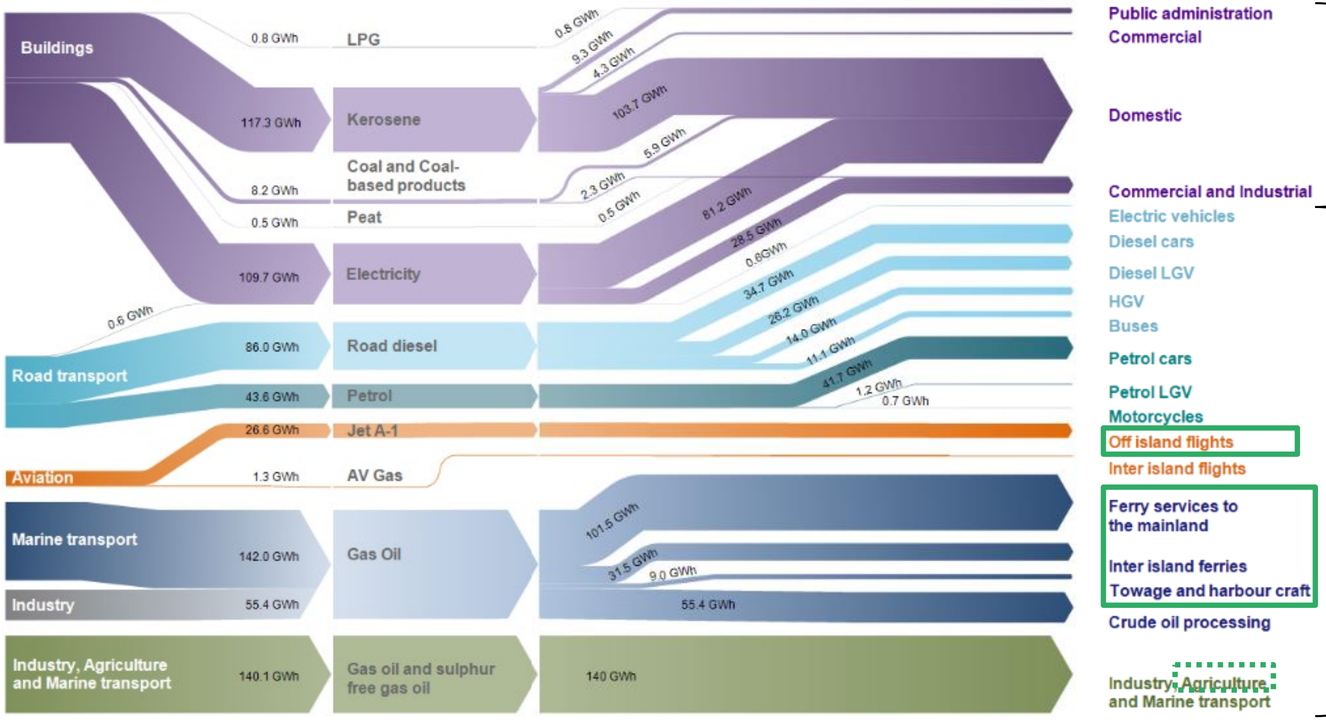


- 22,190 people
- 732 GWh Energy Use
- Net exporter since 2013
- Net Zero ambition

Electricity Profile



Energy Literacy

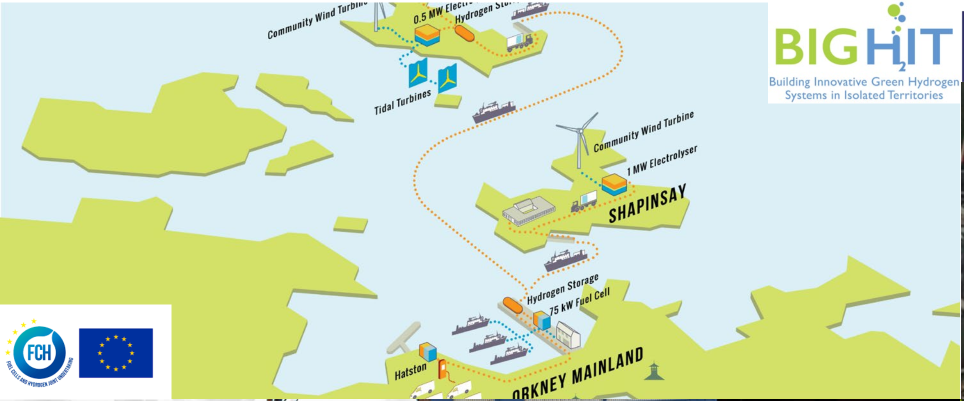


Heat & light

Transport (largely)

Projects

EMEC HYDROGEN



BIG HIT
Building Innovative Green Hydrogen Systems in Isolated Territories

Innovate UK

HyFLYER

Challenges

- Energy trilemma
- **Security**
- **Sustainability**
- **Affordability**
- People & skills
- Technology
- Data
- Infrastructure
- Orkney climate
- Interconnection
- Investment
- Time

Climate crisis: CO2 levels rise to highest point since evolution of humans

'We don't know a planet like this'

Harry Cockburn | Monday 13 May 2019 11:00 | 54 comments

Click to follow The Independent

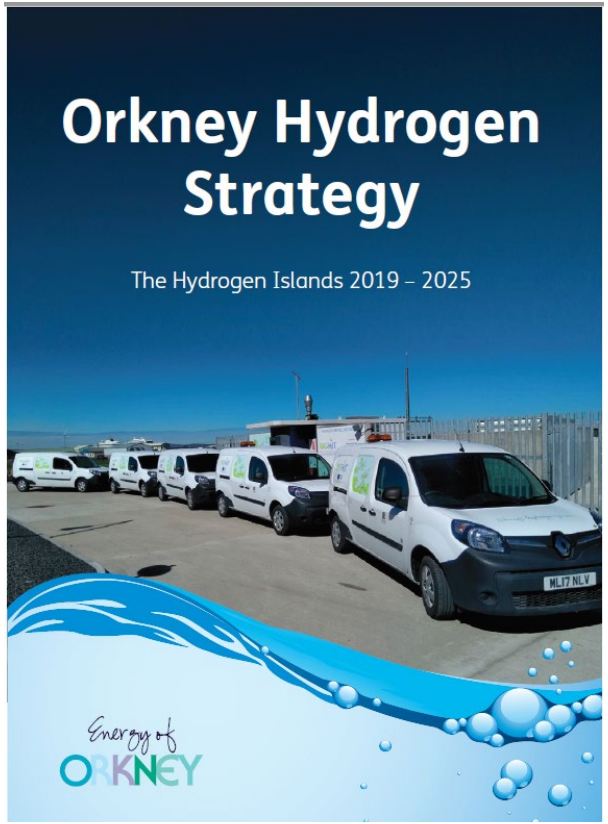
Burning fossil fuels remains the biggest producer of CO2 *(Getty)*

Key learning points

EMEC HYDROGEN

- Addressing the problem
- Regulatory Barriers
- Learning by doing
- Collaboration
- Proliferation
- Determination

Lloyd's Register
Maritime & Coastguard Agency
European Commission
Orkney Islands Council
UKRI Innovate UK
Ferguson Marine
ULEMCo
Community Energy Scotland
Intelligent Energy
ZeroAvia
Aerospace Technology Institute
Symbio FCell
Calvera
Foundation for the Development of New Hydrogen Technologies in Aragon
Scottish Hydrogen & Fuel Cell Association



Final thought

"If you don't like the news… go out and make some of your own."

– Wes Niskar, 1970




Thank you

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Rebecca Rosling

Head of Smart Customers

EDF Research & Development UK

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Modelling integration of wind farms and Electrolysers

Rebecca Rosling, Head of Smart Customers R&D, EDF

Scottish Renewables Hydrogen Seminar

10th December 2020

eDF R&D UK Centre

EDF IN THE UK

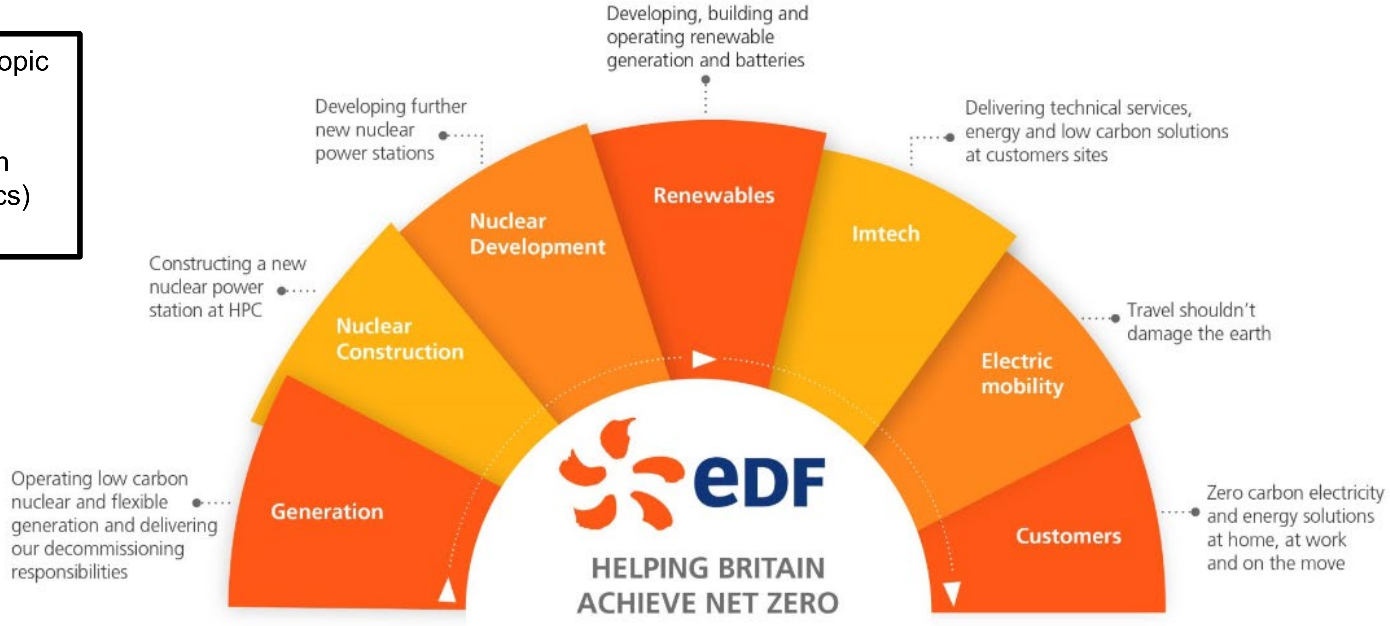
EDF is helping Britain achieve Net Zero by leading the transition to a cleaner, low emission electric future and tackling climate change.

It is the UK's largest producer of low-carbon electricity, meeting around one-fifth of the country's demand and supplying millions of customers with electricity and gas.

EDF in the UK

Hydrogen growing topic across EDF

Dedicated Hydrogen subsidiary (Hynamics) launched in 2019



HYDROGEN SUPPLY CHAIN: FROM PRODUCTION TO CONSUMPTION

hynamics
EDF GROUP

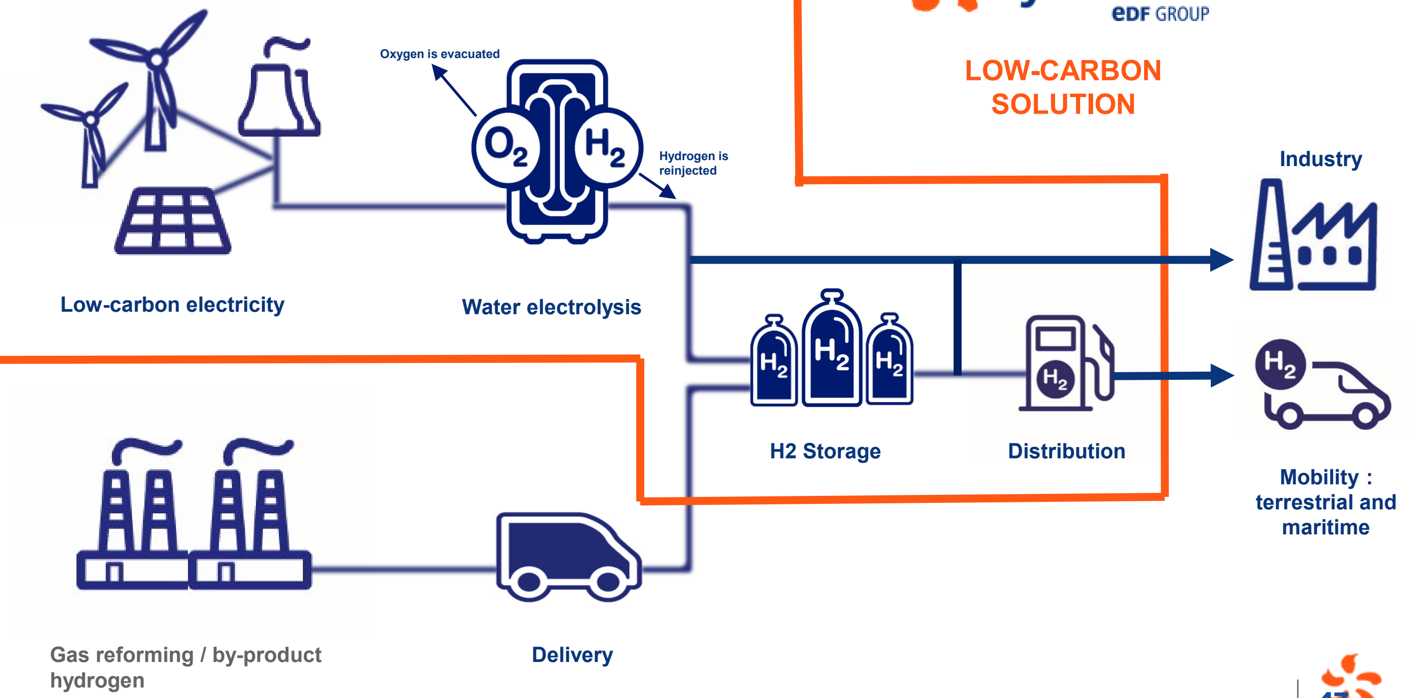
LOW-CARBON SOLUTION

Low-carbon and on-site production

- Production via water electrolysis
- No ongoing emissions

Carbon-based and centralised production

- Production based on steam methane reforming
- H2 Plant and truck delivery to the place of consumption.
- **1 kg of H2 produced ➔ 10 kg of CO2 emitted**



EDF ENERGY

R&D UK Centre at a glance

People

65 **Researchers**

90% with Master or PhD qualifications

15 Nationalities

10 Expats from group

14 PhD students

2 R&D Group experts

Organization

5 **Teams**

Nuclear

Renewables

Customers

Digital Innovation

Com & Bus Dev

4 **Locations**

5 **strategic Academic Partners**

Imperial College London

Manchester 1824

University of Bristol

University of Strathclyde

UCL

+15 academic partnerships

Funding

83% Contracts with EDF Business Units or EDF Group

17% External Grants, Contract R&D

2020 Budget

£7.5m

Governance

3 Directors from EDF UK Business Units

3 Directors from EDF Group (EDF R&D)

UKC Board

EDF ENERGY

Hy4Fleets – decarbonising HDVs

Hy4Fleets is a **6 month feasibility study project** funded by Innovate UK that will develop and test the value for an assessment tool to support decision making and encourage the transition of diesel-powered heavy duty vehicles (HDVs) to hydrogen fuel cell fleets.

Main Driver: Address the gap in ***technical*** and ***economic insights*** on the hydrogen switching process that presents a barrier to the uptake of hydrogen vehicles by fleet operators. Methodology and tool will be validated by the Sizewell C project as case study.

Project Objective: Development of an ***hydrogen switching assessment tool*** to evaluate the ***operational***, ***environmental*** and ***economic*** performance of hydrogen HDVs fleets (buses and trucks) in real-world settings. Building on EDF's EV Suitability Tool (CELEST).

Further validation of the hydrogen switching assessment tool will be conducted by **running a trial with a partner** that can provide fleet profile data as another use case

Hy4Fleets

Innovate UK

Catalysing Green Innovation: strand 2: Securing the future of ZEV

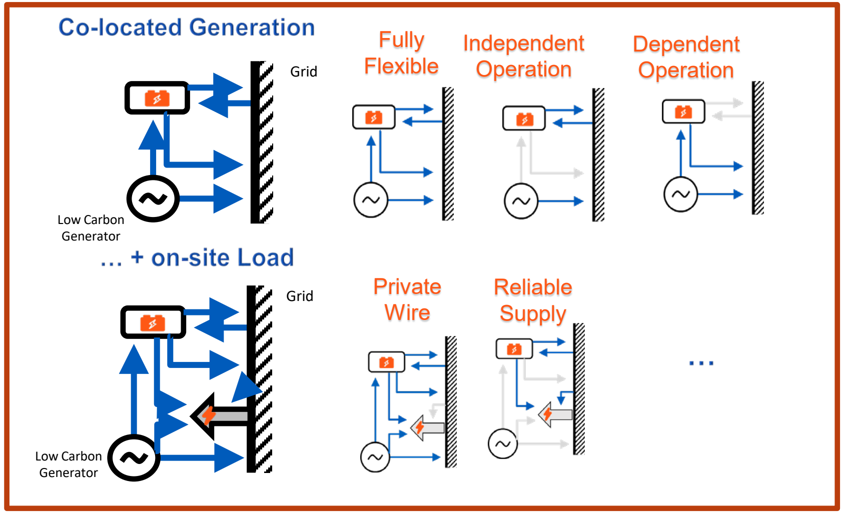
Project start date: *1st Oct. 2020*
Project end date: *31st March 2021*

EDF ENERGY

Integrating Hydrogen with Renewables and Batteries

Modelling overview

GEM Storage – Batteries and more…



EDF has developed a full modelling suite for energy storage and flexibility

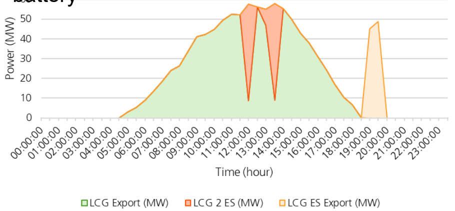
It simulates the operation of an assets through its lifetime taking into account multiple different markets

Used for both **investment appraisal** and **dispatch**

Can model different configurations of batteries, generation and load

Being expanded to support smart charging, V2G, Hydrogen…

"Dependent Operation" – solar panel plus battery



Day-Ahead (DA) Market Arbitrage

- Seize price arbitrage opportunities with ESS
- Schedule LCG exports at optimum market conditions

Intraday (ID) Market Arbitrage

- Seize price arbitrage opportunities with ESS
- Adjust forecast errors based on DA volumes

Balancing Mechanism (BM)

- Recover curtailed energy during network / system congestion
- Arbitrage between BM and other markets
- Adjust forecast errors based on DA and ID volumes

Frequency Response (FR)

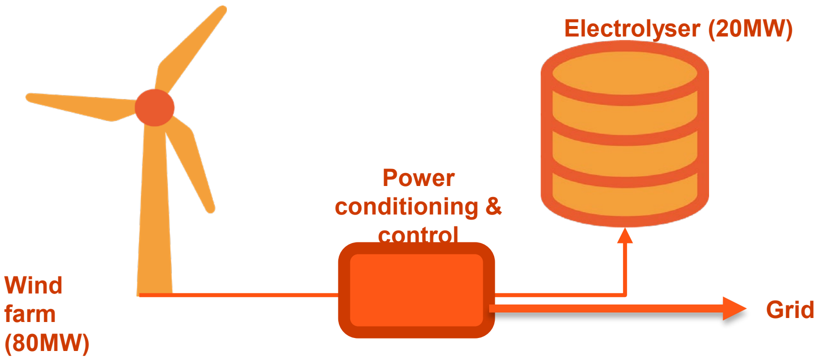
- Uninterrupted operation of LCG during provision of FR
- Modelled implicitly and not optimised

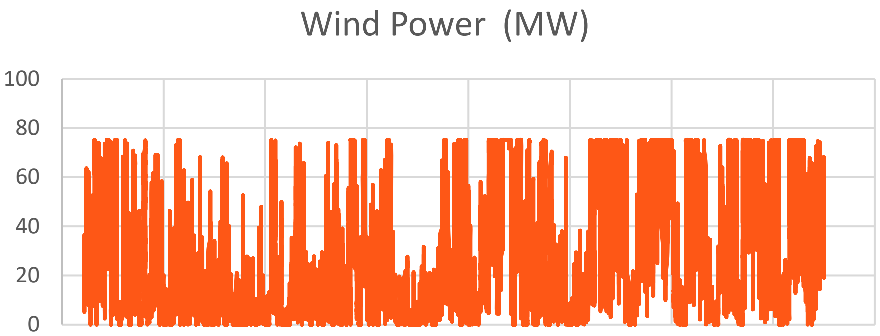
Optimization of Non-Energy Costs

- Reduction of charges associated with NECs with specific electrical configurations
- Option to include ROC

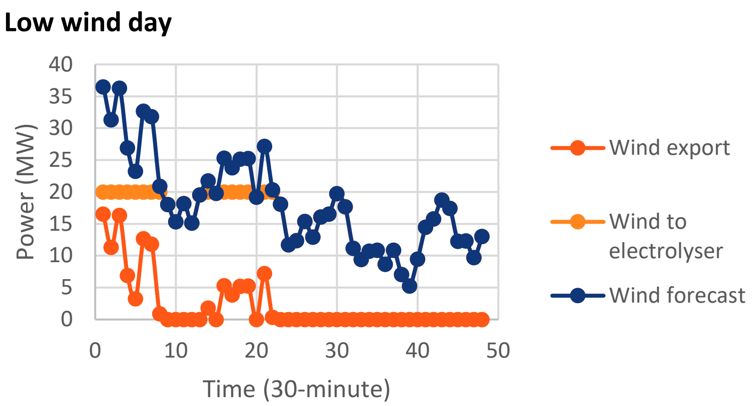
Integrating Hydrogen with a Wind Farm

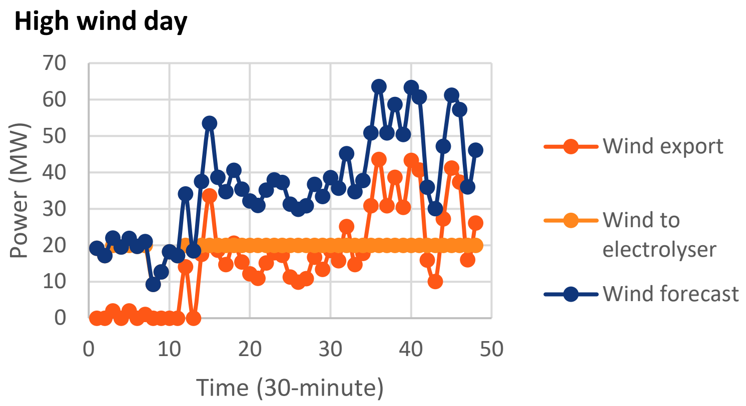
In 2020 we used this modelling capability to explore the impact of adding electrolysis capability to a wind farm





Results- Hydrogen @£213/MWh, fixed electricity price



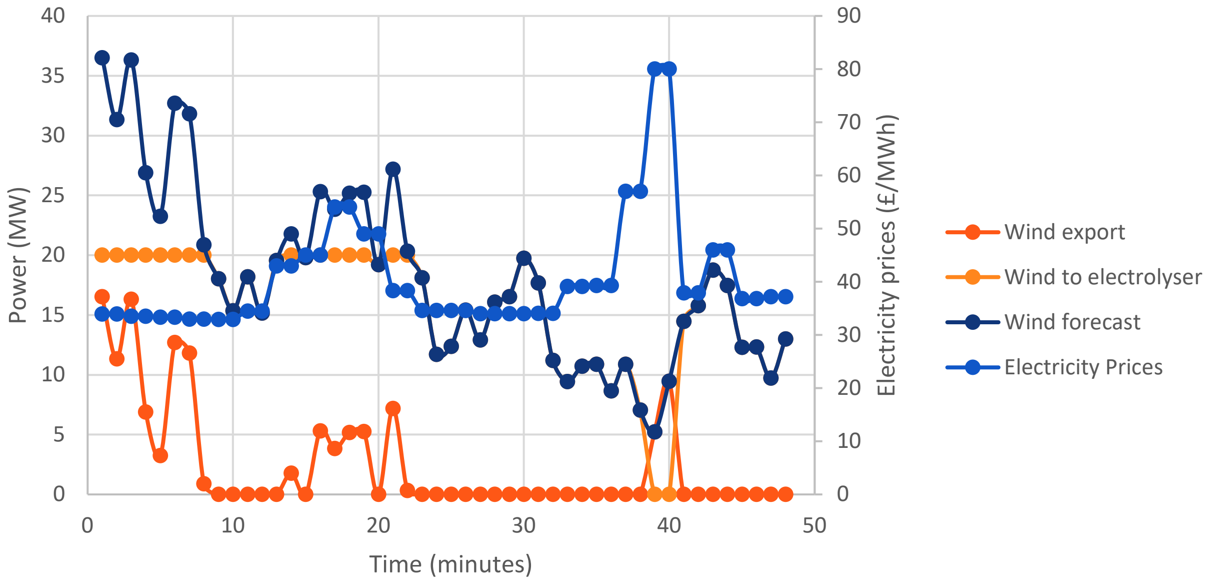


When wind power is above 20MW, i.e. above the maximum electrolyser capacity, power to the electrolyser is prioritised and the remaining wind power is exported to the grid.

When wind power is below 20MW, hydrogen production is prioritised and wind exports are zero.

Results – Hydrogen @£100/MWh, varying electricity prices

Low wind day

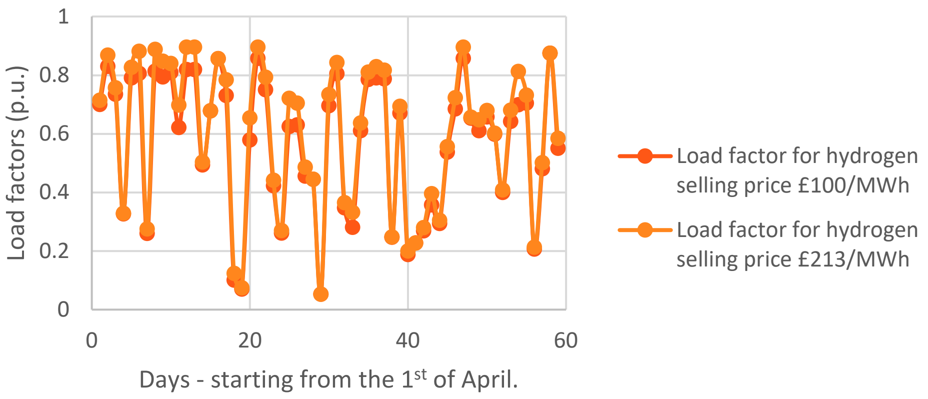


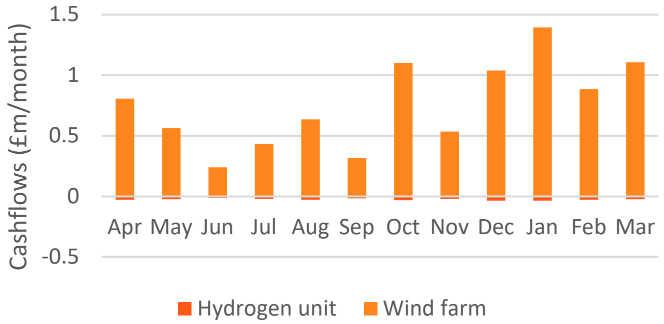
Compared to the previous case, the selling price for hydrogen has been selected as £100/MWh and the electricity price profile (£/MWh) has been added in the graph to illustrate the differences observed.

Because now, electricity prices during peak time are comparable to the hydrogen selling price, i.e. ~£80/MWh, during this period the available wind is exported to the grid and the power to the electrolyser goes to zero.

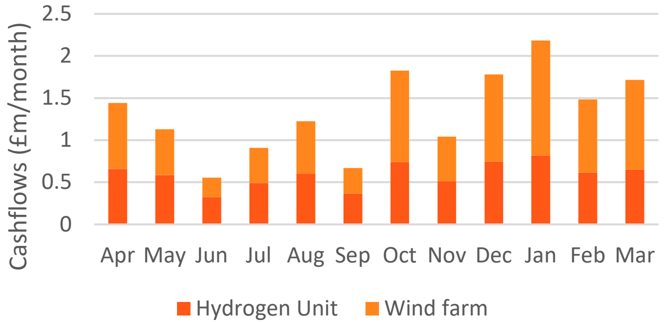
Wind farm and Electrolyser – Overall Results

Daily load factors:

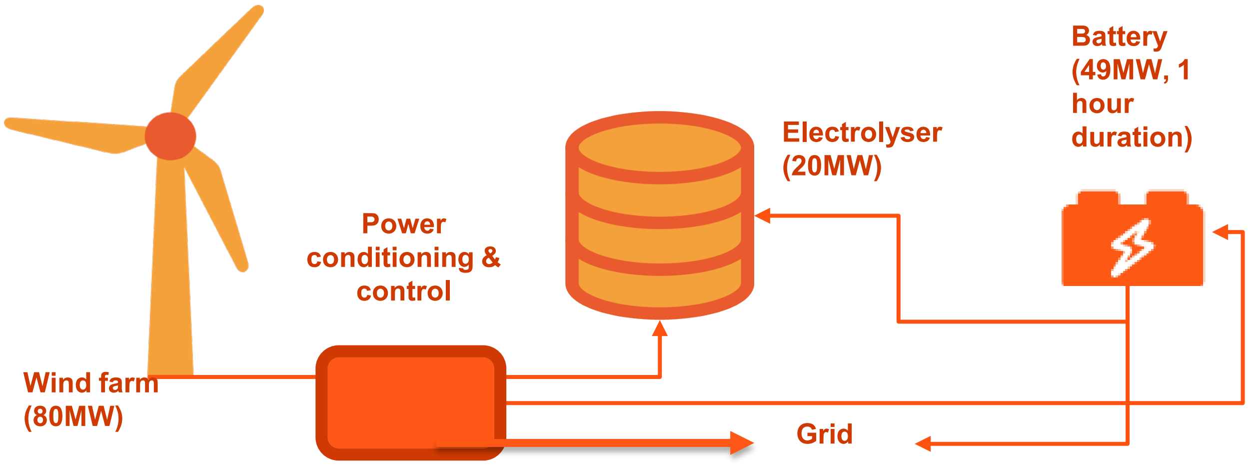




Business Case / Hydrogen selling price	Annual wind energy production (MWh)	% sent to the electrolyser	% sent to the grid	Electrolyser load factor
Business Case 1 / £100/MWh	230,000	45.96	54.04	54%
Business Case 1 / £213/MWh	230,000	48.59	51.41	57%



Integrating a Wind Farm, Electrolyser and a Battery

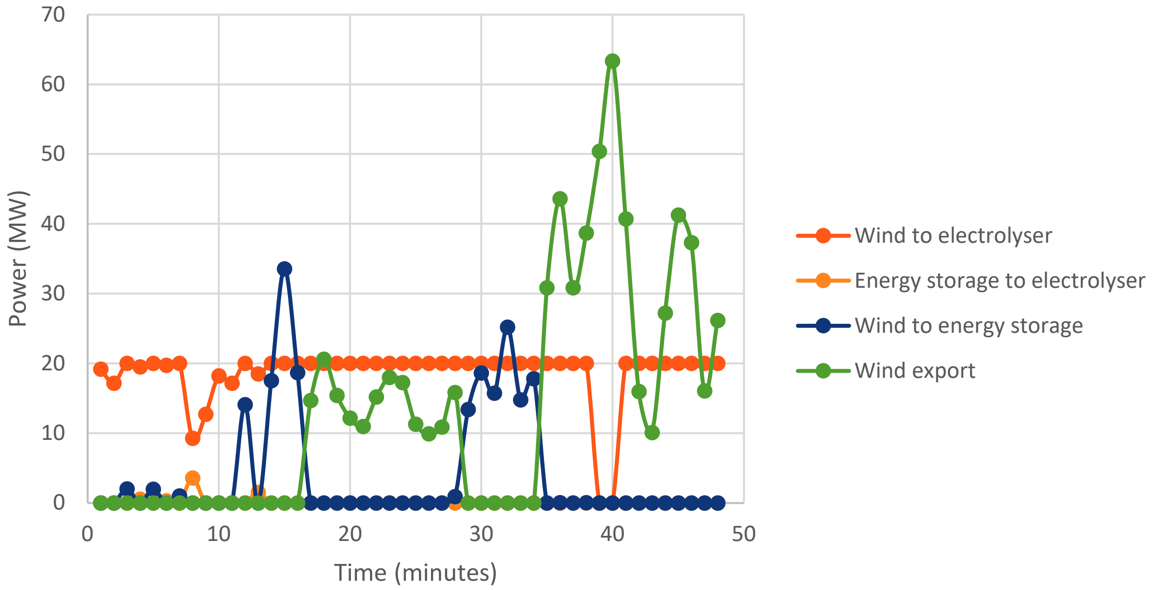


Questions to be examined:

Is wind surplus (wind above maximum electrolyser capacity) used to store energy to the energy storage unit or selling energy to the grid is prioritised?

Does wind deficit (wind below maximum electrolyser capacity) means the energy storage unit will prioritise giving energy to the electrolyser or sell it to the grid?

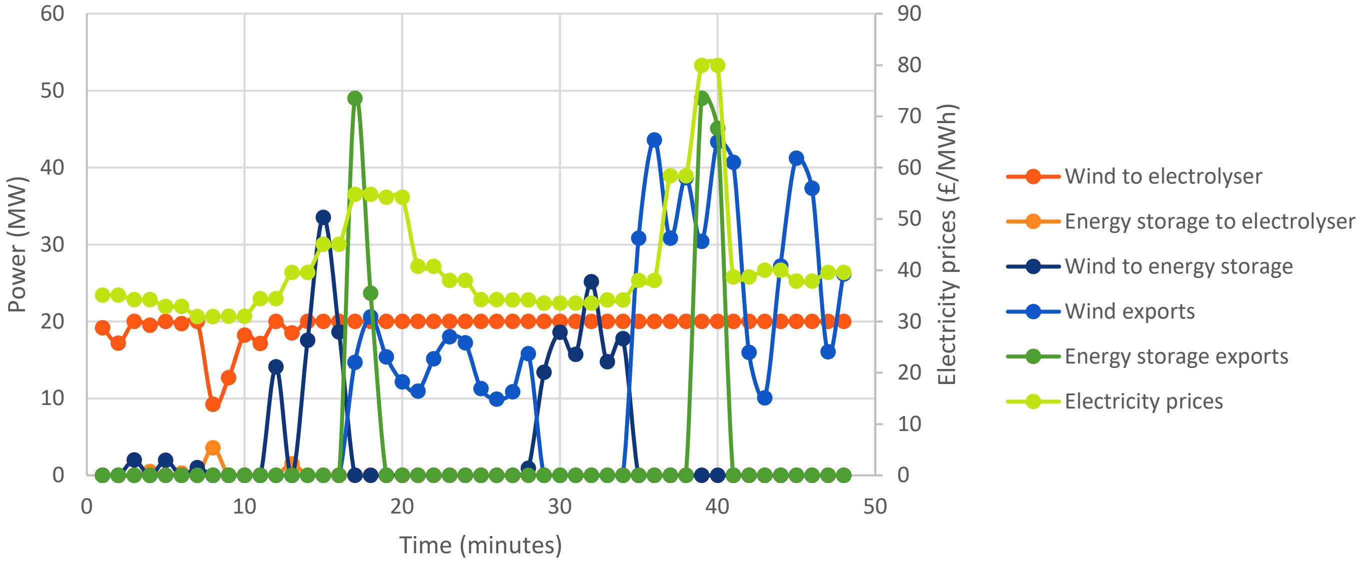
Results- Hydrogen @£100/MWh, high wind day



When wind power is above 20MW, power to electrolyser is prioritised and the remaining goes to the energy storage unit, as e.g. at HHs 28-35. The store is then full and discharges at HHs 39-40 when higher prices occur

When the hydrogen selling prices decreases significantly and becomes comparable with peak electricity prices, then wind export and energy storage discharge to the grid are prioritised, as in HHs 39-40.

Results- Hydrogen @£213/MWh, high wind day



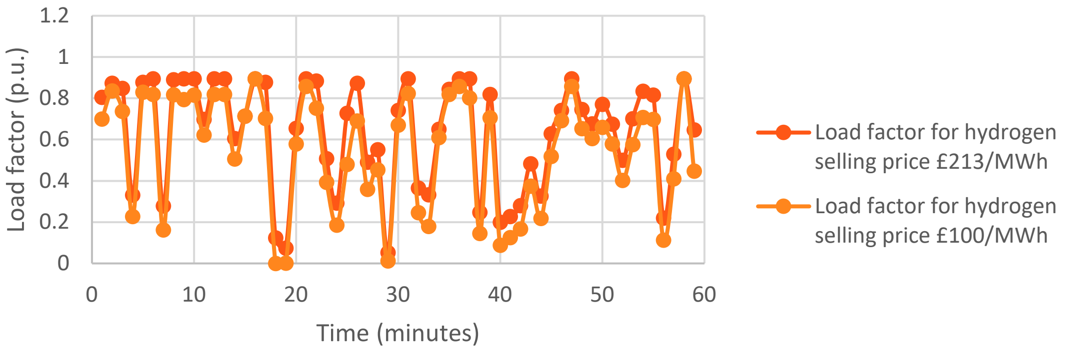
In periods of low prices (e.g. HHs 29-34), wind surplus goes to energy storage (if electrolyser needs are being met).

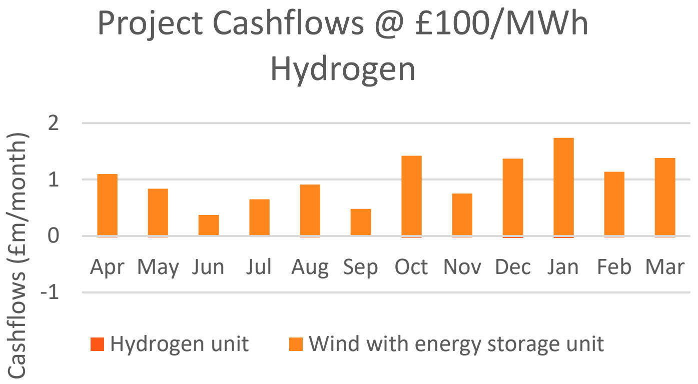
In periods of higher prices (e.g. HHs 17-18, 37-40), wind surplus goes to the grid (if electrolyser needs are being met), and energy storage also exports (if not empty).

High Hydrogen price means electrolyser needs prioritised all the time.

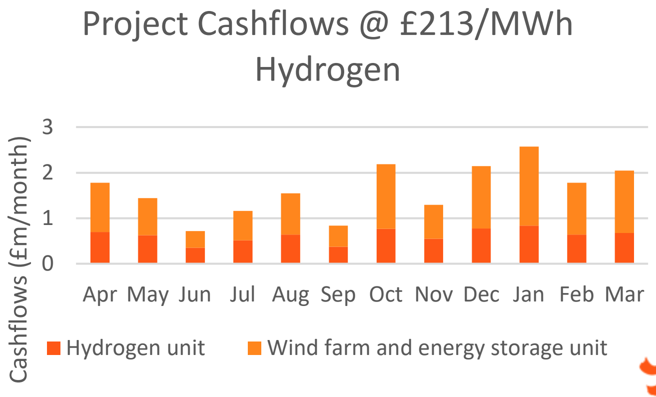
Business Case 2: Results

Daily load factors:





Business Case / Hydrogen selling price	Annual wind energy production (MWh)	% sent to the electrolyser	% sent to the grid	% sent to the energy storage unit	Electrolyser load factor
Business Case 2 / £100/MWh	230,000	44.20	44.5	11.30	53%
Business Case 2 / £213/MWh	230,000	48.36	41.92	9.72	59%



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Rob Duncalf

Head of UK, US & Strategic Projects, Hydrogen

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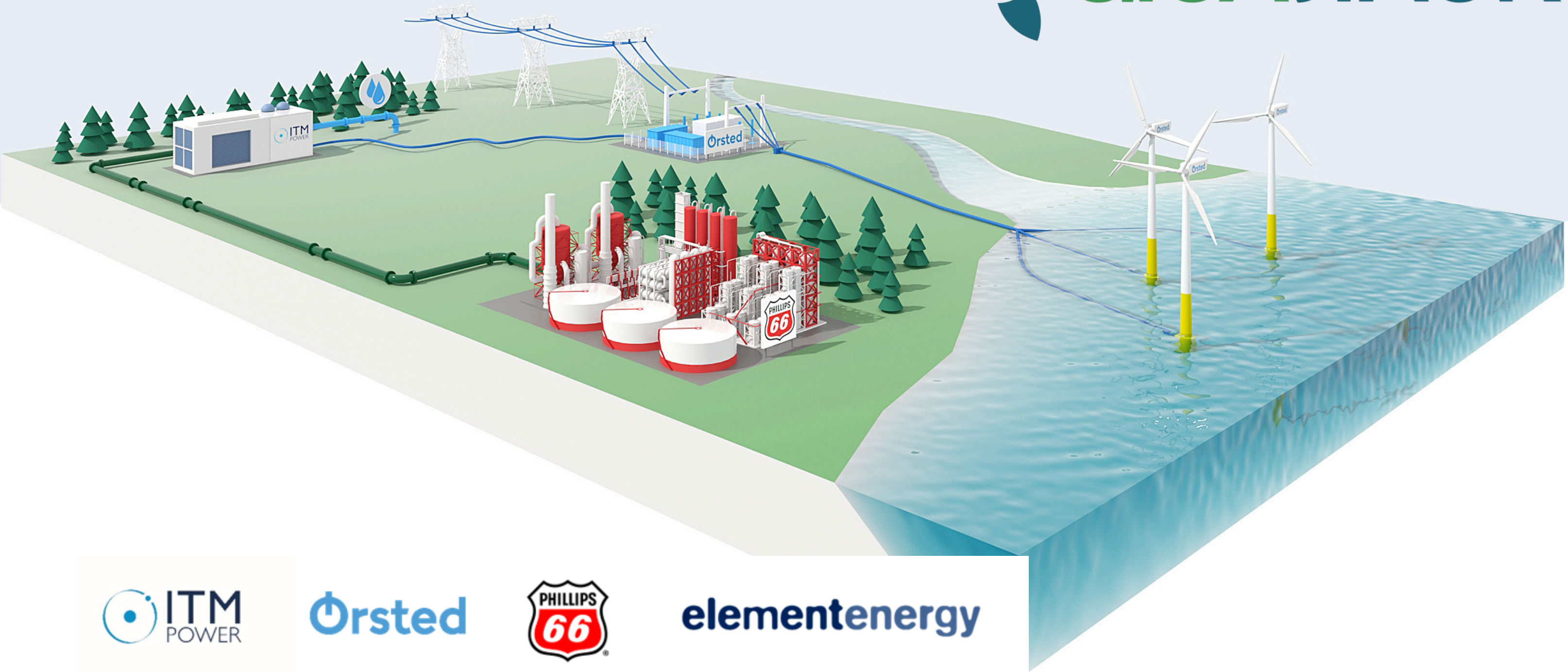
GIGASTACK



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Renewable hydrogen buildout timeline

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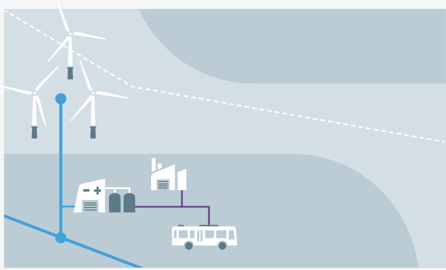
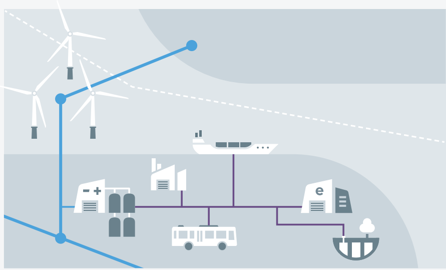
2020-2025
Co-located projects



Develop renewable hydrogen to replace fossil hydrogen

- **Gigastack feasibility study**
- **Yara Green Ammonia Project**
- **Lingen Refinery**
- 1-1 link with refineries, marine transport fuel, chemical plants

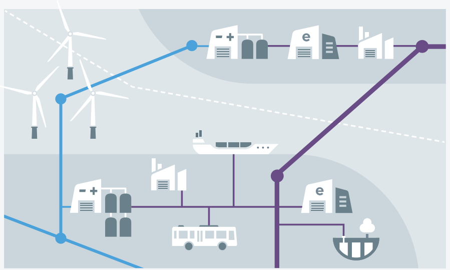
2025-2030
Hydrogen clusters



Optimise use of infrastructure, add storage

- **Green Fuel for Denmark**
- **Westküste 100**
- ❖ Hub at Grangemouth
  ❖ Hub linking airports and marine transport ports
  ❖ Fertiliser production

2030-2040
Integrated hydrogen grid



A transnational hydrogen grid and market

- ❖ Integrated hydrogen network?
  ❖ Exports?
  ❖ Aviation and marine fuel hub?

We see many similarities between our offshore wind journey and the required cost-out journey for hydrogen towards 2030

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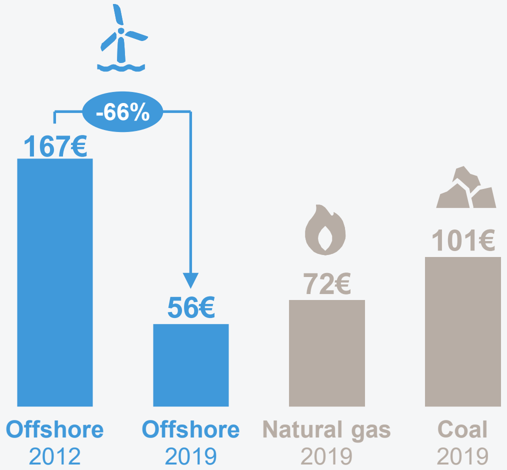
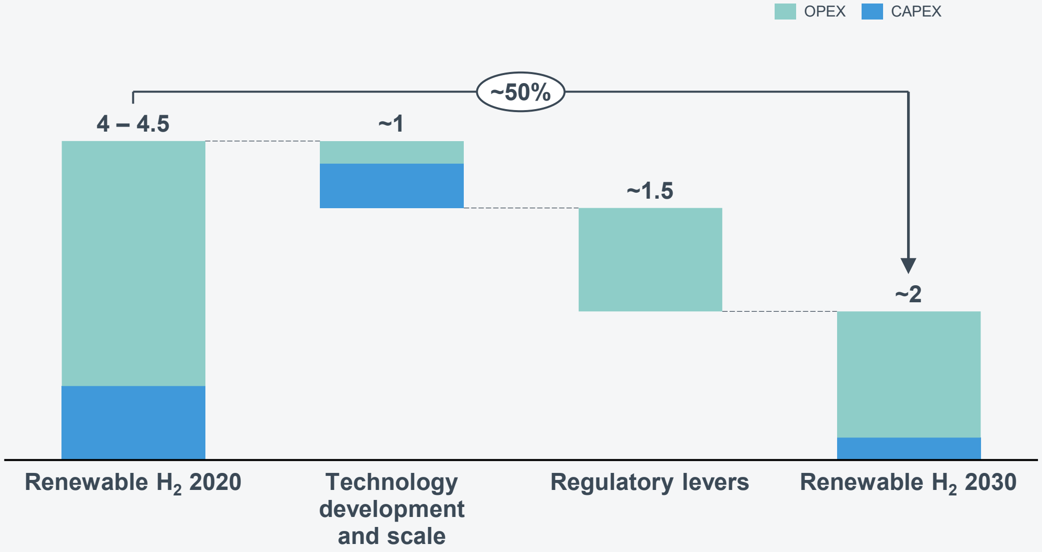
Levelised cost of electricity[1]

EUR/MWh, 2012[2] and 2019[3]



Renewable hydrogen cost-out: Denmark[1]

Levelised cost of hydrogen, EUR/kg



Calculations based on consistent sets of power, natural gas and CO_2 prices

Source: Ørsted and IEA, BNEF and Hydrogen Europe

1 BNEF H1 2019 LCOE Update, current LCOE and Ørsted Calculation. 2 2012 generic offshore wind, Northwest Europe, FID 2012. 3 Offshore wind 2019: Ørsted calculations from UK CfD Round III. Onshore wind: average of DE, NL and UK mid-scenarios. Solar PV, Gas: average of DE, UK mid-scenarios. Coal: DE mid-scenario. Nuclear: UK mid-scenario. Exchange rate EUR:USD: 0.89, YoY inflation 2017-2018: 1.75%

Ørsted's hydrogen vision

With the right framework and timely investments, we believe renewable hydrogen can be cost-competitive by 2030. But the cost-out journey must be started today, as developing renewable hydrogen and e-fuels are critical to keep global temperature increase below 1.5°C by end-century.

https://orsted.com/en/about-us/whitepapers/decarbonising-society-with-power-to-x

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