CARBON TRUST

GREENTECH AND SHIPPING FORUM

Renewable Energy Integration and Future Fuel Production

19 APRIL 2023

1. Introduction to Carbon Trust
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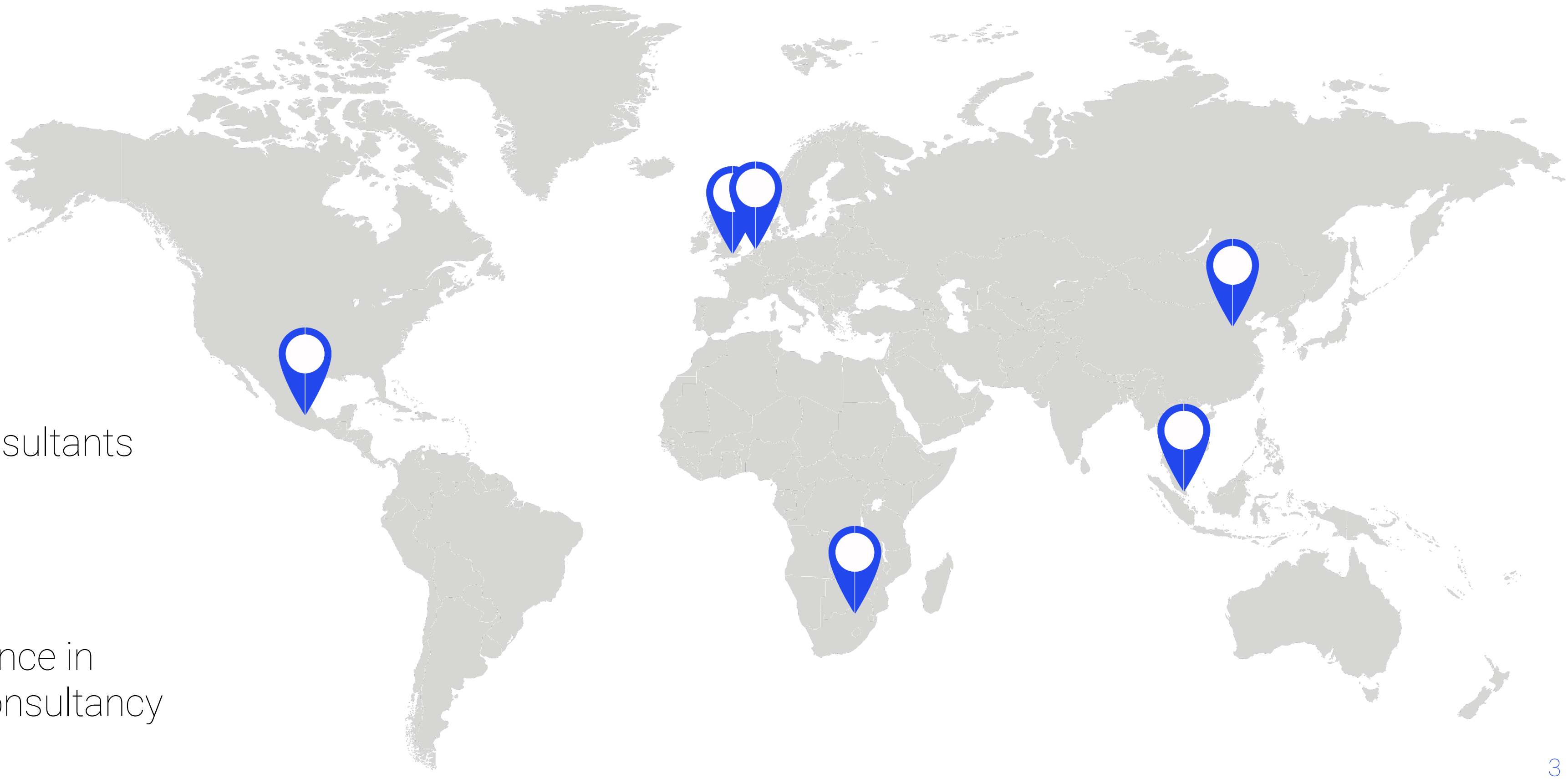
3. Future Fuel Production
4. Key Discussion Points

Our mission is to accelerate the move to a decarbonised future.

5
continents

450+
experts and consultants

20
years of experience in sustainability consultancy



We are pioneers in designing and deploying high impact climate tech accelerator initiatives around the world

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Offshore Wind and Energy Programmes

- £100 million invested
- 15% levelized cost of energy reduction
- £34 billion overall savings generated
- 150+ innovation projects supported

Transforming Energy Access

- Research and innovation platform supporting early-stage testing and scale-up of innovative technologies and business models that accelerate access to affordable, clean, and modern energy in developing countries

Zero Emission Generators (ZE-Gen)

- Aimed at creating viable alternatives to the use of fossil fuelled generators across developing countries
- Launched at COP 27 with an initial commitment of over £15 million

Coal Asset Transition Accelerator

- First-of-its-kind platform focused on leveraging finance to accelerate the coal transition globally
- Launched at COP26 and scaling up implementation activities

VentureBuilder

- New blended fund backed by Facebook, Shell Foundation, DOEN Foundation, FCDO, and USAID to scale household solar through African-owned distributors in hard to reach countries

Clean Hydrogen Innovation Programme

- Speed up the deployment of clean hydrogen through technical innovation to drive down end-to-end cost and help make clean hydrogen cost competitive with conventional alternatives

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World leading offshore wind programmes

The Offshore Wind Accelerator (OWA)

Carbon Trust's flagship collaborative RD&D programme for bottom-fixed offshore wind.

The Floating Wind JIP (FLW JIP)

The Floating Wind JIP Overcomes challenges and advance opportunities for commercial scale floating wind

The Offshore Renewables JIP (ORJIP)

orjip – working to accelerate offshore consenting

Offshore Renewables JIP aims to reduce consenting and environmental risks for offshore projects.

The Integrator

The Integrator is designed to examine the interplay between offshore wind, existing infrastructure, and other technologies to highlight opportunities for innovation investment.

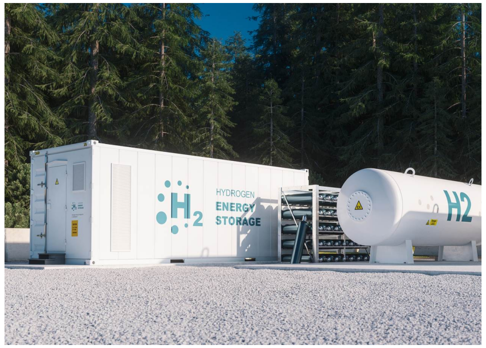
Sustainability JIP (SUS JIP)

The Sustainability JIP mission is to decarbonise future fixed and floating offshore wind farms, to support the transition to a net-zero OSW industry.

Partners we work with:

- Scottish Government / Riaghaltas na h-Alba / gov.scot
- EDF renouvelables
- EnBW
- Ørsted
- TotalEnergies
- VATTENFALL
- Kyuden Mirai Energy
- SCOTTISHPOWER RENEWABLES
- TEPCO
- PARKWIND
- equinor
- sse Renewables
- RWE
- Shell
- skyborn
- OW Ocean Winds
- bp
- SDIC Red Rock Power Limited
- marine scotland
- Fred. Olsen Seawind
- Tohoku Electric Power Co., Inc.
- Crown Estate Scotland / Oighreachd a' Chrùin Alba
- The Crown Estate
- Department for Business, Energy & Industrial Strategy

Spotlight: The Integrator



Hydrogen Production from Offshore Wind

Identifying the key factors affecting the cost of hydrogen production configurations

- **Background:** Hydrogen may be produced offshore at the turbine or a central hub level, or onshore

- **Objective**: To gather detailed data on hydrogen production technology components and to build a cost model to compare different configurations and the key factors which determine their cost

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Roadmap: Power to X

Moving away from 'connect and manage' principles will require policy, regulatory and technical changes to grid management

- **Background**: to deliver sufficient clean energy, offshore wind needs to make better use of its connections to the energy system

- **Objective:** To determine the realities and practicalities of integration of 'Power to X' technologies from the windfarm perspective.

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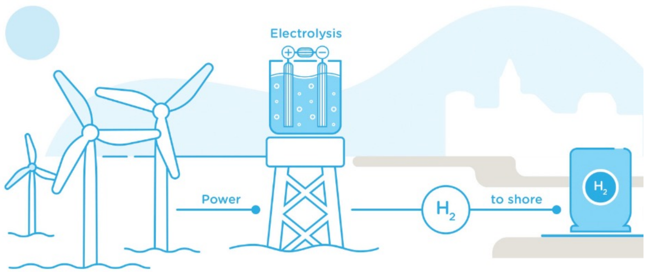
Renewable Energy Integration

Renewable energy overview

- In 2021 global renewable energy production was 8,300 TWh, a 7% increase on 2020 production levels
- Importantly, the share of renewable energy as part of global energy generation peaked at 28.7%
- Recently geo-political events, namely the invasion of Ukraine has demonstrated the need for robust energy security strategy, but also exposed the dependence most countries still have on oil and gas to meet energy demands
- The UK installed 3.19 GW of offshore wind in 2022, taking the current installed capacity to 12.7 GW
- Prices have been steadily falling and are now below conventional production sources (e.g. gas and nuclear) with peak production in 2022 at 87%

Values courtesy of IEA

Spotlight: Hydrogen production from offshore wind

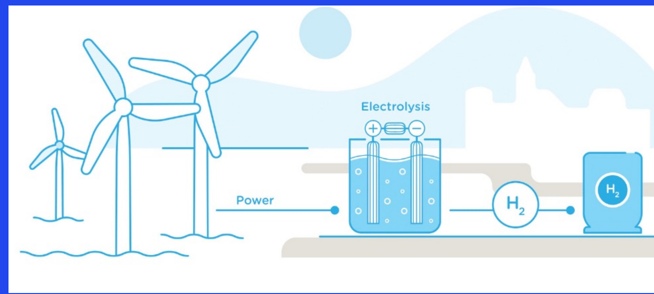


Offshore Production:

Fixed or floating offshore wind platforms with integrated electrolysis systems offshore (either per turbine or centralised)

- Hydrogen is transported via pipeline to areas of demand or stored for future use (onshore or offshore)
- Potential to reuse / repower current offshore infrastructure, such as oil and gas platforms and pipelines / pipeline corridors
- Offshore asset is however limited to one energy vector (H2). Operation and maintenance throughout lifetime more complex

Images courtesy of Ramboll



Onshore production:

Offshore wind farm (or other renewable energy asset) supplies onshore electrolysis system

- Electricity demand can be balanced by other sources, providing a more harmonious supply (preferential for electrolysers)
- Current electrolysers are limited to 5 MW, so onshore systems will need to be 'stacked'
- Generation asses not limited to one energy vector (surplus electricity can be diverted elsewhere). Operation and maintenance less complex

Hydrogen: everyone wants it!

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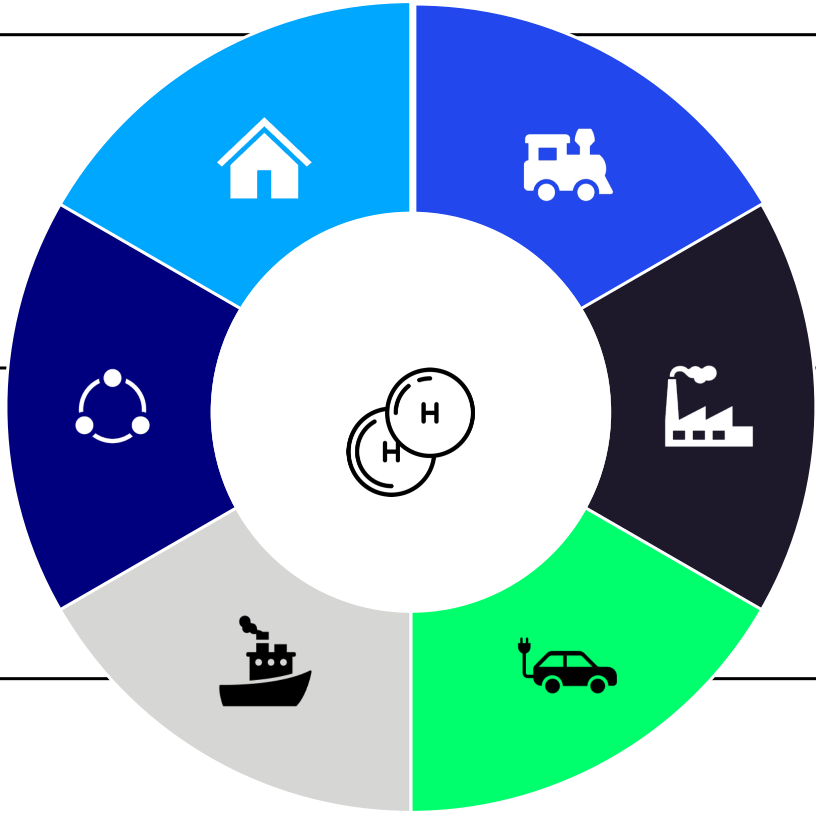
Home heating
Displacing the current domestic gas network with hydrogen is an option to decarbonise domestic heating

Current Hydrogen demand
Global hydrogen production already stands at around 75 MtH2 a year (IRENA)

Shipping
It is anticipated future low and zero carbon shipping fuels will be renewable hydrogen derived



Rail / freight
Although some lines are already electrified, hard to abate routes may look to hydrogen as an alternative

Commercial / industry
Current activities (such as steel production) rely on fossil fuels (coal, gas etc…) and have very high energy demands

Domestic transport
Although battery eclectic vehicles lead, hydrogen fuel cell vehicles are still being developed

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Future Fuel Production

Future maritime fuels outlook

- At present, the global maritime fuel demand is in the region of 330 million metrics tonnes (or 87 billion gallons)
- To meet current demand using renewable sources would require 3,000 TWh of electricity – this is equivalent to the worlds current renewable energy production (ICS)
- Shipping will have to compete with the demand for renewable energy once other sectors outside electricity generation look to decarbonise
- There are however opportunities for region with energy demands below their generation potential, for example:
    - Ireland has an annual electricity consumption of 27 TWh GW but an achievable offshore wind capacity of between 258 TWh and 613 TWh

International Chamber of Shipping 'Fuelling the Fourth Propulsion Revolution'

Project Spotlight: electrofuel production

Liquid Wind - eMethanol production

Biogenic carbon dioxide is captured and combined with renewable hydrogen to generate green electrofuel:

- Initial project 'FlagshipONE' being pioneered by Danish energy company Orsted
- The plant will be operational in 2025 and will produce 50,000 tonnes of e-fuel per year.
- Adjacent a port facility with access to storage and offloading of liquid fuels for ships
- A standard e-fuel facility could produce up to 100,000 tons of green electrofuel and upcycle 150,000 tons of carbon dioxide per year

https://www.liquidwind.se/

H2Carrier - eAmmonia production

Industrial scale floating green hydrogen and ammonia facility:

- Capacity in the range 100 000 - 230 000 tonnes of green ammonia (eAmmonia) per year using a converted very large gas carrier (VLGC)
- With a new build vessel, production can be scaled up to 1GW renewable power capacity

https://www.h2carrier.com/

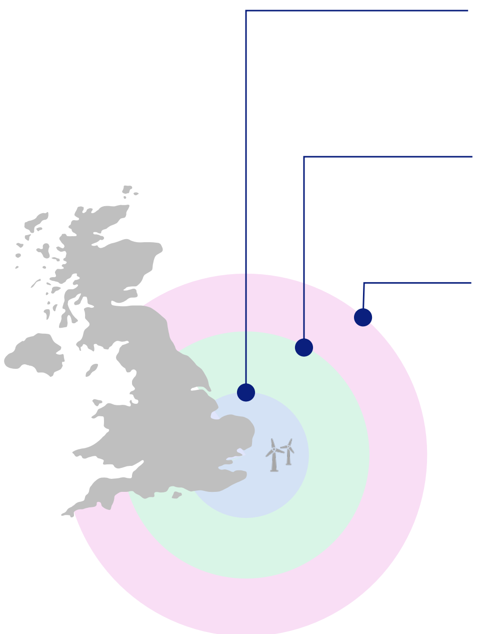
Momentum behind electro-fuels is building

https://www.irishexaminer.com/business/companies/arid-40907663.html

https://stateofgreen.com/en/news/denmark-and-germany-to-build-green-hydrogen-pipeline-by-2028/

https://www.h2bulletin.com/australia-partners-with-singapore-on-hydrogen-in-the-maritime-sector/

Comparison of future fuels



	Operability	Energy Density	Conversion Loss
Electricity	• Inter-port / wind farm • Ferry routes (short) • Short sea (short)	1.15 MJ/L (converted)	-
Hydrogen	• Inter-port / wind farm • Short sea • Ferry routes	9.55 MJ/L (liquid)	~20 - 30% (via electrolysis)
Ammonia	• Short sea (long) • Deep sea • Ferry routes (long)	12.8 MJ/L (liquid)	~40% (via Haber Bosch process)
Methanol	• Inter-port / wind farm • Short sea • Deep sea	16.05 MJ/L	~50% (requires sequestered carbon to be fully zero emission)

** Values are indicative to demonstrate relationship between density (range) and Conversion loss (efficiency)**

Values courtesy of statista.com

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Key Discussion Points

Key Discussion Points

1. The current energy market is fragile, and venerable to external factors but there is plenty of opportunity for renewable energy
2. Future fuels will be renewable energy-derived and likely use hydrogen as a vector
3. It is unlikely one future fuel will replace current maritime fuels
4. There are numerous options for the production of future maritime fuels
5. There is a balance between energy density and conversion loss for future fuels

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END

Thanks for listening

The Carbon Trust is a company limited by guarantee and registered in England and Wales under company number 04190230 with its registered office at Level 5, Arbor, 255 Blackfriars Road, London SE1 9AX, UK.