An Introduction to Hydrogen

This document introduces the basics of hydrogen production. It explains water electrolysis, technologies, future costs, supply chains and potential opportunities. Prepared by EirWind to provide a simple explanation of hydrogen to inform renewable policy debate in Ireland.

EirWind:

Co-designing opportunities towards the development of Irish offshore wind

MaREI Centre for Marine and Renewable Energy

UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh

Environmental Research Institute

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Why Hydrogen?

Hydrogen can provide an alternative energy vector to the conventional vectors of electricity, gas and solid fuel and can supply the electricity, transport and heat markets. It can also provide the necessary large-scale energy storage for renewable energy production, particularly wind energy, both onshore and offshore, in order to enable more efficient energy system management and provide greater security of supply. In addition, when hydrogen is used as a fuel, the only by-product is water vapour and when derived from wind and solar it is a zero carbon energy source in all applications. By integrating the appropriate hydrogen technology into the Irish energy system the amount of renewable energy harnessed from indigenous resources can be expanded to provide emissions free energy on an unprecedented scale.

Hydrogen Production

There are numerous ways to produce hydrogen (**Fig. 1**). 95% of the world's hydrogen is produced from fossil fuels via steam reforming and gasification but the resulting CO_2 must be sequestered to achieve 'zero emissions'. In contrast, hydrogen can be produced with a zero carbon footprint by using electrolysis driven by renewable electricity.

Coupling electrolysis with renewable energy e.g. offshore wind, in a **power-to-gas** system provides additional grid balancing benefits by providing a controllable load. This can help manage power fluctuations thus alleviating the characteristics related to the wind variability.

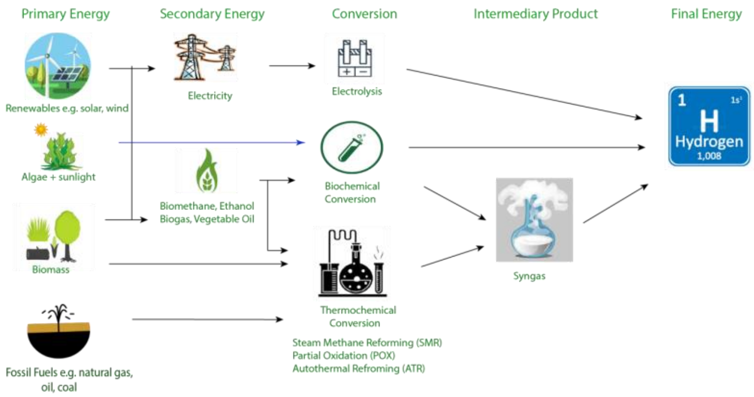

Fig. 1 Typical methods for hydrogen production

Water Electrolysis

Electrolysis is an electrochemical process that splits water into its constituents – hydrogen and oxygen. An electrical current is driven through the water causing a chemical reaction. As a result, hydrogen is collected on the cathode side (-) and oxygen on the anode side (+).

Overall reaction: $$H_2O \rightarrow \frac{1}{2}O_2 + H_2$$

Cathode: $$2H_2O \rightarrow 2H^+ + 2OH^-$$

Anode: $$H_2O \rightarrow \frac{1}{2}O_2 + H_2$$

There are three types of electrolyser technology: **alkaline**, **polymer electrolyte (PEM)**, and **solid oxide (Fig. 2)**. The first two are commercially available, with alkaline electrolyser the most common, due to low cost. PEM electrolyser is more durable and flexible, and better suited for intermittent power sources.

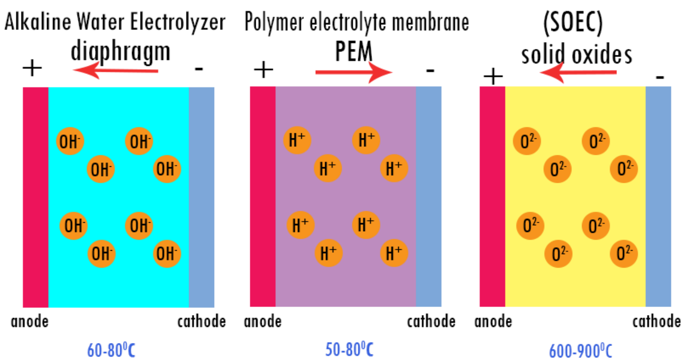

Fig. 2 Schematic illustrations of water electrolysis technologies (adapted from Xiang et al. 2016)

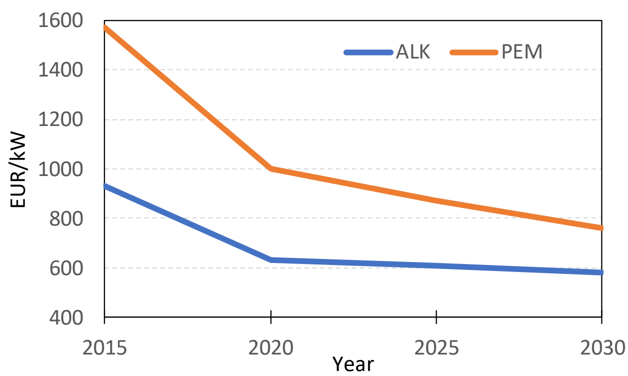

Fig. 3 System costs for electrolysers

Electrolyser prices are predicted to decrease, as depicted in **Fig. 3**, allowing for easy and more cost-effective integration of power-to-gas systems with wind energy systems.

Hydrogen Supply Chain & Potential Opportunities

Table 1 Components of a hydrogen energy chain and key technologies involved (adapted from PURE Energy Centre)

Primary energy source	Primary energy transmission	Hydrogen Generation	Hydrogen Infrastructure		End-use	Potential Market Applications
Natural gas, coal, oil fired power plant	Electricity Transmission	Electrolyser	Compressed Gas	Delivery by truck (gas & solid state)	Fuel cell	Transport
Nuclear power			Liquefaction & liquid storage	Hydrogen pipeline (gas)	Combustion engine	Stationary Power
Renewable Electricity						
Natural gas, biogas	Gas grid, pipeline	Steam reformation	Solid state Storage	Tanker Truck, barge (Liq.)	Hydrogen Turbine	Portable Power
Coal	Delivery truck	Gasification			Boiler	Heating Demands
Biomass	Delivery truck				Catalytic Converter	Cooking/niche applications

Evaluating the hydrogen energy chain provides a breakdown of the key technologies involved at each stage of the value chain including its market applications (**Table 1**).

Hydrogen: New and Future Energy Markets for Ireland

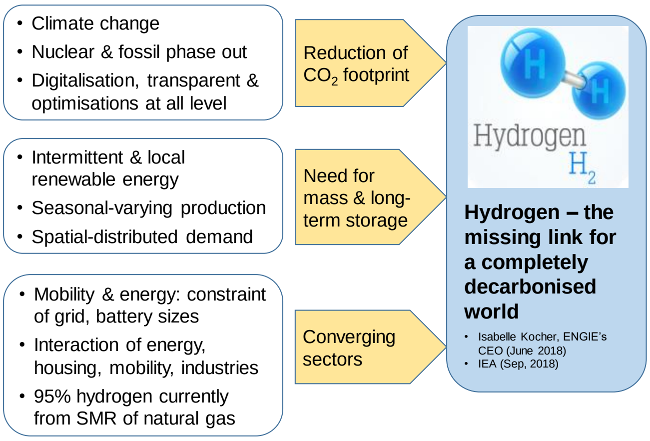

Fig. 4 New and future markets for hydrogen

Hydrogen is the missing link for a completely decarbonised world (an EirWind industry partner)

Energy consumption in the heating and cooling sector and in the transport sector in Ireland, forms 38% and 37% of the country's total, respectively. Hydrogen from offshore wind can help decarbonise these sectors by replacing fossil fuels.

Energy security is a key issue in Ireland. Half of the country's electricity is generated from natural gas but 40-50% of gas supplies are currently imported from the UK. The remaining productive life of the Corrib gas field is just 10 years. Hydrogen can be produced locally from offshore wind generation in Irish waters to replace these fuels.

Key Messages

Offshore power-to-hydrogen is a highly promising solution in Ireland to address several challenges

- Managing the variability of wind & renewable energy resources
- Providing short-term services to keep the electricity grid running stably
- Providing energy storage to help meet electricity demand peaks
- Helping to decarbonise the transport and heating sectors and conventional industrial hydrogen production by replacing fossil fuels

The Eirwind team is researching costs and various benefits of hydrogen production from offshore wind (**Fig 5**).

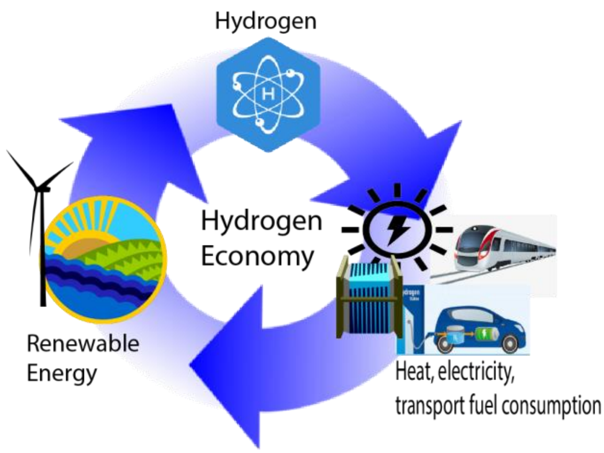

Fig. 5 EirWind research approach

EirWind

Co-designing opportunities towards the development of Irish offshore wind

EirWind is an industry-led collaborative research project, co-designing opportunities for the sustainable development of Ireland's marine resources by using offshore wind as a catalyst for innovation. It utilises the concepts of Marine Spatial Planning (MSP) where relevant, including advanced data-analysis, strategic planning, Irish marine and renewable energy policy initiatives and stakeholder management. Research is conducted by five interactive technical work packages (WP) that will:

- Develop a data management and spatial analysis framework (WP2).
- Improve cost optimization solutions for future development (WP3).
- Improve methods for stakeholder management (WP4).
- Provide development strategies for the distribution and storage of energy (WP5).
- Assess and synthesize other WP outputs to examine potential environmental and economic impacts (WP6).

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Project start date: 01st August 2018; Duration: 2 years; Webpage and contact details: www.marei.ie/eirwind/

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