Understanding the potential of hydrogen for transforming the offshore energy system

Briefing Paper for GOW2019 Workshop

XL centre London, South Gallery Meeting Room 9-10, June 26th 14.00 - 17.15pm

Background

As the UK progresses measures to reduce carbon emissions as set out in the Climate Change Act 2008, our approach to decarbonisation of the energy system has gained new momentum since the Committee on Climate Change publication of the 'Hydrogen in a low-carbon economy' report (Nov 2018). In the UK the North Sea has been the primary energy provider for the last four decades - however, a transformation is now taking place in the UK Continental Shelf (UKCS), with the oil and gas industry decommissioning alongside exploration and production activity. Over 100 platforms, 1,800 wells and approximately 7,500 km of pipeline are expected to be decommissioned in the UKCS by 2025. Operators are required to consider opportunities to re-use, or re-purpose infrastructure before progressing with decommissioning, and whilst some sites are decommissioning, new oil fields are being developed (e.g. Snorre and Gullfaks fields in the Norwegian North Sea by Equinor) with integrated measures for decarbonisation of operations through use of floating wind generated electricity. Many opportunities and new ideas for repurposing O&G infrastructure are being explored, such as for Carbon Capture and Storage (CCS), integration of offshore renewable, aquaculture and hydrogen production and storage.

Offshore wind is growing rapidly thanks to cost reduction, with the UK supporting the largest installed capacity in the world, amounting to a total generating capacity of 7.2GW (August 2018). The majority of offshore wind farms developed so far are near to shore (5 – 20 km) in relatively shallow water (< 30m). As the sector progresses, larger turbines (6~9.5MW) are becoming available and advances in substructures will enable deeper sites (30-50m) to be exploited. The UK plan to enable offshore wind capacity to reach 30 GW by 2030, includes sites 200km offshore and as floating platforms become cheaper, deep water sites with better wind resources will be developed. There is only one commercial offshore floating windfarm in operation in the world currently, and further cost reduction will be required to enable floating wind to be competitive. Future research and innovation in offshore wind technology is required, including in advanced operation and maintenance, blade technology and materials, electrical subsystems and cables, integration with future energy system, disruptive technologies and manufacturing optimisation.

Other sectors such as shipping and ports are also transforming their operations to reduce carbon emissions. Electrification of operations in ports is inter-linked with the drive for an improved environmental footprint as well as improving the operating cost efficiency. The integration of renewable energy is now a real addition with electrical power supply in ports being of ever increasing importance. Ports are also having to consider the implications of decarbonisation and switch from diesel to new fuels for a range of vessel types. The world's first sea-going car and passenger ferry powered by carbon-free hydrogen as energy source is under construction, and implications of alternative fuels for bulk carriers are being considered.

Opportunities and challenges

The energy transition provides opportunities and challenges for all sectors and for the offshore wind energy industry, these include: grid balancing resulting from supply intermittency; adequate back-up capacity when the renewable supply is insufficient to meet demand, resulting mismatch of electricity supply and demand. Infrastructure investment needs for the intermittent offshore wind energy capacity extensions can be substantial, and obtaining appropriate financing may be challenging. For the oil and gas industry, the first issue is to wind down production and get to the stage of decommissioning, which is a highly complex technical and economic challenge. The traditional oil and gas production companies are already beginning to diversify their businesses and redefine their role as energy producers during and after the energy transition.

The above issues may provide some basis for smart sustainable combinations for various UKCS energy players to achieve win-win outcomes. The repurposing and cross sectoral use of existing infrastructure may avoid new infrastructure investment, while the oil and gas companies receive new revenues from their assets. An oil and gas platform may potentially be used for hydrogen production driven by electricity from windfarms (PTG – power to gas) which also have the potential to power operation and maintenance stations and vessels directly. Oil and gas infrastructure including the vast network of offshore depleted storage areas and pipelines could also be used for storage and transport of hydrogen.

Gas platforms and offshore windfarms could also work together to maximise gas production and renewable electricity generation offshore. The concept of gas-to-wire (GTW) involves using the gas produced from gas fields to generate electricity offshore and then transmit it to shore via spare capacity in subsea cables used for offshore windfarms. By installing offshore power generation facilities, operators could export electricity via established windfarm infrastructure instead of exporting gas to shore by pipeline. As a relatively flexible and fast responding form of power generation, it could play a useful role in balancing the electricity grid as supply and demand fluctuates.

The oil and gas and offshore renewable sectors could also work together in setting up joint actions to support new initiatives for the environment restoration as well as enhance public understanding, knowledge and support for the energy transition.

Nevertheless, decarbonising the UK energy system with its seasonal demand poses a very significant challenge and solutions and technologies (such as those using hydrogen) that deliver flexibility and optionality will be highly valuable to the low-carbon transition.

The potential role of hydrogen

Hydrogen is an energy carrier with multiple applications and uses; it can be stored as hydrogen fuel, used in electro-chemical cells or internal combustion engines to power vehicles (cars/buses/ships), for heating and power of buildings, for gas to power for grid buffering, and as a source of industrial energy and chemical feedstock. It can be stored physically as a compressed gas cryogenically or as a liquid or in a materials based form – mainly as hydrides or adsorbed to a variety of organic materials.

There are several routes to producing hydrogen – the first begins and ends with plain water, with the water being split into hydrogen and oxygen by electrolysis. When this process is driven by renewable energy the resulting hydrogen is known as **'green hydrogen'**. When hydrogen and oxygen re-combine in the presence of a platinum catalyst in a fuel cell, electricity and water vapour are produced. The second main route to hydrogen production is by Steam Methane Reformation (SMR) – this is a thermo-chemical reaction which produces **'grey hydrogen'** from natural gas. This process is highly CO2 intensive and so where SMR is combined with carbon dioxide capture and when it is stored underground or used to create new compounds through Carbon Capture Use and Storage (CCUS) the resulting hydrogen is known as **'blue hydrogen'.**

As an energy vector, hydrogen can play a complementary role alongside electricity – in a deeply renewable, deeply decarbonised energy system. There is a significant UK hydrogen economy today, largely around the chemical industry, but there is much more to do to understand how far the UK hydrogen economy could expand, decarbonise and enter other sectors in terms of opportunities, cost reductions and various challenges (technical, commercial and policy related).

It has already been demonstrated that 18% of global final energy demand could be met by hydrogen, equal to about 78 exajoules by 2050, i.e., ~ ten times of current level. The corresponding abatement potential represents 6 gigatonnes of CO2 annually.

There are several projects underway which focus on demonstrating aspects of the energy transition in the UK and overseas, (see table below)

Project	**Description**	**Coordinator**	**Funding source**
H21 Leeds City Gate	Assessing the feasibility from both a technical and economic viewpoint of converting existing methane gas network in Leeds to a 100% hydrogen gas network with steam methane reforming (SMR) and carbon capture and storage (CCS)	Northern Gas Networks	UK
Acorn	A low-cost, low risk carbon capture and storage project specifically designed to make best use of existing oil and gas infrastructure and a well understood offshore CO2 storage site to quickly unlock large-scale CO2 transport and storage solutions.	Pale Blue Dot Energy	EU
HyDeploy	A hydrogen energy project to reduce UK CO2 emission through one year trial, the project is to find out if blending hydrogen of up to 20% with natural gas could reduce CO2 emissions from home cooking and heating without changing customer appliances.	Cadent	UK
The Big Hit	Uses renewable wind and tidal electricity generated on island to produce hydrogen by electrolysis. The hydrogen is stored in the tube trailer and transported to mainland to end users (heating/power and ferries as fuel) for zero-emission operation.	Development of New Hydrogen in Aragon	EU
HySeas III	Target is to deliver the world's first sea-going car and passenger ferry powered by carbon-free hydrogen as energy source. The vessel's fuel (hydrogen) will be produced from a renewable source locally making a paradigm shift towards entirely emission-free marine operation.	University of St Andrews	EU
ELEGANCY	The project aims for the decarbonisation of heating and transport, based on an existing fuel and infrastructure, and commercial model for industrial CCS. This includes large-scale CO2 transport and storage infrastructure for use by other sectors, as well as infrastructure for the rapid introduction of hydrogen as an energy carrier, thus also opening the door for hydrogen generated from spare capacity in the renewable source.	SINTEF Energy Research	EU

Currently, over 95% of hydrogen production is fossil fuel based. Only around 4% of global hydrogen supply is produced via electrolysis. Achieving technology scale-up and cost reductions from wider adoption are currently the most critical challenges, mainly for proton-exchange membrane fuel cell (PEM) but also for alkaline (ALK) electrolyser manufacturers. Continued R&D efforts are also needed to keep improving power density, lifetime and balance of plant efficiencies.

Hydrogen can help further development of renewable energy in hard-to-electrify sectors: such as transport, industry and those that rely on existing gas grids, such as buildings and power. For this potential to materialise, policy and financial support and significant cost reductions are required.

The progressive development of hydrogen end-use applications will require the joint ramping-up of a hydrogen supply chain, including additional capacity for production, purification and pressurising for transport, and transport and distribution capacity. For hydrogen production at industrial scale, long-distance delivery via tanker or through gas or dedicated hydrogen pipelines will be necessary and large capacity storage facilities will also be required onshore (salt caverns) or offshore (depleted oil and gas fields), and so further study is needed for hydrogen storage at an industrial scale.

The rapid expansion of offshore wind energy and increasing offshore decommissioning pose opportunities for realising hydrogen potential in the offshore energy system. However, there are many challenges ahead for this transformation and it is imperative to identify the technical, commercial and policy challenges and barriers to integrating hydrogen into the offshore energy system to facilitate the energy transition. It is also necessary to identify a collaborative programme of whole systems research, demonstration and innovation as well as industry, government and academic collaborations with potential to deliver it.

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