Blue Hydrogen – the fuel of the future?
Could "blue" hydrogen be produced and used here?

When hydrogen is burnt to release energy or to generate electricity, the only waste product is water. No carbon dioxide is produced, so it is regarded as a clean fuel. But how is hydrogen made in the first place?

One method is to manufacture it from natural gas, which mostly consists of methane (CH_4). However the process also produces carbon dioxide, so a way must be found of disposing of this waste product underground, or there would be little benefit from the process. When this happens, the hydrogen is referred to as "blue" hydrogen. Several projects are developing possible solutions to the problem, one of which, HyNet North West, is investigating using a combination of hydrogen energy, in place of fossil fuel gas, and carbon capture and storage (CCS).
The diagram below, from the HyNet leaflet explains their choice of this region.

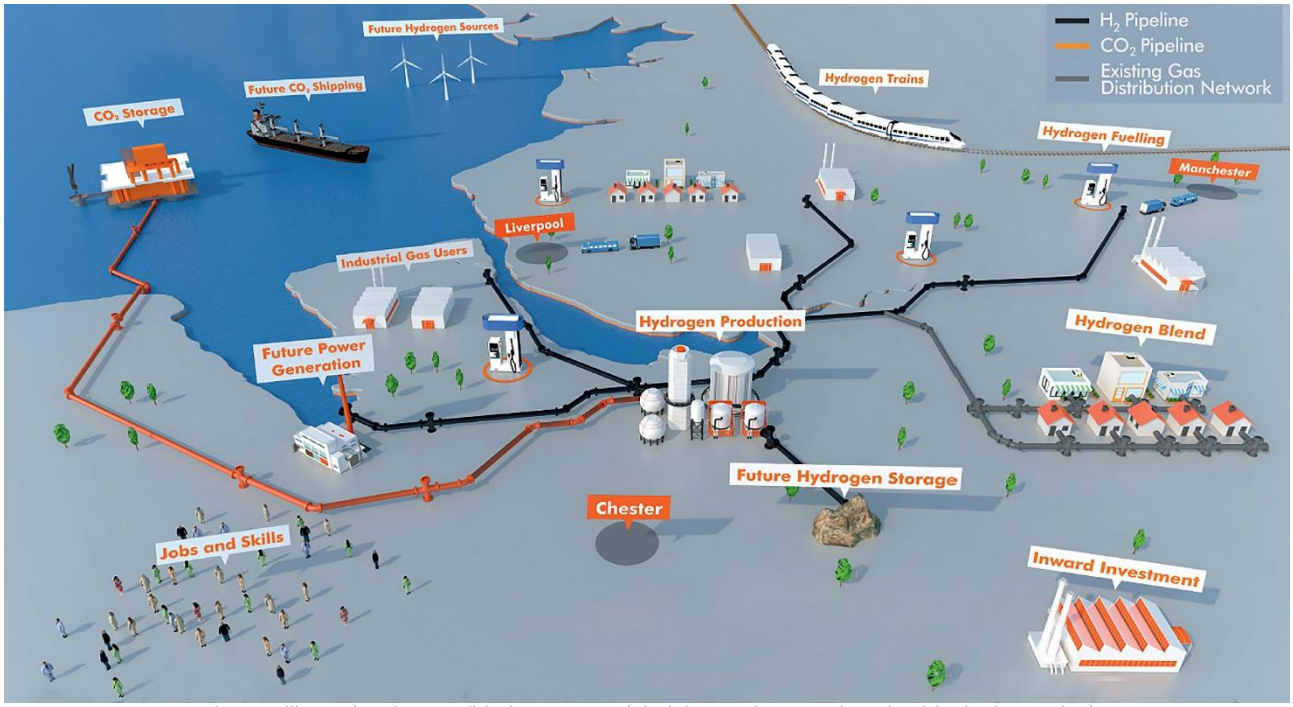


Diagram illustrating the possible future potential of the North West of England for hydrogen fuel

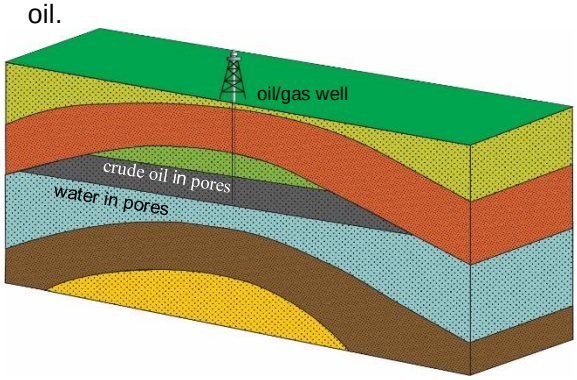
The leaflet states "The region's unique geology make it ideally placed to host HyNet" Why is this?

- Once manufactured, the hydrogen could be liquefied and stored underground in cavities, ready to be piped to consumers. There are many worked-out salt mines in Cheshire.

Salt mine in Cheshire (*P.Kennett)*

Find out what properties of rock salt might make it suitable for storage of hydrogen. Suggested answers are given in italics. (*Rock salt is impermeable and also "flows" to seal cracks as they appear over time*).

- Natural gas is being extracted from the rocks beneath the Irish Sea. The diagram shows an underground structure where natural gas may be trapped, sometimes associated with crude oil.



An up-folded (anticlinal) structure forming a trap for gas and oil

Label the diagram to show the features which have resulted in the gas being trapped there, using labels from this list:

- crest of anticline;
- permeable reservoir rock;
- impermeable cap rock.

Once the natural gas has been extracted, could this structure be used to store carbon dioxide when it is produced as a waste product of the hydrogen manufacturing process? If so, why? *(Yes – if the trap is secure for natural gas, it will also be able to contain carbon dioxide which, unlike natural gas, cannot burn and so is less dangerous)*

What other (non-geological) benefits for hydrogen production does the diagram from the leaflet suggest are present in the North West England region?

(• coastal location for import of natural gas, once the Irish Sea gas field is exhausted;
- *off-shore wind generators for electricity for the manufacturing process;*
- *existing industries, with "brownfield" sites for building the hydrogen manufacturing plant;*
- *large population centres to provide workers and as customers for hydrogen in industries and homes;*
- *existing gas distribution system which could carry a hybrid fuel of natural gas and hydrogen without needing modification;*
- *good transport links.)*

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The back up

Title: Hydrogen – the fuel of the future?

Subtitle: Could "blue" hydrogen be produced and used here?

Topic: An assessment of the potential of the North West of England region for the manufacture and use of hydrogen from natural gas.

Age range of pupils: 16 -18 years

Time needed to complete activity: 15 minutes for basic understanding of the project, plus internet research time.

Pupil learning outcomes: Pupils can:
- critically examine publicity material from a potentially commercial organisation;
- explain how a clean fuel can be made from a hydrocarbon source without releasing carbon compounds to the atmosphere;
- review their existing knowledge of the structure of a natural hydrocarbon trap;
- discuss implications for the industry and population of a region of England;
- (In the follow-up) - carry out research into careers, involving transferrable skills.

Context: Concern about ever-rising levels of carbon dioxide in the atmosphere has accelerated the search for cleaner fuels and several industrial consortia are actively investigating the potential of various regions in the world. Making a clean fuel like hydrogen from a carbon-based fuel may seem counter-intuitive, but it is feasible if the waste carbon gases can be captured and stored safely below ground.

Following up the activity
There is a large well-established petro-chemical industry on Merseyside. Many traditional oil and gas companies are now actively investigating hydrogen projects such as this. Carry out a web search and find out how the skills of existing oil and gas company staff might be used to: find natural gas; develop the manufacture and distribution of hydrogen; find storage spaces for waste carbon dioxide; care for the environment. You might find the following careers, among others; geologist; geophysicist; hydrogeologist, energy engineer; petroleum engineer; metallurgist; technician; ecologist; etc.

Underlying principles:
- Hydrogen is referred to by a conventional colour depending on the extent to which carbon compounds are released in its manufacture.
- "Brown" hydrogen was produced from coal for "town gas" in UK from the early 19th Century for more than 150 years, releasing carbon dioxide and carbon monoxide into the atmosphere.
- "Grey" hydrogen produced from hydrocarbon fuels also produces carbon waste to the atmosphere.
- "Blue" hydrogen manufacture also produces hydrogen from hydrocarbon fuels but uses carbon capture and storage for the greenhouse gases produced in its creation.
- "Green" hydrogen production – the ultimate clean hydrogen resource – uses renewable energy to create hydrogen fuel, e.g. wind power to electrolyse hydrogen from water, and no carbon is involved.
- Geological properties of the rocks beneath parts of Cheshire and the Irish Sea are suitable for retaining a volatile gas such as hydrogen, or for the "waste" carbon dioxide, e.g. impermeable salt; porous and permeable rocks such as sandstones for holding the gas in the pore spaces; impermeable cap rocks, such as mudstones for preventing the gas from escaping; anticlinal and other structures in the strata to trap the gases.
- There is enough natural gas beneath the Irish Sea for production to continue for several years.
- Existing hydrocarbon companies are keen to diversify their activities, as hydrocarbon fuels become less in demand and clean fuels become more essential.
- Hydrocarbon company personnel have existing skills which are readily transferrable to the development of the underground facilities which are essential for the storage of hydrogen and for the capture and storage of carbon-based by-products.

Thinking skill development:
Building up an understanding of the geological and industrial characteristics of the North West of England involves construction. Using a carbon-based fuel to generate clean hydrogen involves cognitive conflict. Discussion is a metacognitive activity, and applying knowledge to a real region uses bridging skills.

Resource list:
- copies of this activity sheet for each group of students
- access to the internet

Useful links:

https://hynet.co.uk/app/uploads/2018/06/14490_CADENT_A5_LEAFLET_TIMELINE_DOWNLOAD.pdf
https://hynet.co.uk/app/uploads/2020/10/HyNet_NW-Vision-Document-2020_FINAL.pdf
https://www.prospects.ac.uk/jobs-and-work-experience/job-sectors/energy-and-utilities/jobs-in-the-oil-and-gas-industry
https://utilityanalytics.com/2020/10/the-colors-of-hydrogen-brown-grey-blue-and-green-think-about-it/

Source: Written by Peter Kennett of the Earthlearningidea team, based on materials taken from the HyNet leaflet referred to above. Thanks to Maggie Williams, Liverpool University for advice.