REA position on Hydrogen

Background

The REA believe clean hydrogen will play a major role to decarbonise the economy and will be essential to reach net zero.

Hydrogen is a carbon free molecule that can be used as an energy carrier and for energy storage, as a feedstock and a fuel, with the potential to decarbonise challenging sectors such as:

- Industry – for example, applications that currently use grey hydrogen or *hard-to-abate* sectors;
- Transport - in particular *hard-to-abate* segments such as aviation, marine and heavy freight';
- Heating – for example, in *hard-to electrify* buildings that are on the gas grid; and
- Power – for flexible and back-up power generation.
- Flexibility - It can also provide large scale and long duration storage to help balance energy demand with supply and balance our energy system.

There is much interest in the role that hydrogen can play in a future energy system. In July 2020 the European Commission issued a Hydrogen Strategy to boost clean hydrogen production in Europe, setting a target of 40 GW of renewable hydrogen by 2030. In March 2022, the European Commission unveiled proposals to quadruple the current 2030 targets for green hydrogen supplies to 10 million tonnes of green hydrogen production and 10 million tonnes of imports, as part of its strategy to cut the EU's reliance on Russian gas by two-thirds (Communication on REPowerEU plan).

Some European Countries also set ambitious targets for renewable hydrogen. The German Government, for example, announced a National Hydrogen Strategy, with a 5GW target for electrolysis by 2030. In November 2021 the country announced their plans to double their 2030 target to 10 GW of electrolytic hydrogen capacity.

The UK Government released its long-awaited Hydrogen Strategy on 17th August 2021, setting out the UK approach to developing a thriving low carbon hydrogen sector and to meet the Government ambition for 5GW of low carbon hydrogen production capacity by 2030.

On 7th April 2022 the British Energy Security Strategy was published and doubled the Government ambition to up to 10GW of low carbon hydrogen production capacity by 2030, with at least half of this target coming from electrolytic hydrogen.

Hydrogen production routes and GHG characteristics

Hydrogen has zero emissions at the point of use, but its upstream emissions as well emissions associated with its production and downstream distribution to the point of use vary considerably. We believe it is important to use a consistent approach to measuring greenhouse gases (GHG) emissions across different pathways and clean technologies and this should be based on their full lifecycle.

The low carbon hydrogen standard (LCHS) has been developed by BEIS to ensure that the hydrogen being produced and supported by the Government is sufficiently low carbon to contribute to the UK carbon budget targets and net zero commitments. The standard sets out a methodology for calculating GHG emissions and the maximum acceptance levels of GHG emissions associated with low carbon hydrogen.

There are several means of producing hydrogen, some of which have been commonly labelled with colours, while others have not (e.g. biohydrogen production from biomass gasification and from steam methane reformation of biogas, or hydrogen from the non-renewable fractions of wastes). We have highlighted the most common production methods in the table below, along with the terminology/taxonomy commonly used to label them. To support the development of the LCHS, BEIS procured work to model GHG emissions associated with different pathways and this data can be found here.

Given the wide range of carbon intensity figures reported in published studies for different pathways and colours of hydrogen, and the high degree of uncertainty associated with them, we believe we should move away from labelling different hydrogen production pathways with colours and start categorising them according to their lifecycle carbon intensity. We consider this is what should really be considered to evaluate the decarbonisation value of hydrogen, provided this is measured with a robust methodology and across the full hydrogen lifecycle.

Production methods	Terminology commonly used to label pathways	Notes / comments
Unabated SMR of fossil fuels (mainly gas)	Grey (sometimes Brown Hydrogen though this more specifically refers to hydrogen from coal gasification)	The REA believe Government should set a defined timeframe for phasing out grey hydrogen.
SMR of fossil fuels, with CCS	Blue hydrogen	Variation is according to gas source and CCS capture rate. *Note: Some members have calculated GHG emissions as high as 40 g/MJ for blue hydrogen if the feedstock is imported LNG or gas transported from Russia, rather than natural gas from the North Sea. This is because associated emissions such as from re-compression stages on a pipeline or from cooling gas in a tanker cannot be easily captured. Further information on GHG emissions for this pathway is included in BEIS' LCHS and associated supporting documents.*
ATR of fossil fuels, with CCS	Blue hydrogen	Variation is according to gas source and CCS capture rate. *See also note above re SMR plus CCS.*
Molten metal pyrolysis of natural gas	Turquoise hydrogen	This technology is still in the laboratory phase.

Thermal Plasma Electrolysis (TPE)	Emerald hydrogen	While the chemistry of TPE is the same as for pyrolysis (i.e. CH_4 => C + $2H_2$), the physics by which this is achieved are very different. TPE is anticipated to have CO_2e emissions roughly similar to SMR/ATR plus CCS. This technology is considered to be further advanced than pyrolysis: commercial pilots should run by the end of 2022.
Electrolysis using electricity produced from grid electricity	Green hydrogen	For information, the CertifHy 2019 project[1] suggests that the threshold for which hydrogen could be regarded as low carbon is 36.4 g CO_2e/MJ. *Further information on GHG emissions for this pathway is included in BEIS' LCHS and associated supporting documents.*
Electrolysis using renewable electricity	Green hydrogen (Sometimes hydrogen through electrolysis using solar power is defined as yellow hydrogen)	Emissions from green hydrogen are normally regarded as zero, though there may be emissions associated with manufacturing and maintaining solar panels and wind turbines or other renewable electricity source. *Further information on GHG emissions for this pathway is included in BEIS' LCHS and associated supporting documents.*
Electrolysis powered by nuclear energy	Pink hydrogen	Modelled emissions intensity of pink hydrogen can be found in the LCHS and supporting documentation.
Gasification of biomass	Biohydrogen	With CCS this pathway can deliver negative GHG emissions. *Further information on GHG emissions for this pathway is included in BEIS' LCHS and associated supporting documents.*
SMR/ATR of renewable methane (from biogas)	Biohydrogen	With CCS this pathway can deliver negative GHG emissions. *Further information on GHG emissions for this pathway is included in BEIS' LCHS and associated supporting documents.*

Gasification, or other advanced conversion of non-renewable waste streams (such as fossil wastes like plastic, rubber, gaseous wastes)	Defined as Recycled Carbon Fuels under the Renewable Energy Directive	This pathway can deliver benefit beyond carbon savings, such as supporting the circular economy and maximise the value of wastes in line with the waste hierarchy.

Note: ATR = Autothermal reforming. SMR = Steam Methane Reforming. An explanation of the difference is reproduced at the end of this paper.

It is important that carbon emissions are reduced as swiftly as possible, and there is a balance to be struck between building scale by implementing measures which are not perfect, but which can be improved, or restricting deployment to only totally zero carbon measures, which may take longer to scale up.

The extent to which non-zero emission hydrogen production methods (e.g. electrolysis when the grid is not carbon free, or SMR/ATR when carried out on fossil fuel) can be viewed as acceptable to stimulate the transition, has been subject to debate. Integrating hydrogen into the energy system also has aspects of the chicken and egg question. Deployment is required in both hydrogen production and the infrastructure for hydrogen utilisation, but at the same time demand for hydrogen is required to support development of hydrogen production and infrastructure.

Only renewable sources of energy provide the opportunity to achieve zero emissions (via electrolysis), or negative emissions (via bioenergy with carbon capture and storage - BECCS).

Hydrogen used today is largely produced from fossil fuels, unabated. Clearly this form of hydrogen is significantly polluting in terms of GHG emissions. It is produced for a number of reasons unrelated to addressing climate change, but it clearly has no role whatsoever in addressing global climate change, as it makes the problem worse. The REA advocates a move to greener production methods, irrespective of the end use and believe the Government should set out a phase out date for unbated, fossil fuel derived hydrogen as soon as technically feasible.

When the carbon capture storage (CCS) element is operational, effective and permanent, fossil derived hydrogen is an option in the transition towards a net zero carbon economy. Overall carbon budgets are important and the sooner the emissions are reduced the better. The REA will only support a transitional role for this form of hydrogen where the carbon is captured and stored or utilised in in an application where the carbon is permanently sequestered and if it meets the Government's Low-Carbon Hydrogen Standard.

REA is highly supportive of electrolytic hydrogen produced from co-located renewable electricity sources, as this represents a truly zero emission pathway. In addition, grid-connected electrolysers have an important role to play to support the scale up of the hydrogen sector and deliver the necessary cost reductions. We have set out here our view on the rules to evidence that electricity used to power grid-connected electrolysers is low-carbon and on additionality requirements. Electrolytic hydrogen has a crucial role to help balance the increasing shares of renewables in the system, reducing curtailment of renewable electricity and providing seasonal storage, which will be key to enabling large scale balancing of the networks between the peaks of energy generation and demand.

The REA is also very supportive of biohydrogen production pathways. An important by-product of the biohydrogen production process is high quality carbon dioxide. This can be compressed and injected into carbon sequestration networks. When biomass feedstock is used, this carbon dioxide has been captured from the atmosphere through photosynthesis and its storage generates negative carbon emissions. Bioenergy with carbon capture and storage (BECCS) is seen by Government as crucial to help offset residual emissions from sectors that are really difficult to decarbonise.

As highlighted above, going forward we should move away from categorising different pathways with colours and label them according to their lifecycle carbon intensity instead. The LCHS should be the baseline standard for all the hydrogen produced in the UK, as well as supplied from and to. Some pathways will deliver GHG emissions savings beyond the baseline standard.

How does hydrogen fit in with other REA positions on decarbonising heat, power, flexibility and transport?

We support the use of hydrogen across all sectors of the economy, in industry, power, heat, transport, especially where these sectors are particularly difficult to decarbonise by other means. Hydrogen will also have a strategic role in delivering large scale energy storage and grid balancing services.

Industry

Hydrogen is likely to play a key role in decarbonising hard-to-abate industrial sectors where other decarbonisation options such as electrification or bioenergy are not available.

Hydrogen can either be used as a fuel to produce industrial high temperature process heat (e.g. in cement production), as a feedstock/chemical reagent (e.g. in ammonia, methanol or petrochemicals), or as a reducing agent in the production of direct reduced iron (DRI) (steel). For example, the first 'green steel' plant powered by hydrogen has been announced in Sweden[1].

Industrial users are likely to be early adopters of clean hydrogen for a number of reasons, including:

- hydrogen use today is dominated by industry in the oil refining, ammonia production, methanol production and steel production sectors. As explained by the IEA, virtually all of this hydrogen is supplied using fossil fuels, so there is significant potential for emissions reductions from clean hydrogen.
- In addition, certain industrial end users are likely to have fewer cost-effective alternative decarbonisation options.
- It is also easier to convert to hydrogen a large appliance (e.g. a large industrial boiler or furnace) than many small domestic appliances, and the transportation of hydrogen is also easier to address (e.g. when the hydrogen production plant can be built next to the industrial user).

[1] https://www.h2greensteel.com/newsroom/h2greensteel

As for hydrogen use for process heat, hydrogen is suited to decarbonise industrial boilers as it is capable of reaching the high temperatures needed for certain industrial applications. As the CCC reports, 90 TWh of current industry fossil fuel consumption could be switched to hydrogen by 2040 and for around 15 TWh of this demand it may be the only option available (e.g. for direct firing, for which biomass and electrification are rarely technically suited).

However, it is important to ensure hydrogen is definitely the most carbon and energy efficient solution compared to other options that can be more energy efficient, such as direct use of renewable electricity or bioenergy.

Hydrogen blending

The REA's position on blending hydrogen into the gas grid can be found here.

The REA believe hydrogen blending into the gas network has a key role to play to support the scale up of the UK clean hydrogen sector. Government should clearly back the strategic role of clean hydrogen blending into the gas network and support it financially and the above position sets out the reasons why.

Injection of hydrogen in increasing proportions (up to around [20%] by volume) is seen as crucial to provide a reliable source of baseload demand to support early low carbon hydrogen producers and to deliver earlier carbon savings.

We support the view that the existing gas grid is a valuable asset in the transition to a lower carbon energy system, to the extent that it enables reaching net zero by 2050.

The evolution should be as follows:

- Increasing amounts of biomethane replace fossil gas (and continuing to do so until ultimately the only carbon containing molecules in the gas grid are biogenic. This could ultimately entail a reduction in size of the gas grid if there is not enough zero-carbon gas to go around).
- In parallel, increasing amounts of hydrogen are injected until the 20% "blend wall" is reached
- Once the blend wall is reached, parts of the network are converted to 100% hydrogen. The remainder of the grid becomes more and more biomethane rich until fossil fuel is completely replaced.

Domestic heat

We believe hydrogen will play a role to decarbonise domestic heat, especially where other already established low-carbon options are not viable.

There are other various forms of renewable heat production (biomethane, solar thermal, heat pumps, biomass, biopropane and other bioenergy) which the REA continues to support and given the scale of the decarbonisation challenge it is clear that a combination of technologies will be needed and the REA very much believes in a truly multi-technology approach.

We also think that there could be a strong role for hybrid systems, which use a heat pump most of the time, but then switch to (green) gas during stress periods.

Transport

The REA expects hydrogen to be a key transport fuel for sectors which are hard to decarbonise by other means, for example maritime, heavy duty vehicles and rail (where electrification is not possible).

Hydrogen can also be used as a feedstock for the manufacture of synthetic fuels which could play an important role to decarbonise hard-to-abate sectors such as aviation.

Electrolysis and carbon intensity of electricity

In the case of an electrolyser directly connected to a renewable energy generating station, it is clear that the power for electrolysis is renewable. The only carbon emission that could be attributed to this would be in the embodied energy in the generator (e.g. wind turbines or PV and the electrolyser itself).

When the electrolyser is taking electricity from the grid, the carbon intensity of the electricity needs to be taken into account. We have set out here our view on the rules to evidence that electricity used to power grid-connected electrolysers is low-carbon and on additionality requirements.

Power and energy storage

Electricity can be converted into hydrogen by electrolysis, and later used to generate electricity [or supplied as a fuel or feedstock to meet demand in other sectors]. The round-trip efficiency of this is currently lower than other storage technologies such as batteries, but the capacity is very much greater, opening up the potential for inter-seasonal storage of renewable energy via geological storage. In light of such longer duration, large scale energy storage is necessary if we are to successfully transition our power system to a net zero world and so hydrogen could play a very valuable role in the mix in a future energy system.

Carbon capture and storage

Even when the CCS/CCUS element of blue hydrogen is operational, effective and permanent, blue hydrogen can never be zero carbon. Carbon accounting must be used to the full life cycle carbon emissions including taking into account the longevity of the storage and any methane leaks upstream of reformers, as well as the energy costs of compressing the CO_2 for storage and the emissions from the source of natural gas (e.g. extraction and distribution).

Any economic analysis should cover the full costs of the storage, including insuring the high-pressure CO_2 pipeline infrastructure against future catastrophic leaks.

CCS/CCUS is a technology applicable to storing biogenic carbon as well as fossil carbon. When combined with biohydrogen production (BECCS/BECCUS), it can deliver negative carbon emissions and is therefore considered a Greenhouse Gas Removal technology.

Annex

The difference between SMR and ATR Hydrogen Production

SMR (Steam Methane Reformation) and ATR (Autothermal Reforming) are two alternative routes of hydrogen production. ATR is more suited to the removal (and subsequent storage) of CO2. An explanation of the difference between the two processes is given below [2]

Reformer

In the reformer the methane is converted into syngas, a combination of carbon dioxide and hydrogen gas, using heated steam. ATR and SMR use different techniques for the reforming step.

a *Steam methane reforming (SMR)*

In a SMR reforming step a mixture of hydrogen and carbon monoxide is produced using an endothermic reaction. The process operates in a range of 500-900°C for which heat is generated via the burning of natural gas. Capturing the CO_2 of these flue gasses outside the reformer is difficult, among other because of the large nitrogen percentage and lower operating pressure.

The chemical reaction of the process is: $CH_4 + H_2O \leftrightarrow CO + 3H_2$ (endothermic)

b *Autothermal reforming (ATR)*

ATR produces hydrogen via an endothermic and exothermic reaction creating a heat balance. The process temperature is between 900-1,150°C. ATR requires oxygen as input, however does not require the burning of natural gas for heat input. All the CO_2 is contained in the reactor at elevated pressure enabling high-capture percentages.

The chemical reactions for the process are:

$CH_4 + H_2O \leftrightarrow CO + 3H_2$ (endothermic)

$C_mH_n + \frac{m}{2}O_2 \leftrightarrow mCO + \frac{n}{2}H_2$ (exothermic)

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[2] CE Delft, Hydrogen Report, July 2018, https://www.cedelft.eu/en/publications/download/2585