Department for
Business, Energy
& Industrial Strategy

Consultation on a UK Low Carbon Hydrogen Standard

Closing date: 25 October 2021

August 2021

Any enquiries regarding this publication should be sent to us at:
hydrogenproduction@beis.gov.uk

Executive Summary

The Prime Minister's *Ten Point Plan for a Green Industrial Revolution*[1] sets out that, working with industry, the UK is aiming for 5GW of low carbon hydrogen production capacity by 2030. In support of this ambition, we are introducing supportive policies intended to de-risk investment and incentivise the roll out of new low carbon hydrogen production facilities. Crucial to this will be ensuring that the hydrogen being produced is sufficiently low carbon to contribute to our carbon budget targets and net zero commitments.

Working with industry, academia, and regulators, BEIS is therefore assessing and comparing options for a UK low carbon hydrogen standard that defines low carbon hydrogen, including:

- Setting out the methodology for calculating greenhouse gas (GHG) emissions (e.g., the Life Cycle Assessment system boundary and assumptions for delivery conditions of the hydrogen produced); and
- Setting out the maximum acceptable levels of greenhouse gas emissions associated with low carbon hydrogen.

Our current intention, to be further informed by responses to this consultation, is that low carbon hydrogen producers seeking government support, through the Net Zero Hydrogen Fund, and/or the Hydrogen Business Model would be required to comply with the resulting standard in order to secure support. We intend that any future changes to the standard would not apply retrospectively to contracts already awarded through the Hydrogen Business Model. We are considering whether the standard could also be developed into a certification scheme to support the deployment of low carbon hydrogen across the economy and support future international trade in low carbon hydrogen.

When looking at the methodological choices that could be made when designing a low carbon hydrogen standard, we have generally provided options throughout the consultation and discussed the advantages and disadvantages we consider they would bring. Responses to this consultation, together with the E4tech and Ludwig-Bölkow-Systemtechnik GmbH (LBST) research[2] and further internal analysis, is intended to help in development of a standard.

For many of the factors related to the scope and GHG calculation requirements, the choice of option is clear from a technical or policy perspective, or the analysis shows that one approach is strongly preferred. However, there are some decisions where there remain a number of options that may be appropriate for a UK standard. A low carbon hydrogen standard needs to include several elements which ensure credibility, transparency, and ease of use. The key elements being consulted are set out below.

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[1] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution
[2] https://www.gov.uk/government/publications/options-for-a-low-carbon-hydrogen-standard-report

- **The scope of the standard, including its use and coverage across different production methods and geographic location.**

In line with our approach to growing the UK hydrogen economy, as set out in our Hydrogen Strategy[3], we expect to support a variety of different production methods to deliver the level of hydrogen needed to meet net zero. We are therefore minded to adopt a single label of 'low carbon' that can be applicable to all production methods that meet the GHG threshold.

We expect the standard to include consideration of GHG emissions. Whilst other environmental impacts have not been considered through this work (e.g., water consumption, air quality), we are not excluding the potential for further work on these areas through other routes or policy mechanisms.

- **The system boundary of the standard, chain of custody, purity and pressure, embodied emissions, and global warming potential factors.**

Whether the standard should be applied at the point of hydrogen production or at the point of use, setting the 'system boundary' interacts with the choice of the system used to assess compliance of the hydrogen produced through the value chain ('chain of custody'), requirements for hydrogen purity and pressure, and the geographical boundary of the scheme. Our minded to position is setting the system boundary at the point of production, which would cover raw materials acquisition, upstream emissions, and hydrogen production emissions.

We propose excluding embodied emissions (such as construction and decommissioning emissions) from the scope of a UK low carbon hydrogen standard as this is not currently accounted for in the UK's carbon budgets accounting or other comparable global standards / schemes. However, should the UK or global context change, this could be reviewed and updated accordingly.

It is our intention that a UK low carbon hydrogen standard will use Global Warming Potential (GWP) factors that are in line with wider UK Government policy on GHG accounting. When calculating overall GHG emissions, the standard could also include a GWP factor to account for any hydrogen losses incurred when the hydrogen passes through the supply chain (known as fugitive losses).

- **Consideration of different primary energy inputs and feedstock emissions**

We need to consider options for how to treat energy inputs, such as the use of electricity as a primary energy input for electrolysers. We are mindful of the need to conduct further analysis to assess any potential impacts that decisions around the use of electricity as primary input energy for hydrogen production could have on the wider energy system, including the availability of low carbon electricity and the changing impact of grid electrolysis over time. We may therefore consider additional criteria to mitigate any negative impacts or unintended consequences. We will use this analysis as part of our considerations for how the standard will be applied and will set out more detail on our findings in the Government Response to this

[3] https://www.gov.uk/government/publications/uk-hydrogen-strategy

consultation. We would welcome any evidence from stakeholders that could contribute to this work.

If the hydrogen production method has mixed inputs (e.g., high, and low carbon inputs), the standard will need to define whether the outputs are treated as one consignment or whether the operator can separate this into several different consignments (with different GHG intensity levels). A decision on this element will need to be made alongside considerations on the Net Zero Hydrogen Fund and Hydrogen Business Model, as this would impact on the eligibility of projects.

How waste fossil feedstocks, such as the non-biogenic fraction of municipal solid waste, would be accounted for under a UK low carbon hydrogen standard is highly dependent on the trade-offs between reporting effort, accuracy, and potential for change over time. We invite stakeholders' views and evidence on whether waste feedstocks should be considered with counterfactuals under the standard.

- **Further GHG methodology / calculation considerations**

For many of the factors related to the scope and GHG calculation requirements, the choice of option is clear from a technical or policy perspective, or the analysis shows that one approach is strongly preferred. In these areas we have set out 'minded to' positions in this consultation, whilst inviting stakeholder views. This includes using units of gCO2e/MJ LHV when measuring GHG emissions intensity and defining an emissions threshold on an absolute basis.

Areas that need further consideration from a technical perspective include the method adopted for allocating emissions to by-product hydrogen: the allocation of upstream and process GHG emissions between hydrogen and other products is usually done on an energy basis. For by-product hydrogen though, this approach may significantly over-allocate emissions to hydrogen when other significant co-products do not have an energy content, as is the case for processes such as chlor-alkali. We invite views and evidence on what allocation method should be used for by-product hydrogen to inform our thinking.

We will also need to consider how negative emissions from hydrogen production should be treated in a standard. If the standard allows for reporting of negative emissions (through the inclusion of GHG credits for biogenic CCUS), there is a risk that less efficient biohydrogen chains could deliver more negative emissions than efficient ones. We will need to consider how to ensure inefficient production chains are not incentivised through this process.

- **A threshold for GHG emissions.**

In setting a GHG emissions threshold, we will need to strike a balance between the need to encourage growth by supporting market development and cross-border investment, while managing value for money risks and ensuring that the standard makes a direct contribution to our carbon reductions targets. We are consulting on what level, and type, of emissions standard would best achieve this: including whether it is right to set this as an absolute level (rather than relative to a counterfactual fuel), what threshold would be appropriate, and whether this threshold should tighten over time.

- **Delivery and administration of a UK low carbon hydrogen standard**

This section discusses at a high level the options and requirements for assurance, communication and claims, and governance.

There is a trade-off between the level of rigour and credibility versus the burden placed upon economic operators implementing the standard, and the number of participants. Options are discussed for the type and frequency of reporting and verification.

Options for governance of the standard are also set out: whether the standard should be delivered and administered by BEIS, or by an independent industry-led or multi-stakeholder organisation.

Contents

General information

Why we are consulting

To set out initial options considered and invite stakeholder views relating to a UK low carbon hydrogen standard. This will ensure that the different options can be fully tested and refined where appropriate.

Consultation details

Issued: 17 August 2021

Respond by: 25 October 2021

Enquiries to: hydrogenproduction@beis.gov.uk

Consultation reference: UK low carbon hydrogen standard

Audiences:

The consultation will be of particular importance to hydrogen producers, as well as those with an interest in wider energy system impacts and decarbonisation. It will also be of interest to stakeholders in the hydrogen industry, as well as those with a wider interest in the UK's net zero ambition.

Territorial extent:

The scope of this consultation is UK-wide. Our preferred approach is for the low carbon hydrogen to be applicable on a UK-wide basis to support decarbonisation across the UK. We will continue to work with the devolved administrations as we develop and finalise the standard.

How to respond

Respond online at: https://beisgovuk.citizenspace.com/clean-growth/hydrogen-standards

or

Email to: hydrogenproduction@beis.gov.uk

When responding, please state whether you are responding as an individual or representing the views of an organisation.

Your response will be most useful if it is framed in direct response to the questions posed, though further comments and evidence are also welcome.

Confidentiality and data protection

Information you provide in response to this consultation, including personal information, may be disclosed in accordance with UK legislation (the Freedom of Information Act 2000, the Data Protection Act 2018, and the Environmental Information Regulations 2004).

If you want the information that you provide to be treated as confidential, please tell us, but be aware that we cannot guarantee confidentiality in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not be regarded by us as a confidentiality request.

We will process your personal data in accordance with all applicable data protection laws. See our privacy policy.

We will summarise all responses and publish this summary on GOV.UK. The summary will include a list of names or organisations that responded, but not people's personal names, addresses or other contact details.

Quality assurance

This consultation has been carried out in accordance with the government's consultation principles.

If you have any complaints about the way this consultation has been conducted, please email: beis.bru@beis.gov.uk.

Introduction

The UK will need significant amounts of low carbon hydrogen in our energy mix if we are to meet our legally binding 2050 net zero commitments. In April 2021, the UK Government responded to recommendations from the Climate Change Committee (CCC) on the UK's sixth carbon budget (CB6) by setting the world's most ambitious climate change target into law, to reduce emissions by 78% by 2035 compared to 1990 levels. Analysis by the Department for Business, Energy, and Industrial Strategy (BEIS) on CB6 suggests 250 – 460 TWh of hydrogen could be needed by 2050, delivering 20 – 35% of final energy consumption.

The Prime Minister's *Ten Point Plan for a Green Industrial Revolution*[4] established our ambition in this area, working with industry to deliver 5GW of low carbon hydrogen production capacity by 2030. The UK's first Hydrogen Strategy[5], published alongside this consultation, goes further by setting out a comprehensive package of measures to facilitate the transformation of low carbon hydrogen production in the UK, including capital and revenue funding support.

As we look to grow the UK's nascent hydrogen economy, we must consider the range of methods that could be used to produce hydrogen. Often badged with broad labels such as 'blue' or 'green', hydrogen production can encompass a wide variety of energy inputs and processes, all with different GHG emissions intensities. There is, however, no single understanding or formal definition of what is actually meant by 'low carbon' hydrogen in the UK.

We therefore appointed E4tech and the Ludwig-Bölkow-Systemtechnik (LBST) to provide advice and undertake research to inform policy decisions on a potential emissions standard that could define and standardise what is meant by 'low carbon' hydrogen. This work has informed the contents of this consultation, and we would recommend reviewing the report[6] alongside this consultation.

This 'Consultation on a UK low carbon hydrogen standard' sets out options for an emissions standard that could underpin the deployment of low carbon hydrogen for use across the economy. Depending on the outcome of the consultation, low carbon hydrogen producers seeking government support (such as capital and revenue funding support) would be required to comply with the standard.

In developing policy on a UK low carbon hydrogen standard, we have been mindful of the importance to encourage, rather than inhibit, new hydrogen production. To grow from a

[4] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution
[5] https://www.gov.uk/government/publications/uk-hydrogen-strategy
[6] https://www.gov.uk/government/publications/options-for-a-low-carbon-hydrogen-standard-report

near-zero base of low carbon hydrogen production at present to meeting our ambition of 5GW by 2030 means we need to kickstart the hydrogen economy in the UK now. To achieve this, we recognise that action is needed across the entire hydrogen value chain, and we are taking a coordinated approach to ensure that the broader enabling environment, including regulation, policies, and incentive mechanisms, are put in place in across the 2020s to kickstart the hydrogen economy and lay the foundation for a thriving market in hydrogen goods and services. Our natural assets, expertise, and innovation position us as a potential leader able to create strong supply chains with jobs and growth expected across our industrial heartlands. Further information on how we are addressing these, and other issues are included in the UK Hydrogen Strategy.

We think a standard can help with this: providing a clear and early message on our expectations for low carbon hydrogen, to ensure that any investment made today is directed towards production technologies that are consistent with the UK's net-zero commitments and carbon budgets. We also do not want a UK low carbon hydrogen standard to place undue administrative burden on parties where this is avoidable.

As well as developing a UK standard, we are focused on working with others to ensure the global hydrogen market, as it develops, is underpinned by common standards. International collaboration is vital to ensuring we effectively unlock the potential of hydrogen. By sharing expertise, concentrating our efforts, and working together to remove deployment barriers, we can expedite the development of low carbon hydrogen methods, and accelerate their roll-out. Governments cannot do this alone: global alignment will send a strong market signal of demand, and incentivise the private investment required to foster rapid innovation and associated cost reductions. Development of clear sets of common standards is essential to securing these benefits: they will deliver the clarity and confidence required to avoid fragmentation, and ensure investment is targeted to maximum gain, while environmental protections are upheld and extended. The UK is already a member of the International Partnership on Hydrogen and Fuel Cells in the Economy and participates in the taskforce looking at developing a common methodology for calculating GHG emissions associated with hydrogen production.

The consultation is separated into sections covering the following areas:

- The broad **scope** of the standard, including its use and coverage across different production methods and geographic location.
- How we would set the **system boundary** of the standard, including chain of custody, purity and pressure, embodied emissions, and global warming potential.
- Consideration of **energy inputs and feedstock emissions**, including interaction with the electricity grid.
- Further sections on the **methodology and potential thresholds for GHG emissions**.
- Options for the **delivery and administration** of a UK low carbon hydrogen standard.

It should be noted that all references in this consultation to life cycle emissions analysis are current estimates. This analysis will be subject to further internal review and consideration of information / views gathered through this consultation, as well as any relevant information received in respect of the associated consultations on the Net Zero Hydrogen Fund[7] and Hydrogen Business Model[8] design.

[7] https://www.gov.uk/government/consultations/designing-the-net-zero-hydrogen-fund
[8] https://www.gov.uk/government/consultations/design-of-a-business-model-for-low-carbon-hydrogen

The proposals

In this consultation, we set out initial options considered for a UK low carbon hydrogen standard that could underpin the deployment of low carbon hydrogen for use across the economy.

Our current intention, to be further informed by responses to this consultation, is that low carbon hydrogen producers seeking government support, through the Net Zero Hydrogen Fund, and/or the Hydrogen Business Model would be required to comply with the resulting standard in order to secure support. This is to ensure that any hydrogen incentivised through these schemes is contributing to our ambition to grow the hydrogen economy and carbon reduction targets.

We are considering whether the standard could also be developed into a certification scheme to support the deployment of low carbon hydrogen across the economy and support future international trade in low carbon hydrogen.

We expect to finalise design elements of a UK low carbon hydrogen standard by early 2022, while continuing work on delivery and administration considerations, and will work closely with industry to ensure its effective application. This programme of work will be kept under review, and we will evaluate its effectiveness during implementation to ensure it is meeting objectives and achieving value for money.

What is a UK low carbon hydrogen standard?

With increasing global interest and attention on the potential role that hydrogen can play in our net zero future, naming conventions such as 'green' or 'blue' have been used in varying forms as a broad way of categorising some of the different methods that can be used to produce low carbon hydrogen. As part of this work, we have considered several initiatives that have been developed around the world to characterise hydrogen as 'low carbon' or 'green', such as CertifHy[9] and TÜV SÜD[10]. Industry groupings and other international stakeholders are active in considering emissions from hydrogen production. For example, the Hydrogen Council recently published a report on life cycle emissions. The UK participates in a working group under the International Partnership for Hydrogen and Fuel Cells in the Economy, looking at developing a common global methodology for calculating emissions associated with low carbon hydrogen production.

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[9] CertifHy is a voluntary Guarantee of Origin scheme within the EU, EEA, and Switzerland
[10] TÜV SÜD is a voluntary renewable hydrogen standard in Germany.

In developing this consultation, we have worked with industry, academia and regulators on understanding and comparing options for an emissions standard that defines low carbon hydrogen, including:

- Setting out the methodology for calculating GHG emissions (e.g., the Life Cycle Assessment system boundary and assumptions for delivery conditions of the hydrogen produced); and
- Setting out the maximum acceptable levels of GHG emissions associated with low carbon hydrogen.

Supporting Net Zero

While some countries are focusing on a singular route to domestic hydrogen production deployment, analysis from both BEIS and the independent Climate Change Committee (CCC) shows that a mix of hydrogen production methods, including large scale gas reforming with carbon capture, utilisation, and storage (CCUS) and electrolytic hydrogen from low carbon electricity, is most likely to be appropriate for the UK.

A low carbon hydrogen standard has an important role in supporting this diverse range of technologies to come forward: by allowing a range of technologies to compete – as long as they are able to produce hydrogen that is sufficiently low carbon – we are maximising the UK’s chances of growing the hydrogen economy and unlocking the important role that hydrogen has to play in meeting our net zero commitments.

A UK low carbon hydrogen standard will therefore need to be applicable across different production technologies, including the main types of production expected to come forward during the 2020s (gas reforming with CCUS, and electrolytic hydrogen). Other production methods, including smaller scale projects and those which are further down the technology readiness levels, such as hydrogen from biomass gasification with CCUS and hydrogen from nuclear technologies, will also be covered by a UK low carbon hydrogen standard.

As hydrogen has a variety of potential end uses a UK low carbon hydrogen standard is expected to provide a GHG emissions threshold applicable equally across all end uses. However, this standard will not supersede any existing quality / safety standards for end use applications.

Overarching considerations

Our work is informed, in part, by the work of the previous DECC[11] Green Hydrogen Working Group, the DECC Call for Evidence on a Green Hydrogen Standard[12] published in 2015, and the resulting Government response. This is in addition to the more recent work undertaken by E4tech and LBST.

The E4tech and LBST study focused on four work packages (WP):

- WP1: Through interviews and research, identified the key challenges to be addressed in the development of a low carbon hydrogen standard in the UK, and global lessons learned. Five case studies of relevant schemes were conducted: CertifHy, TÜV SÜD, the Renewable Transport Fuel Obligation (RTFO), California Low Carbon Fuel Standard (LCFS) and the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE).

  Through the input of the UK's Hydrogen Advisory Council's Standards & Regulations Working Group, working sessions with BEIS and the findings from the WP1 interviews, defined eight criteria to guide the choices made when developing a low carbon hydrogen standard.
- WP2: Conducted lifecycle assessments of GHG emissions for representative hydrogen production pathways and downstream distribution chains in the UK, including a sensitivity analysis.
- WP3: Using a set of criteria developed during the project, defined and evaluated the possible options for a standard and made some recommendations for a UK standard.
- WP4: Provided a very high-level view of considerations for the delivery and administration of a standard.

The link to the full published report from this project, titled 'Options for a UK low carbon hydrogen standard', can be found here.

We deem the following issues out of scope for our work on a UK low carbon hydrogen standard, which are covered by other existing workstreams in BEIS, the Department for Transport, the Department for Environment, Food, and Rural Affairs, and the Health and Safety Executive:

1. End use safety / quality standards e.g., regulations for use of hydrogen in transport, or regulations on hydrogen boilers;

[11] Department of Energy & Climate Change, a precursor to BEIS
[12] https://www.gov.uk/government/consultations/green-hydrogen-standard-call-for-evidence

2. Gas Safety (Management) Regulations and entry standards for blending hydrogen into the gas grid;

3. Standards for other (non-hydrogen) decarbonised gases;

4. Wider environmental standards and regulations (e.g., water consumption, air quality), though we are not excluding the potential for further work on these areas later. Hydrogen producers will, of course, need to comply with current and future regulations on air pollutants including nitrogen oxides (NOx); and

5. Gas quality – e.g., the Wobbe Index

Consultation questions

In this consultation, we set out some initial options considered for the design and administration of a UK low carbon hydrogen standard.

The consultation has been informed by the report by E4tech and LBST on behalf of BEIS, as well as extensive industry engagement and we intend to finalise design elements of a UK low carbon hydrogen standard by early 2022. Depending on the outcome of this consultation, this standard is expected to support the eligibility and assessment processes of low carbon hydrogen projects seeking government support (including capital and revenue support schemes), allowing us to incentivise hydrogen production for use across the economy. We are also considering whether the low carbon hydrogen standard could be developed into a certification / guarantee of origin scheme to underpin deployment of low carbon hydrogen production, giving consumers confidence that the hydrogen they purchase is truly low carbon, and potentially supporting future international trade.

Government and private investment

The Net Zero Hydrogen Fund is for co-investment in new low carbon hydrogen production, with £240m confirmed for the period out to 2025. Consultation on scheme design was launched in parallel to this consultation, and the link can be found here.

We are also consulting on our preferred Hydrogen Business Model to bring through private sector investment and will provide more details this year on a revenue mechanism, which will provide funding for the business model. We intend that any future changes to the standard would not apply retrospectively to contracts already awarded through the Hydrogen Business Model. The link to the consultation can be found here.

Depending on the outcome of this consultation and further internal work, we expect a UK low carbon hydrogen standard to provide clear criteria for businesses seeking support from government on hydrogen production, for example through the Net Zero Hydrogen Fund, and/or the Hydrogen Business Model.

Scope

This section covers the broad scope of the standard, including its use and coverage. The UK Low Carbon Hydrogen Standard will support our 2030 5GW ambition on a pathway to net zero. The standard will need to be applicable across the main low carbon hydrogen production methods such as electrolysis or gas reforming with CCUS, other production technologies under development such as biomass gasification and hydrogen from nuclear energy, as well as by-product hydrogen from industrial processes. We expect the standard to include consideration of GHG emissions. Whilst other environmental impacts were not considered through this work (e.g., water consumption, air quality), we are not excluding the potential for further work on these areas later through other routes or policy mechanisms.

We expect that a UK low carbon hydrogen standard will:

- Ensure hydrogen projects supported by government are consistent with our net zero commitments;
- Help focus private sector investment on new low carbon hydrogen production methods (while ensuring existing production methods are not excluded from the scope of the standard if they are made sufficiently low carbon); and
- Provide confidence to end users that the hydrogen purchased is a true low carbon alternative to existing fuels.

Criteria defined for assessing options for a UK low carbon hydrogen standard

Through the input of the UK's Hydrogen Advisory Council's Standards & Regulations Working Group[13], working sessions with BEIS officials, and the findings from the WP1 interviews, eight criteria were defined to guide the choices made when developing a low carbon hydrogen standard:

1. Inclusive

- Open to all possible routes and scales (including hydrogen imports/exports).
- Treating all technology pathways equally based on GHG emissions alone.
- Able to be used by different end users.
- Flexible and able to deal with the addition of new and more complex routes or unique circumstances.

2. Accessible

[13] www.gov.uk/government/groups/hydrogen-advisory-council

- Cost-effective, with appropriate and acceptable costs of compliance for operators and for the scheme administrator.
- Simple, user-friendly, and adapted to business requirements.

3. Transparent

- Information is freely available about the approach, assumptions, impacts and process for making future changes.
- Impartiality is maintained in all decision making.
- Stakeholders can actively engage with governance, assurance, monitoring and proposed changes.

4. Compatible

- Can operate alongside UK schemes for other energy vectors (e.g. fuels, power), has the ability to convert certificates between vectors, and uses comparable GHG emission metrics.
- Is compatible with other countries' hydrogen standards, facilitating international trade.

5. Ambitious

- Consistent with the UK's net zero pathway requirements.
- Low threshold for GHG emissions, with other sustainability criteria defined where needed.
- Use of conservative assumptions if defining default GHG emission values.
- Supporting innovation and improved chain lifecycle GHG savings over time.

6. Accurate

- Low uncertainties regarding GHG emissions estimates and any categorisations or labels.

7. Robust

- Avoidance of fraud and misuse, with strong penalties in place.
- Frequency of reporting and auditing is adapted to the complexity of supply chains and identified risk levels, implementing at least a "limited" assurance level.
- Priority is given to auditors' skills and training, and strong grievance procedures established.

8. Predictable

- Providing investment security for the industry, and the ability to reliably forecast compliance.

- Limited likelihood of large swings in GHG emission values which may tip marginal chains close to a threshold over in certain years.

Geographical scope

The standard will need to define a geographical scope. Possible options include:

- Only UK production and use included
- UK production only, with use in the UK or export
- UK and imported production included, for use only in the UK

Whilst the UK is currently working with other countries to discuss alignment of future standards, allowing imported hydrogen to be part of the standard could potentially have consequences on the accuracy of the GHG emissions or could present a barrier to trade if countries use, for example, other system boundaries or rules for electricity use. The E4tech and LBST report analyses elements of some of the existing international standards on hydrogen.

Q1.	**Do you agree that the standard should focus on UK production pathways and end uses whilst supporting future export/imports opportunities? Yes/no. Please expand on your response.**
Q2.	**Would there be benefits in developing the standard into a certification scheme? Yes/no. Please provide detail.**
Q3.	**a. Is international consistency important, or should the UK seek to develop a low carbon hydrogen standard primarily based on the UK context and criteria set out above? Please provide detail.**
	b. If elements of a UK standard differ to comparable international standards or definitions, would this impact the ability to facilitate investment in the UK or cause issues for business operations across borders? Yes/no/unclear at this stage. Please provide detail.
	c. If answering yes to 3b, what elements of existing low carbon hydrogen standards or definitions are most important to ensure international consistency?

Allowable production pathways

The standard could either be applicable to (a) any existing and future hydrogen production pathway (i.e., including the different processes in the value chain for production methods) or (b) only a specific list of pathways, which could be updated periodically or on request. If a list of specific production pathways were allowed in the standard, the producers would still need to demonstrate compliance but could potentially have default emissions values, which could be a more cost-effective option for users. For new or novel production pathways, there could be a method of calculating emissions. A no list option would allow the standard to be applicable to any production pathways. However, this could mean that all operators may have to incur additional costs to achieve compliance.

Q4.	**a. Should the standard specify a list of hydrogen production pathways, which would be updated periodically or on request? Yes/no.**
	b. If yes, we would welcome respondents' views on what production methods could have significant potential in the UK in the near term.
	c. If no, we would welcome respondents' views on alternative options.

Categorisation

Through this standard we are looking to define what is meant by 'low carbon' hydrogen, by setting a GHG threshold for GHG emissions. Some comparable standards or schemes in operation also apply different labels according to production method. For example, the CertifHy scheme distinguishes between 'green' hydrogen from renewable sources and 'low carbon' hydrogen from fossil fuels. These alternative labels / categories often mean that the hydrogen must meet further characteristics (such as using renewable inputs) as well as meeting a GHG threshold to qualify. Applying different labels such as this could be used when assessing eligibility to access different levels of funding.

In line with our approach to growing the UK hydrogen economy, as set out in our Hydrogen Strategy, we expect to support a variety of different production methods to deliver the level of hydrogen needed to meet net zero. We are therefore minded to adopt a single label of 'low carbon' that can be applicable to all production methods that meet the GHG threshold. Any differentiation in funding for projects meeting the 'low carbon' criteria would therefore be made through the relevant application process rather than through further distinctions in the standard.

Q5.	**a. Do you agree that the standard should adopt one label of 'low carbon' hydrogen, or would it be valuable to have multiple categories?**
	b. If multiple categories, what benefits would we get from adopting this approach in terms of emissions reduction and consumer confidence?

System Boundary

Setting the point in the supply chain at which a low carbon hydrogen standard applies (the calculation point) is critical when designing a standard, as it could impact decisions around the reference delivery conditions (e.g. purity and pressure) and the calculation of GHG emissions.

The main options assessed for establishing the extent of the system boundary are:

- **At the point of production** (PoP): This is calculating the GHG emissions of the hydrogen produced at the exit of the production plant.
- **At the point of use** (PoU): The GHG emissions of delivered hydrogen include production emissions as well as the emissions from downstream distribution to the end user. However, any emissions from the final use of the hydrogen are excluded.
- **At the point of use + in use emissions** (PoU + in use): The GHG emissions calculation includes production emissions, distribution emissions, and emissions arising from the use of hydrogen (e.g., any hydrogen 'slip' as fugitive emissions during the use phase, or high-temperature combustion nitrous oxide (N2O) emissions, or other carbon dioxide (CO2) & methane (CH4) emissions given the hydrogen will not be 100% pure). However, this is not calculating the GHG emissions of the service provided (generated heat, power, transport mobility, etc.) by taking into account in use efficiencies – the emissions calculation is still per unit of hydrogen consumed.

For all options, all upstream emissions back to the point where emissions contributions are no longer material are considered.

The choice of the system boundary should be considered taking into account the need for the standard to be applicable across all potential end uses, and the role of this standard as a criterion for BEIS policy mechanisms such as capital and revenue support.

Our minded to position is setting the system boundary at the point of production. A point of production system boundary could risk omitting potentially significant downstream emissions but would have lower cost of compliance, the ability to interact with other guarantees of origin schemes and would broaden access to hydrogen imports.

Q6.	**a. Do you agree that a UK low carbon hydrogen standard should be set at the 'point of production'? Yes/no.**
	b. If no, what would the advantages be of the standard making assessments at 'point of use' or 'point of use + in use emissions'?

Chain of Custody

Chain of custody (CoC) requirements define how compliant hydrogen (i.e., hydrogen produced that meets the standard) passes through the value chains until it reaches the chosen system boundary. CoC requirements should ensure sufficient traceability and transparency across the value chain, while not adding unnecessary administrative efforts or costs for the operators implementing the standard.

Two lead options are being considered:

- **Mass balance systems:** could be an option for a standard with a downstream system boundary set at the point of use, to underpin schemes where the objective is solely to support low carbon hydrogen production. This ensures some physical traceability for compliant products at all stages of the value chain, but compliant and non-compliant products can be mixed. Operators are required to monitor and keep records of the balance of compliant and non-compliant batches of inputs to their operation. They are then allowed to claim compliance on outgoing products if they are in the same proportion as the entering inputs (taking into account process efficiencies, losses, etc.). Mass balance is currently used in TÜV SÜD (if assessing to the point of use), the RTFO and is under development in CertifHy.

- **Book and claim (certificate trading) systems**: could be an option for a standard with a downstream system boundary set at the point of production, to underpin schemes where the objective is solely to support low carbon hydrogen production. Compliant operators deliver products onto the market and "book" equivalent volumes of compliant products to be traded, via a certificate platform. Buyers can acquire compliance certificates and "claim" a contribution to the production of an equivalent volume of compliant products. Book and claim systems are more affordable than other CoC systems, but they do not guarantee any physical traceability and are therefore generally seen as less reliable. Book and claim is currently allowed in the EU CertifHy scheme. Note that an operator already using a mass balance approach (e.g., for RTFO compliance) would be able to use the same data to comply with a standard based on book & claim. However, it is less clear whether the reverse will be possible – under current REDII[14] discussions, it is being debated whether an upstream guarantees of origin (book & claim) system could be combined with a downstream mass balance system, and what accompanying changes would be necessary in assurance systems.

[14] EU Directive on the promotion of the use of energy from renewable sources

Q7.	**Which chain of custody system would be most appropriate for a UK low carbon hydrogen standard: a mass balance or a book and claim system? Please explain the benefits of your chosen option.**
Q8.	**Should other CoC options be considered instead? Yes/no. If yes, please provide detail.**

Hydrogen purity and pressure reference delivery conditions

Different hydrogen production pathways produce hydrogen at different purities and pressures, and different hydrogen end uses have different purity and pressure requirements. If the downstream system boundary is the point of use, then this point of use will have a defined purity and pressure set by the end user. However, if the downstream system boundary is the point of production, it may be necessary to define a reference purity and pressure to enable comparison between production routes. This would avoid the situation where a process producing very low quality (i.e., low purity or low pressure) hydrogen appeared to meet the GHG threshold, despite significant additional emissions then occurring outside the system boundary when it requires purification and/or compression.

Note that work done under the Hy4Heat programme[15] recommended a minimum purity standard for domestic end use of 98-100%, which has been taken forward as the basis of the new hydrogen appliance design standard issued by BSI (PAS 4444). By contrast, for use in fuel cell vehicles, hydrogen purity of 99.999% will be required (ISO 14687:2019).

The main options considered are:

- **Not specified** – in this case the GHG intensity of hydrogen would be considered "as is" at the calculation point, at its current purity and pressure level. This approach is taken in the RTFO and LCFS, where the calculation point is at the point of use + in use emissions, with end user requirements determining the purity and pressure.
- **Defined reference purity and pressure** – here purity and pressure levels would be specified as GHG calculation references. If hydrogen exited the system boundary at lower purity and/or pressure, default factors for the extra emissions associated with purification and/or compression to reach the reference purity and pressure would be added to the GHG emissions calculations. This approach is taken by CertifHy for pressure (i.e., hydrogen can be produced at lower pressures, but CertifHy GHG calculations always have to assume at least 3MPa is achieved), and by TÜV SÜD for purity (where the extra emissions required to achieve the required minimum 99.9% purity are estimated and verified by an auditor). For pressure, TÜV SÜD also

[15] https://www.hy4heat.info/

requires GHG calculations to assume compression to 3MPa unless hydrogen is fed into the natural gas network at lower pressure.

- **Minimum purity and pressure** - CertifHy requires a hydrogen purity of at least 99.9%vol, i.e., only hydrogen at this purity or above is currently permitted to be certified under the scheme, although this may change in the future, with more flexible options being allowed for local uses.

Q9.	**a. If the system boundary was set at the point of production, should there be defined reference purity and pressure levels for a UK low carbon hydrogen standard? Yes/no.**
	b. If yes, what should they be?
	c. If no, what are the benefits to not defining reference purity and pressure levels?
Q10.	**a. Should there be minimum pressure and purity requirements for hydrogen to meet the standard? Yes/no.**
	b. What could the potential implications of setting minimum purity and pressure requirements be?

Embodied emissions

There are additional emissions associated with the raw materials and processes used to manufacture, construct, maintain and decommission capital equipment used in hydrogen production, as well as equipment used in energy generation, vehicles used for the transportation of hydrogen, hydrogen storage etc. Calculating these embodied emissions would involve estimating material usage in the capital equipment, the location of production and relevant emissions factors, and then dividing up these capital emissions (typically incurred in the years before hydrogen production starts) across the operational lifetime. Available estimates suggest that these emissions would be relatively modest in almost all cases (~1 gCO2e/MJLHV of hydrogen for ATR (autothermal reforming) with CCUS, and ~4 gCO2e/MJLHV of hydrogen for wind electrolysis) and will fall over time with the decarbonisation of our global energy supply and the manufacturing sector.

There are therefore three potential options we have considered:

- **Excluded**. This would be consistent with current hydrogen standards, low carbon fuels standards, and REDII, which do not include embodied emissions within scope.

- **Included for hydrogen production technology only**. This would only include equipment procured by the project owner, for which it may be easier to request data from manufacturers.
- **Included for all supply chain equipment.** This would cover energy generation sources, hydrogen production technology, transport vehicles, storage vessels etc. This option could be complex, costly, and difficult to audit, but would likely be the most ambitious in terms of emissions coverage and reduction.

We propose excluding embodied emissions from the scope of a UK low carbon hydrogen standard as this is not currently accounted for in the UK's carbon budgets accounting or other comparable global standards/schemes. This will ensure low carbon hydrogen production is on a level playing field to other energy vectors. However, should the UK or global context change, this could be reviewed and updated accordingly.

Q11.	**a. Do you agree that embodied emissions should be omitted from the calculation of GHG emissions under a low carbon hydrogen standard, to ensure comparability with global and UK schemes? Yes/no.**
	b. If no, what are the benefits to including embodied emissions in the calculation of GHG emissions, and what should be done to ensure that hydrogen is on a level playing field to other energy vectors?

Choice of Global Warming Potential factors

Global Warming Potential (GWP) factors are used to estimate the radiative forcing of 1 unit of a greenhouse gas compared to 1 unit of CO2. It is our intention that a UK low carbon hydrogen standard will use GWP factors that are in line with wider UK Government policy on GHG accounting, including the Global Warming Potential for Hydrogen.

When calculating overall GHG emissions, the standard could include a GWP factor to account for any hydrogen losses incurred when the hydrogen passes through the supply chain (known as fugitive losses). The GWP factor would be set in line with existing Government policy and is currently subject to ongoing work within BEIS. Including a GWP factor for hydrogen would give more accurate calculations of GHG emissions from hydrogen production. Improving knowledge on fugitive losses would also improve the accuracy of the GWP of hydrogen over time and could support further emission reductions.

Whilst including a GWP factor of hydrogen in the standard would give a more accurate representation of emissions, there would be disadvantages to this route:

- Estimations of the GWP of hydrogen have high uncertainty (current estimates lie between 0 – 14 tCO2e/t hydrogen), partly because it is an indirect GHG, and so the figures used may change over time, which could cause uncertainty for the hydrogen production industry.

- Hydrogen GWPs are not included in any other schemes such as CertifHy or TÜV SÜD, so including them would reduce comparability.
- Measuring hydrogen losses can be complex, as hydrogen measurement techniques may not be sufficiently accurate to estimate low level of losses.

Q12.	**a. Do you agree that a UK low carbon hydrogen standard should include the global warming potential of hydrogen? Yes/no.**
	b. If no, are there other options for accounting for the GWP of hydrogen outside of a UK low carbon hydrogen standard that could support compatibility with existing standards/schemes?

Materiality

Life Cycle Assessment (LCA) analyses typically define a “materiality” level: if emissions from an input or process are estimated to be below a small percentage of the final result, typically 1%, they can be excluded. For example, in the PAS2050 specification for assessing LCAs, a product carbon footprinting standard, the cut-off is 1%, provided that at least 95% of total emissions are included.

A materiality threshold for data quality is also possible, and is used in other hydrogen standards e.g., up to 5% of the input energy can be conservatively estimated without the need for exact measurements. This reduces the effort of measuring energy consumption that is quantitatively minor (e.g., auxiliary systems such as pumps, ventilation, etc.). This does not imply that 5% of the energy will not be accounted for, but rather that 5% of the energy consumption are estimated rather than measured in detail[16]. TÜV SÜD applies a materiality threshold of 5%. An earlier CertifHy report also referenced use of a 5% threshold, but CertifHy now specifies that production batch audits “shall be performed in accordance with the ISO 14063-3 standard as well as the EU Directive 2003/87/EC. The Auditor will perform the audit with all due means to verify accuracy and completeness of the Production Batch registration.”[17]

Q13.	**a. Should a materiality threshold for total emissions be included in the life cycle assessments of hydrogen pathways? Yes/no.**

[16] Technical Report on the Definition of ‘CertifHy Green’ Hydrogen”, Deliverable No. D2.4, “Technical Report on the Definition of ‘CertifHy Green’ Hydrogen”, Status: Final, 26 October 2015, https://www.certifhy.eu/publications-and-deliverables.html

[17] CertifHy Scheme Subsidiary Document Procedure 1.1 “GO Issuing”, 11 March 2019, https://www.certifhy.eu/publications-and-deliverables.html

	b. If yes, what would the most appropriate level be and why?

Inclusion of CCU as an allowable benefit in GHG calculation

Carbon (typically CO2) can be captured from several hydrogen production pathways. This CO2 can either be sequestered (such as through permanent underground storage), or else utilised in different downstream applications. The treatment of CCS (carbon capture and storage), allowing a reduction in lifecycle GHG emissions of hydrogen, is commonly applied in existing standards. There is, however, no commonly adopted method for the treatment of CCU (carbon capture and utilisation) in existing standards. There are also no clear and consistent rules for CCU in international standards such as ISO (International Organization for Standardization) and CEN (European Committee for Standardization).

The inclusion of CCU within hydrogen GHG emissions calculations would require clear and consistent rules for the calculation and potential credits. It may also be necessary to consider the source of the carbon that is utilised in CCU; distinctions should be made between biogenic, or fossil carbon, as well as whether distinctions should be made regarding the origin of any CO2 currently used by downstream users, as this will have bearing on emissions savings. Several options are possible to account for CCU in a Low Carbon Hydrogen Standard.

- CCU could be **included only with proven displacement** of CO2 from fossil origin, potentially with additional rules about this fossil CO2 having previously been purposely generated (to ensure fossil fuels are being displaced).
- CCU could be **included only with proven permanent abatement of CO2**. For this option, clear rules need to be set as to the minimum time before the carbon can return to the atmosphere.
- CCU could **not be given any credit**.

CCU with proven displacement or permanence of the CO2 remaining out of the atmosphere could potentially be included in a UK low carbon hydrogen standard. Should one of these options be chosen, a GHG credit can be given to the hydrogen production if operators demonstrate that the utilisation of captured carbon ensures that it will not return to the atmosphere over an agreed minimum period of time (e.g. via its use in construction materials), and proof that by using the CO2, the operators have reduced overall net emissions compared to the counterfactual scenario where the CO2 was not used. This demonstration of permanence would require clear rules, which may vary according to the type of utilisation. A list of authorised utilisations could be established and maintained.

Q14.	**a. Should CCU with proven displacement or permanence be included as an allowable benefit in GHG calculations under a UK low carbon hydrogen standard? Yes/no.**

	b. If yes, what should a suitable minimum time be for proven permanence and which applications should be eligible?
Q15.	**Should CCU credits only be allowed for biogenic carbon, and not allowed for fossil carbon sources? Yes/no.**

Energy inputs/ feedstock emissions

Low carbon electricity and additionality considerations

Hydrogen produced from electricity (as the primary energy input) is only as low carbon as the electricity used to produce it. The UK has dramatically reduced greenhouse gas emissions from electricity generation, achieving a 72% reduction between 1990 and 2019[18]. However, there is more to do, and electricity generation is still a significant source of carbon dioxide emissions, with the average carbon intensity from generation at 198g/kWh in 2020[19].This will need to fall further, and as we progress towards net zero, we will deliver an overwhelmingly decarbonised power system in the 2030s, with over 75% of electricity projected to be from low carbon sources by 2030[20].

The standard will need to determine how the use of low carbon electricity should be accounted for and the evidence that is required to prove the electricity comes from a low carbon source. The wider electricity system impacts caused using electricity as a primary energy input for hydrogen production also need to be considered.

In developing this standard, we have considered whether government policy support should be available to all hydrogen production facilities regardless of energy input, or only a subset of these projects that have taken steps to source low carbon energy as an input. Rapid growth of electrolytic hydrogen production over the 2020s is a critical element of our UK Hydrogen Strategy, and we do not want to limit growth with rules that overly constrain the primary energy input.

A range of options have been considered (these options are not mutually exclusive, and several options could be allowed):

- Allow low carbon electricity use to be claimed based on physical links. There is the risk of very few electrolysis-based pathways being incentivised using this option alone, but it would offer strong evidence that the electricity used is low carbon. Options could include:
    - Off grid – the whole system (low carbon electricity source and electrolyser) is not connected to the grid;
    - Use of curtailed / constrained power – the generator is connected to the grid but supplies the electrolyser only when grid supply is not possible;

[18] The 2019 figures are provisional estimates. BEIS (2020), 'Provisional UK greenhouse gas emissions national statistics 2019', https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2019
[19] https://www.gov.uk/government/statistics/digest-of-uk-energy-statistics-dukes-2020
[20] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019

    - No import from the grid – the generator supplies to the grid and to the electrolyser, but the electrolyser does not use electricity from the grid (with additionality requirements).

- Allow low carbon electricity to be claimed based on traded activities alone. This could require hydrogen producers to prove a certain percentage of their power demand is met by PPAs with existing plant or guarantees of origin. This option would be more inclusive and help provide proof that the hydrogen producer is not buying their electricity from high carbon sources but could lead to additional GHG intensive electricity generation to make up for increased demand. This could include:
    - Cancellation of guarantees of origin or equivalent – i.e. the user buys and cancels certificates associated with low carbon power production.
    - Bilateral power purchase agreement with cancellation of guarantees of origin or equivalent – i.e. the user buys low carbon power and cancels certificates associated with it.
- Allow low carbon electricity use to be claimed based on traded activities, with cancellation of guarantees of origin or equivalent, and with further conditions. There is a risk that allowing users to claim low carbon power use based on retiring guarantees of origin alone has unintended consequences, such as driving additional high carbon power generation. The further conditions could include:
    - Temporal correlation with electricity generation (e.g. at hourly level in order to ensure that electrolysis supports grid stability and integration of large shares of fluctuating renewables);
    - Geographical correlation with electricity generation (e.g. within a certain distance, or the user not being on the other side of grid congestion that would prevent the renewable electricity being used, i.e. there is available transmission capacity); and
    - Additionality considerations (below).
- Allow electrolysers to plug into the existing grid. This option is low cost and straightforward but can only be guaranteed to be low carbon if the grid mix is sufficiently decarbonised. To calculate GHG emissions of this option, we would need to take an average carbon intensity of the grid if hydrogen producers are unable to provide local or temporal carbon intensity data related to the grid at the time of use. For hydrogen producers only relying on this option, compliance with a UK low carbon hydrogen standard may only be guaranteed if the carbon intensity of the grid is sufficiently low, or proof can be provided that grid electricity used is only during times of low carbon generation and/or electricity market prices are low. This may mean certain projects are disincentivised until the grid mix is sufficiently decarbonised.

A decision on this element will also need to be made alongside considerations on the Hydrogen Business Model, as it is likely to impact on the eligibility of projects and could play a role in influencing the operating mode of electrolysers that could be supported by the Hydrogen Business Model. We are planning to conduct further analysis in the coming months regarding the impact of electrolysis on the wider energy system, including availability of low carbon electricity and the potential impact of grid electrolysis over time. We will use this analysis as part of our considerations for how the standard will be applied and will set out more detail on our findings in the Government Response to this consultation. We would welcome any evidence from stakeholders that could contribute to this work.

Q16.	**As the grid is decarbonising rapidly, so will grid connected hydrogen production pathways. How should government policy take into consideration hydrogen production pathways using grid electricity as primary input energy now? Please explain the benefits to the approach you have suggested.**
Q17.	**a. What options should we consider for accounting for the use of electricity under a UK low carbon hydrogen standard? Do the options outlined seem appropriate? Are any of these particularly problematic? Please explain your reasoning.**
	b. Of the options considered, should further conditions be included to mitigate any negative impacts or potential unintended consequences, such as driving additional high carbon power generation, and what could these conditions be?
Q18.	**What evidence should BEIS consider ahead of making decisions around the use of electricity as primary input energy for hydrogen production?**

Additionality considerations

A further decision for the standard is whether to define a requirement for additionality, to ensure that use of electricity for hydrogen production incentivises new low carbon power generation rather than just diverting low carbon electricity (or renewable heat and other energy vectors such as biomethane) from other users with the increased demand met by higher carbon options.

There is a risk that including such a requirement would increase costs around hydrogen production and could impact the deployment of new electrolytic hydrogen production essential for 2020s. Further analysis will be conducted over the coming months to understand the impacts of electrolytic production on the electricity system over the 2020s, and our policy approach will be focused on ensuring we balance the need to meet our ambitious target of 5GW of low carbon hydrogen production capacity by 2030, whilst avoiding any unintended consequences.

We are considering a range of options, including more than one option being allowed under the standard:

- **No requirement**: ensure additional electricity deployment required to match increased demand due to hydrogen electrolysis is low carbon through other policy instruments, such as renewable electricity or carbon intensity targets for the power sector. Not including an additionality requirement under a UK low carbon hydrogen standard still allows the use of the options listed above for ensuring hydrogen production supports low carbon electricity generation, such as allowing low carbon electricity to be used based on traded activities or physical links. This approach could also be used once the generation mix already is sufficiently decarbonised allowing the administrator to be confident that additional power demand will be met by low carbon power. This option is inclusive but does rely on other policies to ensure the growth in low carbon electricity supply.
- **New build requirement**: require that all or a percentage of power used for electrolysis has to come from new build low carbon power generation assets. This option – as for the fund contribution option below– requires hydrogen producers to prove additionality, but on its own would not require other users of low GHG inputs to prove additionality (for example users of lower GHG intensity natural gas sources). It could also have a large impact on the capital requirement for new electricity users producing hydrogen.
- **Pay existing levies:** ensuring that all electricity that is used for the production of electrolytic hydrogen is subject to existing low carbon levies to fund low carbon power deployment.
- **Fund contribution:** require that all new electricity users pay a fixed rate per kWhe that has to go into a separate fund for low carbon power development/deployment. This could be achieved through the creation of a new fund specifically to fund additional low carbon generation (beyond that which is already supported through the existing levies) commensurate to the level of additional demand.

Different existing schemes and standards have opted for different approaches. CertifHy is still considering these options. Under the current RTFO, the supplier must provide data to prove additionality, such as planning proposals for new renewable power sites that will be constructed at the same time or after the fuel production plant. TÜV SÜD requires additionality for renewable electricity, with three options for satisfying this requirement (at least >30% from new renewable energy sources, a €2/MWhe payment into a development fund, or a specific technology mix that it can be assumed renewables are not being displaced or that the expansion of energy from renewable sources is promoted).

We are planning to conduct further analysis on potential additionality requirements being included as part of the standard, and we would welcome any evidence from stakeholders that could contribute to this work. We intend to set out further detail in the Government Response to this consultation.

Q19.	**How should low carbon electricity use in hydrogen production be accounted for in order to support the deployment of hydrogen production via electrolysis, whilst avoiding unintended consequences such as increased generation from high carbon power sources (impacting grid decarbonisation)?**
Q20.	**Should a UK low carbon hydrogen standard include a requirement on additionality and why? Please explain the benefits to the approach you have suggested.**
Q21.	**Should additionality considerations also apply to renewable heat and other input energy vectors such as biomethane, in the same vein as for low carbon electricity and why? Yes/no. Please explain the benefits to the approach you have suggested.**

Accounting for waste fossil feedstocks

The accounting of waste fossil feedstocks under a UK low carbon hydrogen standard, such as the non-biogenic fraction of municipal solid waste, is highly dependent on the trade-offs between reporting effort, accuracy, and potential for change over time. There are several options for the accounting of waste fossil material used for hydrogen production. These take into account the GHGs released during the processing of the material and can also consider the impacts of diverting that waste stream from an alternative fate (counterfactual) on the life-cycle emissions of hydrogen. In some cases, the counterfactual can store carbon for a long time (e.g. through the disposal of plastic to landfill, where it may not degrade for many years), or can provide a service which would need to be replaced by an alternative process (such as generating electricity in an incinerator, which could be replaced by grid electricity).

Rules are yet to be defined for the accounting of fossil wastes in other schemes: under the EU's RED II[21], the methodology for 'recycled carbon fuels' is currently being determined through preparation of a delegated act, and similarly under the RTFO the approach to be used for recycled carbon fuels has been developed.

[21] Recast of the Renewable Energy Directive: https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii

Options considered here are:

- **Consider as a fossil feedstock without counterfactuals:** the definition of the feedstock as a waste does not confer any benefit, and any release of fossil GHGs to atmosphere during feedstock processing (or elsewhere in the supply chain, e.g., during fuel use due to minor impurities) is counted as a fossil emission.
- **Consider as a fossil feedstock with counterfactuals**: Any GHGs from feedstock processing (or elsewhere in the chain) released to the atmosphere are counted as fossil emissions. But in addition, avoided emissions from the displacement of a counterfactual feedstock use (e.g., combustion in an incinerator) are credited to the hydrogen production chain, along with additional emissions generated to compensate for the displaced counterfactual use (e.g., producing an equivalent amount of grid electricity). A simplified version of this approach is proposed in the RTFO Consultation, with a single counterfactual proposed.[22]

Q22.	**a. Should waste fossil feedstocks be considered with counterfactuals under a UK low carbon hydrogen standard? Yes/no. Please explain the benefits to the approach you have suggested.**
	b. What are the potential implications of supporting the use of any particular waste streams in hydrogen production?

Mixed inputs

If the hydrogen production method has mixed inputs (e.g., high, and low carbon inputs), the standard will need to define whether the outputs are treated as one consignment or whether the operator should separate this into several different consignments (with different GHG intensity levels). If separate consignments are allowed, there is also a decision around whether each consignment is required to meet the GHG threshold, or whether it be acceptable for some not to meet the threshold, and under what circumstances. For example, this may include electrolysers or chlor-alkali facilities consuming both grid electricity (which is a mix of renewable, nuclear, and fossil generation sources) and low carbon electricity, or gasification plants consuming residual waste (which is a mix of biogenic and fossil fractions). A decision on this element will need to be made alongside considerations on the Net Zero Hydrogen Fund and Hydrogen Business Model, as it

[22] In the proposed Department for Transport (DfT) methodology, the diversion of the fossil fraction of RDF or industrial waste CO gases is assumed to have an energy-from-waste power generation counterfactual (so fossil feedstock emissions from producing hydrogen or power cancel each other out, i.e., assuming no CCS, but then additional grid electricity emissions assuming a 26% generation efficiency need to be accounted for). See DfT (2021) "Targeting net zero - Next steps for the Renewable Transport Fuels Obligation" https://www.gov.uk/government/consultations/amending-the-renewable-transport-fuels-obligation-rtfo-to-increase-carbon-savings-on-land-air-and-at-sea

impacts which projects would be eligible. For example, whether projects are only eligible if the whole impacts of the project were beneficial in GHG terms, or whether it be acceptable to provide support for only the portion of the output hydrogen meeting the standard. This decision could also affect the choice of threshold value, given that it could affect the supply of hydrogen likely to be available under a given threshold value.

Options could include:

- **Averaging** across all consignments (so all hydrogen produced has the same GHG emissions intensity and must meet the GHG threshold set).
- **Separate consignments** (with potentially different GHG emissions). For example, if an electrolyser has 60% low carbon electricity, 40% high-carbon electricity inputs, the operator may be able to claim 60% low carbon hydrogen, 40% high-carbon H2, or vice versa.
- **Separate consignments but with averaging** – separate consignments are used but the average emissions of all consignments also need to meet a benchmark figure (e.g. in CertifHy, the annual average needs to be below a 'benchmark' Steam methane reforming (SMR) figure of 91 gCO2e/MJ).

The RTFO currently operates using separate consignments for solid/gaseous/liquid feedstocks (based on their renewable vs. non-renewable fractions), and whilst it does split grid electricity use into separate renewable and non-renewable consignments for renewable fuels of non-biological origin (RFNBOs), the same grid average intensity is applied to both consignments. These rules are yet to be fully defined for the accounting of mixed inputs in other schemes, including in the EU's RED II.

Q23.	**What is the most appropriate way to account for hydrogen produced from a facility that has mixed inputs (high and low carbon)? Please explain the benefits to the approach you have suggested.**

GHG methodology

The GHG emissions threshold at which the standard is set will depend on several methodological choices that will need to be made, among which:

- **Units**: almost all existing standards use gCO2e/MJ LHV (Lower Heating Value) for calculating GHG intensities of hydrogen or transport fuels, but some use kgCO2e/kg hydrogen. Other options could include for example kgCO2e/kWh HHV (Higher Heating Value). Our minded to position is to use gCO2e/MJ LHV.

- **Allocation of emissions to by-product hydrogen**: The allocation of upstream and process GHG emissions between hydrogen and other products is usually done on an LHV energy basis. However, this approach may significantly over-allocate emissions to hydrogen when other significant co-products do not have an energy content, as is the case for some processes such as chlor-alkali. A different allocation method to energy allocation will therefore need be adopted in these cases, as already occurs in CertifHy, TÜV SÜD and the LCFS. This could be enthalpy-based (based on the relative enthalpy[23] of the products), market value-based (emissions based on the relative market value of the products) or use system expansion (consider emissions saved by displacing the co-products in their market, through the best available technology).

- **Negative emissions**: If the standard allows for reporting of negative emissions (through the inclusion of GHG credits for biogenic CCS or CCU), then, given the same annual tonnage of CO2 captured in processing, less efficient chains could actually deliver biohydrogen with a more negative GHG intensity (a lower value in terms of gCO2e/MJ LHV hydrogen), which could lead to some unwanted outcomes. Therefore, if any GHG thresholds under a standard were to ever be set as zero or negative, additional safeguards or requirements would likely be needed to ensure that certain minimum efficiencies are achieved for processing plants and distribution chains, to prevent perverse outcomes whereby only inefficient chains are able to achieve the new threshold.

- **Non-GHG impacts**: for instance, sustainability criteria for biomass routes as is the case for the RTFO. Other non-GHG impacts could include the use of water as feedstock or air quality impacts (e.g. the amount of NOx produced, and the difficulty in abating these emissions, can vary between hydrogen production methods).

[23] Enthalpy equals the internal energy and the product of the pressure and volume.

Q24.	**What are the most appropriate units to calculate GHG emissions of low carbon hydrogen?**
Q25.	**What allocation method should be adopted for by-product hydrogen and why?**
Q26.	**Should the standard allow for negative emissions hydrogen to be reported? Yes/no.**
Q27.	**a. Should non GHG impacts be taken into account? Yes/no.**
	b. If yes, what criteria or factors should be taken into account and how?
	c. If no, please set out your rationale for your answer.

GHG emissions thresholds

Having calculated the GHG emissions of hydrogen, a GHG emissions threshold can be used to determine whether this hydrogen meets the requirements of a standard or not. Assuming other acceptance criteria are met (e.g. any sustainability or additionality rules), then hydrogen GHG emissions intensities below the threshold would be allowed under a standard, and emissions intensities above the threshold would be excluded.

There are several options for GHG emissions thresholds to be defined in a standard.

- **Use of a fossil comparator:** the GHG emissions threshold could be an absolute maximum value or could be set up as a minimum percentage GHG saving versus a fossil comparator (e.g. unabated natural gas SMR). UK and EU schemes often describe this as a minimum % GHG saving compared to a high carbon benchmark, but the requirement is still to be below the absolute threshold level when reporting the hydrogen GHG emissions, rather than being above the required % GHG saving. Whilst a minimum percentage GHG saving has to be translated into an absolute emissions value for assessing compliance with the standard, this latter option has the potential to update the fossil comparator without changing the % saving required. The choice is therefore whether the standard should specify a fossil comparator or not.
- **Single vs two or more GHG thresholds**: A decision will be required as to whether the standard should allow for one or several GHG emissions threshold. Having a single GHG emissions threshold for all chains would be applicable across all technologies and would likely be the simplest solution. It would be compatible with the current RTFO and CertifHy schemes but would not necessarily incentivise lower carbon routes to lower their emissions further. Having two GHG thresholds applicable across all technologies would mean that operators would have the possibility of meeting looser or stricter thresholds, with the potential for preferential support to be provided to those meeting the stricter threshold. It would however be a less simple option and the approach differs from other schemes.
- **Increased ambition over time**: the GHG emissions threshold could decrease over time, either via ad-hoc revision, periodic revisions or with a pre-announced decreasing trajectory. A number of technologies (particularly those reliant on grid electricity as a primary energy input) are projected to see their emissions fall through time. Should this option be chosen, we intend that any future changes to the standard would not apply retrospectively to contracts already awarded through the Hydrogen Business Model.

  Setting the threshold at a lower level from the early stages of hydrogen deployment and keeping this flat over time, would reduce the emissions from hydrogen production compliant with the standard but could reduce the number of pathways that were compliant initially. If this stifled some production methods, this could reduce the overall emissions saving of any policy mechanism or fund. Setting the threshold at a higher level in the early stages of hydrogen deployment, with a tightening in the future to drive improvement, could widen access to different hydrogen production pathways. Widening access could increase the emissions from hydrogen production compliant with the standard in the near-term, but potentially deliver long term decarbonisation benefits, should projects have a plan to sufficiently decarbonise their operations over time. For example, electrolyser projects may switch to only using low carbon electricity over time. However, there is a risk of supporting construction of some projects today that lock in emissions at a higher level than would be acceptable to achieve net zero in the future.

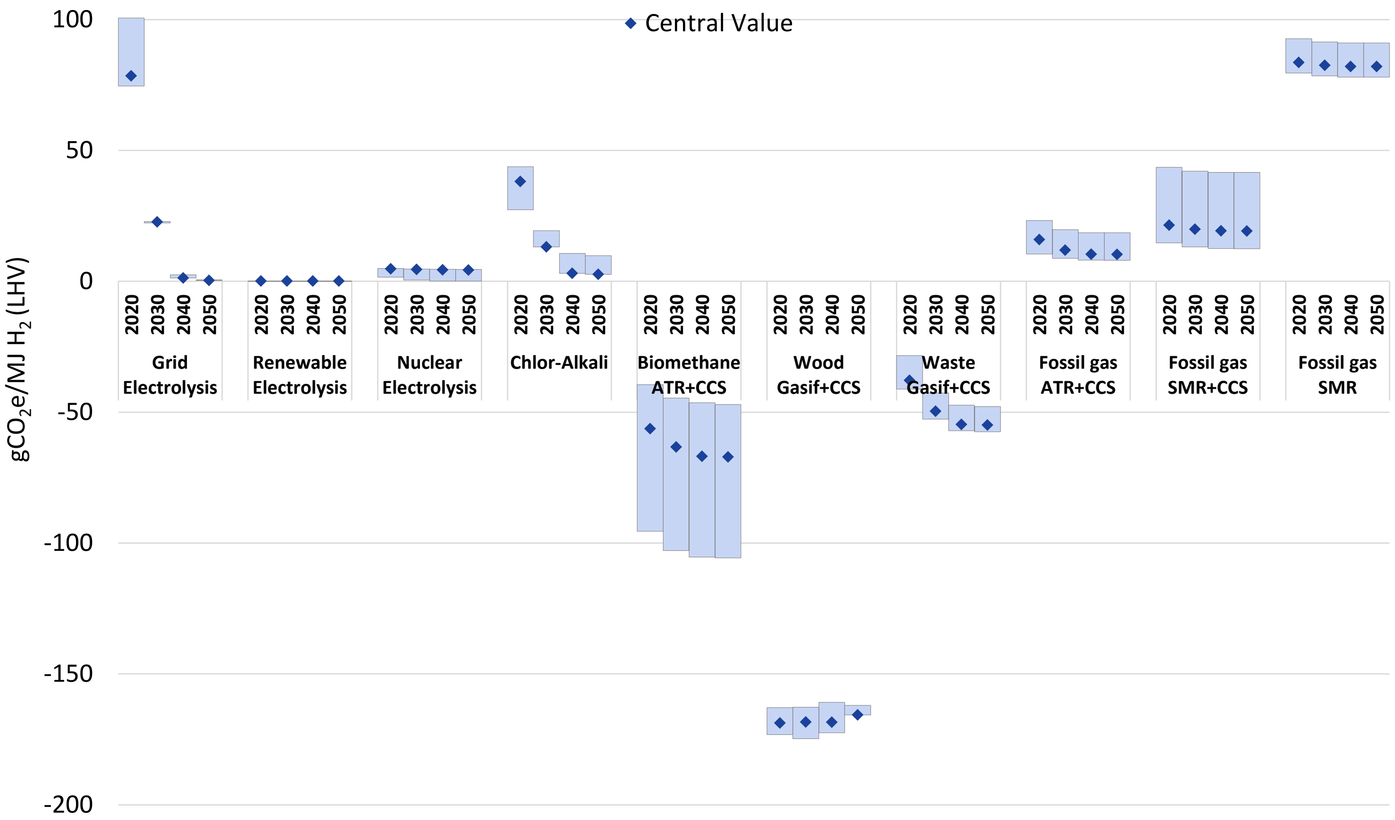
Q28.	**Given the many potential end uses of hydrogen, and the rapid expansion of low carbon supplies required, do you agree that an absolute emissions threshold be adopted, rather than a percentage saving based on a fossil comparator? Yes/no. Please provide detail.**
Q29.	**Should the standard adopt a single threshold or several, and why?**
Q30.	**a. Should the GHG emissions threshold be set at a higher level in the early stages of hydrogen deployment, with a trajectory to decrease over time? Yes/no. Please explain the benefits to the approach you have suggested.**
	b. If yes, should this decreasing trajectory be announced from the offset? Yes/no. Please explain the benefits to the approach you have suggested.

GHG impacts of different hydrogen production pathways

We commissioned E4tech and LBST to assess the GHG impacts of different hydrogen production pathways most common in the UK. Figure 1 shows their results. More information, including the LCA methodology, is provided in their report.

The bars represent the range of impacts across the scenarios, where the bottom of the bar represents results from Scenario 2 (Best, Low impact) and the top of the bar represents results from Scenario 3 (Worst, High impact). The dark blue dot represents the results from Scenario 1 (Central, Baseline impact).

Figure 1: Hydrogen production emissions (scenario ranges, 2020 to 2050)

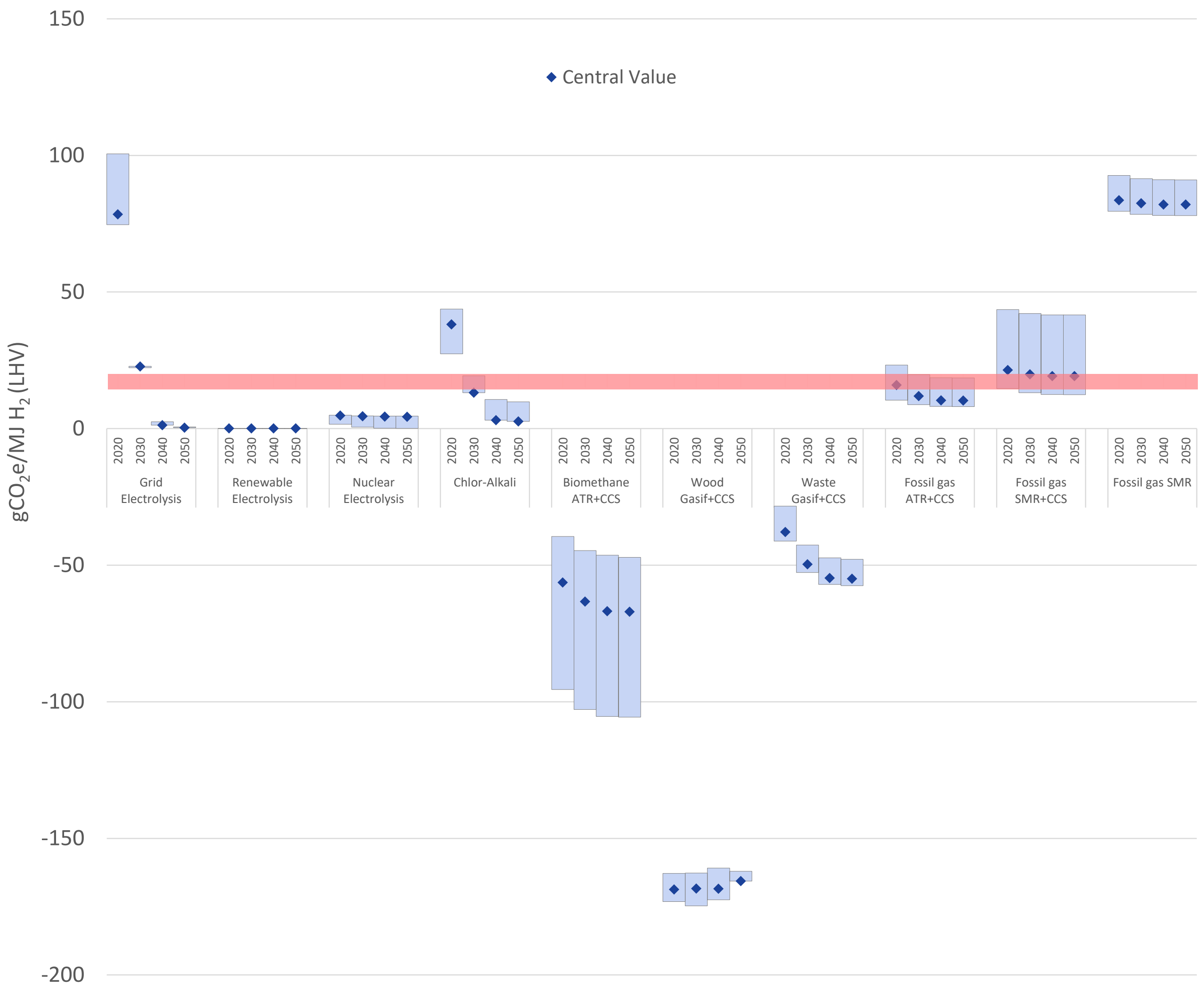


An indicative GHG threshold

The threshold at which a UK low carbon hydrogen standard is set could have significant impacts for the development of a hydrogen economy.

Figure 2 (red line) shows the potential impacts of an example threshold of around 15-20 gCO2e/MJLHV of produced hydrogen. This threshold is for illustrative purposes only and may not reflect the threshold that will be set in the UK Low Carbon Hydrogen standard.

Figure 2: Hydrogen production GHG emission ranges across different scenarios between 2020 and 2050 (red bar showing an example range)



This example threshold is held flat over time, but alternative thresholds could be set slightly higher initially, but falling over time to 2050 (see question 28 above which seeks views on whether the standard should be tightened through time).

If the threshold were set at this level, it would likely include hydrogen produced from the following methods:

- Renewable and nuclear electrolysis
- All the biomethane, biomass and waste gasification routes involving CCS
- Some biomethane and biomass gasification routes without CCS.
- The majority of ATR with CCS chains and SMR with CCS chains that have high efficiency and capture rates (presuming that retrofits of CCS with high capture rates are possible this would be included).

Hydrogen produced from the following technologies would be unlikely to fall within this threshold present:

- Chlor-alkali (although emissions from this technology are predicted to fall below the level in around 2030)
- Grid electrolysis until shortly after 2030 (once the UK grid has sufficiently decarbonised), without the use of traded activities such as power purchase agreements, unless arrangements were made for separate consignments (see 'mixed inputs' section above)
- Most fossil gas routes where CO_2 capture rates are below ~85% or those relying on LNG.

Changes to the GHG methodology or system boundary would impact some of the potential pathways that are included or excluded under a UK low carbon hydrogen standard. For example, separate consignments for grid electrolysis, chlor-alkali or waste gasification could lead to different fractions being included/excluded, or the counterfactual approach for waste fossil feedstocks.

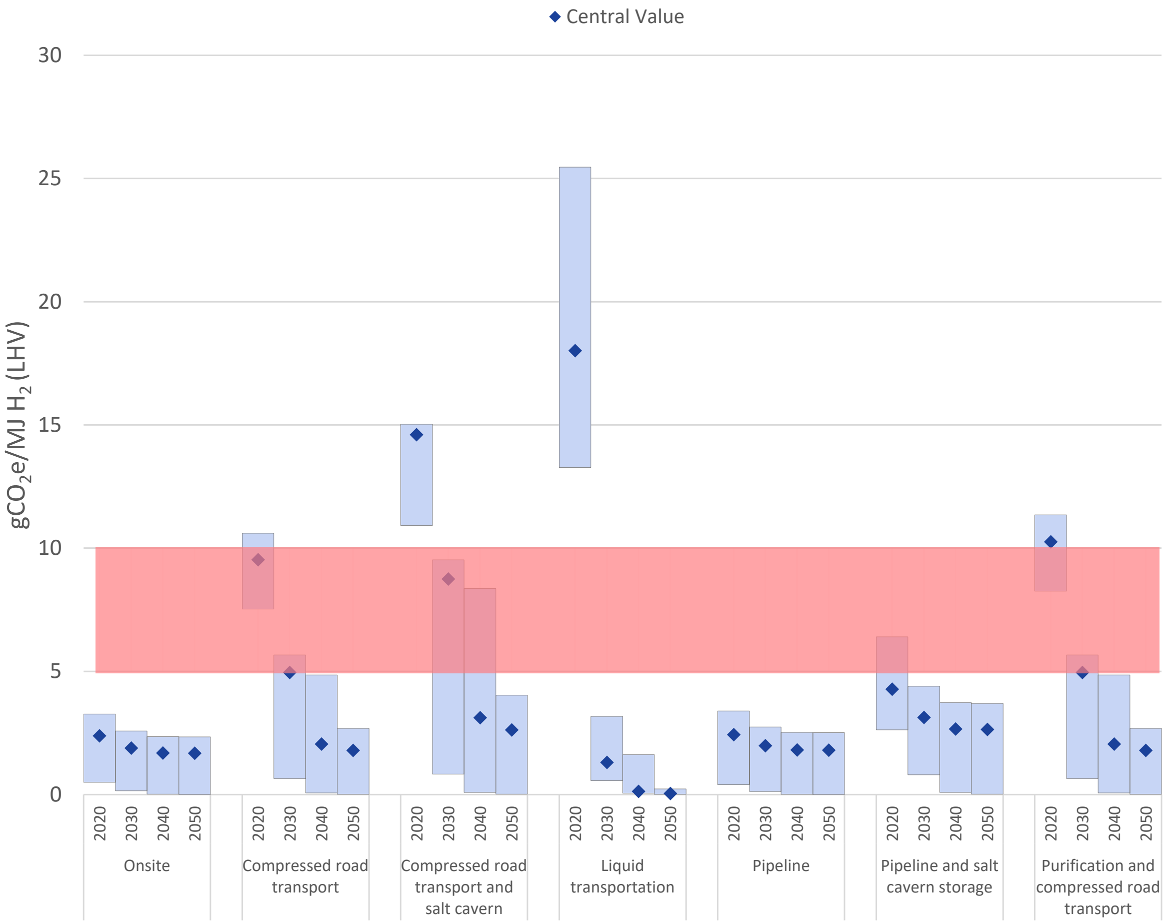
Q31.	**What would be an appropriate level for a point of production emissions threshold under a UK low carbon hydrogen standard? Please set out your rationale for your answer.**
Q32.	**a. Could some net zero compliant hydrogen production pathways be disadvantaged by the introduction of an emissions threshold set at 15-20gCO2e/MJLHV? Yes/no.**
	b. If yes, please explain which methods are likely to be disadvantaged and why.
33.	**a. How could we ensure that a low threshold does not negatively impact projects on a trajectory to net zero and learning by doing at the early stages of hydrogen market development?**
	b. What impact could this have on the UK achieving 5GW production capacity by 2030?

It would be possible to give some limited leeway on the thresholds to selected routes, for example some biofuels plants built before a certain date are given an additional 10%

leeway in RTFO, RED and TÜV SÜD. This could be justifiable where hydrogen supplied from those older plants continued to save significant emissions compared with the alternative means of supplying the same service, and those plants could provide a material contribution to UK hydrogen supply without preventing the introduction of newer, lower emission hydrogen pathways into the market.

Q34.	**a. Should the UK low carbon hydrogen standard provide for some limited leeway on the threshold for existing hydrogen production facilities? Yes/no. Please explain the benefits to the approach you have suggested.**
	b. If yes, is a 10% leeway suitable? Yes/no.

Figure 3: Downstream distribution emissions (scenario ranges, 2020 to 2050, red bar as an example threshold range)



If a hydrogen standard were to cover up to the point of use (instead of point of production), then downstream distribution chain emissions would have to be included. A separate threshold specifically for downstream distribution emissions is unlikely to be required, if a combined GHG threshold is chosen that covers the whole chain from well-to-point-of-use instead. Downstream distribution may only add up to 5-10 gCO2e/MJLHV of additional emissions to the delivered hydrogen emissions (with the exception of long-distance compressed road transport or liquification, which will add more emissions), and these downstream emissions will fall over time with UK grid and transport decarbonisation.

Q35.	**What would be an appropriate level for a UK low carbon hydrogen standard if it were considering point of use emissions? Please set out your rationale for your answer.**

Delivery and administration

Options for the delivery and administration of a UK low carbon hydrogen standard will need to consider the requirement to develop a robust monitoring system, alongside the potential costs and administrative burden that complex compliance requirements could mean for the hydrogen industry.

There are several entities who could administer and deliver the standard. Some of the options considered are:

- The standard could be **administered by BEIS**, which would potentially offer a higher level of coherence with other policies and net zero goals. Participation of external stakeholders and industry could be ensured via consultation for major revisions to the standard.
- An **industry-led organisation** could help ensure that the standard responds to business requirements. This option would require a clear framework as to how the organisation could be set up, its role and attributions and what overview BEIS would retain over potential revisions of the standard.
- A **mixed model of governance** (multi-stakeholder entity) could also be considered. Views are welcomed on how such a model could operate.

Reporting options

There are a number of possible reporting options that could be adopted by a low carbon hydrogen standard.

- The standard could use **default or actual emissions data** to assess operator compliance with the standard. Using default data could be a simple and cost-effective way to prove compliance but complications could arise for new routes that do not yet have default data. It could prove inaccurate in some cases and would not necessarily offer incentives to producers to reduce their emissions. Requiring the use of actual data could, however, be more costly for operators. A hybrid approach could also be adopted, as in the RTFO, where operators could choose to use default or actual data for different supply chain components (with the default emissions values set at high enough values to incentivise the use of actual data). Whether default or actual data are used could also have an impact on how the scheme is set up and how auditors will operate.

Several options are being assessed for reporting:

- **Self-reporting**: the standard administrator conducts verifications and makes decisions on compliance and issuance of certificates. Operators are required to self-report on each product consignment and/or, for example, quarterly. The standard administrator may conduct desk-based or on-site verifications of operation sites, consignments of products or claims whenever required.

- **Annual third-party verification**: the standard administrator delegates verification of compliance to accredited certification bodies, which take compliance and certification decisions. A systematic desk-based or on-site verification/audit of operation sites, consignments of products or claims is conducted on an at least annual basis.
- **Annual third-party verification + consignment reporting**: A verification/audit of the operation site(s) is conducted every year, but consignments of products must be reported and independently verified by an approved auditor at a defined frequency (depending on batch size), which must be at least once a year.

Q36.	**Which type of organisation would be best placed to deliver and administer a Low Carbon Hydrogen standard? Please include examples where possible of effective delivery routes for comparable schemes.**
Q37.	**Should default data, actual data or a hybrid approach be used to assess GHG emissions? Please explain the benefits to the approach you have suggested.**
Q38.	**What should the options be for reporting and verification of low carbon hydrogen? Do any of the options outlined seem appropriate? Are any of these particularly problematic?**
Q39.	**Are any other options not listed here that are better suited for low carbon hydrogen reporting? Any thoughts on how possible trade-offs between accessibility and robustness or between accuracy and simplicity could be addressed?**
Q40.	**What would be an appropriate frequency for verification or audit?**
Q41.	**Over what period of time should the standard be introduced?**

General

Q42.	**Do you have any other comments relating to the carbon standard proposals set out in this document?**

Next steps

This consultation will close on 25 October 2021, after which responses will be analysed and it is expected that the government response will be published in early 2022.

Following the government response, we will work with industry and across government to finalise design elements of carbon hydrogen standard.

This consultation is available from: www.gov.uk/government/consultations/designing-a-uk-low-carbon-hydrogen-standard

If you need a version of this document in a more accessible format, please email enquiries@beis.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.