Business models for carbon capture, usage and storage:
Decarbonised Gas Alliance response
September 2019

Consultation questions

1. Have we identified the right parameters to guide the development of CCUS business models?

We agree that the parameters chosen are appropriate, but there are several additional parameters that should guide the development of CCUS business models:

- **Net zero:** The UK now has legislation in place mandating net zero greenhouse gas emissions in 2050, which was not the case when the CCUS Action Plan was launched at the end of 2018. The Committee on Climate Change (CCC) has said that "CCS is a necessity not an option for reaching net-zero GHG emissions".[1] Therefore, business models need to enable CCUS to make a full contribution to meeting the UK's net zero target in practice, in a cost-effective manner.

- **Timing:** The CCC previously concluded that the first CCUS cluster should be operational by 2026, and that two clusters capturing at least 10 million tonnes a year should be operational by 2030. In its net zero report, the CCC concluded: "For a net-zero target it is very likely that more will be needed." By 2050, the report found that a major CO_2 transport and storage infrastructure would need to service at least five clusters.[2] The CCUS Action Plan, although less ambitious, states that "the UK should have the option to deploy CCUS at scale during the 2030s" if costs come down. Taking this together, business models need to ensure that:
    - Early deployment in more than one cluster is achieved in practice;
    - Rapid scale-up is feasible.

- **Anchor projects:** There are a number of promising anchor projects that are at various stages of early development. Projects such as HyNet, Acorn, Teesside Collective and Zero Carbon Humber could all make a major contribution to decarbonising the main industrial clusters, with consortia already collaborating. Business models need to ensure a good environment for projects such as these to be developed in practice.

- **Infrastructure:** Business models need to ensure that infrastructure is developed at an appropriate and efficient size. For example, it would be less efficient and cost-effective to build multiple smaller CO_2 pipelines in the same area, so a CO_2 pipeline should be large enough to transport CO_2 from multiple sources, even if only part of its capacity is used initially. Projects based around clusters or anchor customers should be structured to take advantage of future potential for expansion, for example for blending additional hydrogen in the local distribution network once regulation allows.

- **Co-ordination:** Business models need to overcome the significant challenges of co-ordination. First, to effectively decarbonise an industrial cluster is beyond the capacity of a single company or industry. Multiple facilities, with no common owner, will need to decarbonise, and will need to share common CO_2 infrastructure. Second, providers of T&S infrastructure will need to be confident that enough capture will come online, and builders of capture plants need to know that the T&S infrastructure will be in place at the right time. If CO_2 service companies are set up (see our response to Questions 2 and 7 below), they will need confidence that any enabling infrastructure installed will be utilised. Without effective co-ordination, business models are less likely to succeed.

- Avoiding further offshoring: With industrial profit margins at low levels and fierce international competition, it is important to avoid adding extra costs to industry that provide an incentive to relocate overseas. As we detail in our answer to Question 13, between 1997 and 2016, the UK's production of emissions fell by 35%, but the emissions embodied in the goods and services we *consume* in this country only fell by 9%,[3] as manufacturing declined dramatically. Energy intensive industry employs over a million people in the UK,[4] and is at the heart of many communities, often being the largest employer in the area. It is important both for people and the environment that industry stays in the UK.

- Evolution: As we have seen for renewables, business models will inevitably adapt as the market matures. The risks to investors are likely to look very different in the initial stages compared with a mature industry, and therefore business models should have the flexibility to evolve over time.

2. Bearing in mind our emerging findings on CCUS business models, do you have any views at this stage on how the business models might be integrated?

Our answers to the following questions try to address the integration point, but in summary:

- We would recommend a RAB-based model, with a grant, for T&S, and CfDs with a grant or capacity payment for power, industrial capture, and hydrogen production. Costs incurred by potential CO_2 service companies, which aggregate emissions from several smaller emitters on a site, as well as getting to sufficient pressure to inject into the larger T&S pipeline, should also be passed through to the CfDs on the capture side.

- To ensure a level playing field for all technologies, the CfD for industrial capture could include wider industrial CO_2 abatement technologies, including fuel switching to e.g. hydrogen.

- To ensure a level playing field for hydrogen production, a CfD for hydrogen production should include production from electrolysis as well as from natural gas or bioenergy with CCUS.

- To link up with T&S development, a strategic plan should be developed by government, specifying the levels of CCUS desired in each region, and auction levels (even if delivered in several rounds) should be compatible with this, providing certainty to T&S developers, and through this to capture plant developers.

3. Do you have proposals to mitigate CCUS-specific risks?

There are several measures which can help to mitigate CCUS-specific risks.

Cross chain risks

- Flexibility needs to be built into business models. If one part of the chain is not operating, it is not the fault of the other part, and that second part should not be penalised.
- Maintenance of the whole chain needs to be planned jointly, to ensure that all parts of the chain are being maintained at the same time, thus minimising the number of days that CO_2 would have to be vented. It is worth noting that building a parallel asset to ensure 100% availability would not be cost-effective, as it would only be in use for a few days each year.

- Similar to contracts for the supply of natural gas to power stations, there should be a target level of reliability and an agreed maintenance time in the contract, without penalties for venting CO_2 if the targets are met. This should include factoring in the risk of electricity outages for e.g. pumps and compressors, that are outside the control of the project – if, for instance, a repeat of the blackouts on 9 August 2019 were to occur.

Stranded asset risks

- It is worth noting that the risks of stranded assets are more acute for early CCUS projects, and will diminish as more infrastructure is developed. Again, flexibility needs to be built into contracts if there are delays to the start-up of other parts of the chain.

Long-term CO_2 storage risks

- Our understanding is that, the CCS Directive notwithstanding (including whether it will continue to be applicable to the UK post-Brexit), liabilities for CO_2 storage could be handed back to the State earlier than 20 years after the last injection. The shorter the timeframe post-decommissioning, the easier it will be to insure for the risk of leakage. We would recommend 5 years as a more appropriate timeframe, at least for early projects.
- To overcome uncertainty on the CO_2 price at the time of any leak, it may be helpful for government to define a forward schedule of gradually rising annual CO_2 prices for this purpose, allowing the financial risk to be quantifiable for investors. This would mean that government would need to take on the risk of the actual CO_2 price differing from the price schedule, although government would of course benefit if the actual CO_2 price was lower.

We would also emphasise that the CCUS Advisory Group (CAG) made several detailed recommendations to mitigate CCUS risks. We will not repeat them here, but we would agree with their analysis.

4. Are there any other CCUS-specific risks that need to be considered? If so, what are your proposals for mitigating them?

There are several additional risks and mitigations:

- **Investor risk:** There is a risk for investors in T&S assets that, for example, a 5 million tonne pipeline is built, but only 500,000 tonnes of CO_2 are captured. Equally, there is a risk for investors in capture facilities that the early T&S fees are extremely high, to protect T&S investors against the above risk. The overall objective, though, is to make sure that early T&S assets are future-proofed, even if this means they are oversized initially.
    - *Mitigation:* Business models need to ensure that T&S fees for early capture plants are not too high as to discourage investment, or that initial overpayment is able to be passed through e.g. through a CfD. Equally, they should ensure that enough capture comes online so that T&S investors are not discouraged. This suggests that a more strategic plan is needed from government as to how much capture is required in the first phase for a specific region. Contracts can then be put in place for the desired level of CO_2 capture, providing certainty for the T&S operator and hence lower T&S fees for the capture plants.

- **Timing risk:** Certain parts of the chain may well be in place before others. For example, the Industrial Strategy Challenge Fund for industrial cluster decarbonisation runs until 2024. If it funds capture plant, then the capture plant would need to be ready by 2024. But the T&S infrastructure may take longer to install.

- *Mitigation:* It should be possible for a capture plant to run in non-capture mode, without penalty, until T&S infrastructure is available.

- **Political risk:** A major risk is a repeat of the last-minute cancellation of the CCS competition in late 2015, which resulted in a major loss of confidence amongst investors. There is, firstly, a risk of a repeat, and secondly, a risk that insufficient private sector investment is forthcoming, given the events of 2015.
  - *Mitigation:* The best way to build confidence is to stick rigorously to timetables set out in the CCUS Action Plan, including publishing a response to this consultation by the end of 2019. Business models should also be put in place in 2020 – if a second consultation is required, it should take place in the first quarter of 2020, leaving time for preparatory work before the Autumn Budget of 2020, when we also assume that a Spending Review will be published (given that the current Spending Review is for one year only).

5. Have we identified the most important challenges in considering the development of CO_2 networks?

There are several challenges that appear to have been missed:

- **CO_2 shipping:** For clusters without access to offshore storage (for example South Wales), and for distributed cement plants and other industry that is not located in clusters, CO_2 will likely need to be carried by ship or truck. Business models need to consider how CO_2 transported in this way will be funded.

- **Asset sizing:** Given the significant T&S risks, there may be an incentive to build pipelines that are smaller than optimal, because there is a greater chance of ensuring they are full at an early stage. This would also make power CCUS more difficult to achieve, if the CCUS plant were to run flexibly rather than baseload, as there may not be enough spare capacity in the CO_2 pipeline. On the other hand, large CO_2 pipelines may require high pressure CO_2 to be injected, which may be difficult for smaller emitters on their own to achieve. This would likely necessitate infrastructure to aggregate emissions from several smaller emitters on a site.

- **Cross-border transport of CO_2:** The London Protocol currently prevents CO_2 being transported internationally for the purposes of underground storage, although an amendment will be tabled in October. This restriction removes a potentially important source of revenue for T&S operators, and prevents UK capture projects from shipping CO_2 overseas, which may be necessary if sufficient UK T&S infrastructure is not built or is delayed.

6. Do you agree that a T&S fee is an important consideration for any CO_2 T&S network? In your view, what is the optimal approach to setting the T&S fee?

Yes. Essentially a capture plant operator is paying for someone to take CO_2 off their hands, including storage liability, so a fee to cover this service is appropriate.

When setting the T&S fee, it is important to ensure that the fee will be subject to change when more capture projects come online. This will provide more confidence for other users coming onto the system that T&S prices will fall, and therefore more confidence for T&S operators that more capture projects will come online. Together with a strategic plan from government on how much capture is needed in the first phase for a specific region, as we set out in our answer to Question 4, it will help to overcome risks for investors.

7. Of the models we have considered for CO_2 T&S, do you have a preference, and why?

We think that all three models considered by the CAG are viable and we agree that a RAB model is the appropriate one.

The trade-off between government-owned and private sector is essentially:

- A government-owned entity would be able to set out a strategic plan for levels of T&S infrastructure in each region, and would benefit from a lower cost of capital than the private sector. It would also mitigate the risk of insufficient private investment.
- Private sector entities would introduce competition, potentially also for storage of CO_2 originating from outside the region, and hence would have a greater incentive to reduce costs.

Taking this into account, our preference would be for the CAG Option 2, a private sector financed RAB with a government grant to cover the capital costs of the first T&S assets in a region. This would help to attract investment by reducing upfront risks before a CCUS industry is established.

Together with this, government should set out a strategic plan indicating desired levels of capture in each region, at least for a first phase, and should be willing to contract for these amounts, as we set out in our answers to Questions 4 and 6, and as we also set out below. This would reduce risks for T&S operators – and hence the T&S fee – still further.

Finally, as explained in our answer to Question 5, large CO_2 pipelines may require high pressure CO_2 to be injected, which may be difficult for smaller emitters on their own to achieve. CO_2 service companies, which aggregate emissions of smaller capture sites and connect to T&S developers, should be considered in the T&S business model, although may sit outside of the RAB. There are several relevant considerations:

- **Technical and cost feasibility:** For smaller plants located within larger sites (e.g. energy parks), options to capture CO_2 and connect to T&S developers are limited, unless third-party CO_2 infrastructure is made available.
- **External price control:** The T&S fee imposed on the capture developer can be passed on through the CfD. The price ceiling to use this infrastructure is constrained by the affordability of capture plant developers. Similarly, appetite for providing CO_2 services is dependent on an acceptable return on investment, likely commensurate with industrial rates.
- **Reduced T&S and capture price:** Smaller emitting plants are incentivised to locate to (or fit capture equipment on their plants located within) sites offering CO_2 services, where infrastructure and risk is shared amongst neighbouring plants. This reduces overall complexity for T&S and capture developers and allows for economies of scale.
- **Reduced grant necessity:** If assurance is given that costs are passable through CfDs on the capture side, CO_2 service companies may not require a grant.
- **Scale of emissions:** Any T&S and industrial capture proposition will inevitably favour large-scale emissions. CO_2 services companies would support smaller emitters, and to meet net zero it will be essential that emissions from smaller facilities are also captured.

8. Are there any models that we have not considered in this consultation which you think should be taken forward for CO_2 T&S, and why?

Our suggestion, that CAG Option 2 should be enhanced with a strategic plan from government on levels of capture in each region, is a different model from the pure CAG Option 2. Our reasons for suggesting this are set out in our answer to Question 7.

9. Have we identified the most important challenges in considering the development of CCUS power projects?

Broadly yes, but there are several key additional challenges:

- T&S interface: A key challenge is to ensure effective interface with T&S infrastructure. If a power CCUS plant is running baseload, this is less of an issue, but if it is running flexibly, it will still need 24/7 access to T&S infrastructure, based on the plant's full load and hence maximum CO_2 capture. This means that the T&S infrastructure will need to have spare capacity, which much of the time is not being used. This may be less of an issue if T&S infrastructure is developed for an industrial anchor project.

- CO_2 capture efficiency: As set out in the Cornwall Insight and WSP report on power CCUS, if plants are running flexibly, they may not be capturing CO_2 at full potential levels, especially if they are only running for short periods of a few hours.[5] Until technology allowing full CO_2 capture for short period is developed, this is a serious impediment, although technologies such as the Allam Cycle may potentially help to resolve this issue.

- The extent of new nuclear development, and whether heat decarbonisation is largely electric or decarbonised gas: There are uncertainties over key external factors, including whether new nuclear is built at scale, and whether heat decarbonisation follows a largely electric or decarbonised gas route. These factors will affect the level of CCUS power generation needed quite substantially. For instance, if no new nuclear is built after Hinkley Point C, and/or if heat decarbonisation follows a largely electric path, then there will be a need for considerable CCUS power generation. If on the other hand new nuclear is built at scale, and/or heat decarbonisation is largely delivered through hydrogen and biogases, then far less CCUS power generation will be needed. This in turn will determine whether CCUS plants will need to run in a largely baseload or flexible manner – and will therefore impact on the choice of business model.

- The importance of hydrogen: It is worth noting that hydrogen may be a good solution for flexible power. For example, it would not face the issue of CO_2 capture efficiency if used for short periods of a few hours at a time.

10. Of the models we have considered for power CCUS, do you have a preference, and why?

Our two preferences are for a baseload CfD and a flexible CfD with capacity payment, as set out in the Cornwall Insight and WSP report:

Baseload CfD:
- This may be more appropriate for early CCUS power plants, which are more likely to run continuously. It may also be needed if new nuclear is not developed at scale and/or if heat decarbonisation is largely through electrification, as far higher levels of CCUS electricity generation would be needed.
- It helps to ensure that T&S developers can depend on a stable stream of CO_2, without the need for spare capacity that will not be used for much of the time, and so reduces risks for T&S developers.
- It avoids the issue of lower CO_2 capture rates from frequent short running times.
- Finally, it is also likely to be more suitable for bioenergy with CCS plants (BECCS), which should run baseload as they deliver negative emissions, which are essential to meeting the net zero target.

Flexible CfD with capacity payment:

- The biggest advantage of fossil generation is dispatchability, so a CCUS business model should encourage this. Given the continuing development of renewables, a flexible CfD encourages mid-merit operations, which is most valuable to the electricity system.
- If new nuclear is developed at scale and/or if heat decarbonisation is primarily through decarbonised gas, lower levels of CCUS power generation will be needed.
- The flexible CfD allows for CCUS plants to operate at higher load factors in earlier years and lower load factors in subsequent years, as more renewables are developed.
- Technology may be developed to allow full CO_2 capture even for short running periods.

We agree with the Cornwall Insight and WSP report that both models are investible propositions, and benefit from investor familiarity with power CfDs to date. Both models allow for cost reductions, especially if auctions are introduced.

Our overall preference, then, is for:

- A ***baseload CfD*** to be provided for the first CCUS plants, providing greater certainty, including for T&S developers. A baseload CfD would also be the best model for BECCS plants that provide negative emissions.
- A ***flexible CfD with a capacity payment*** to be introduced subsequently, which would allow CCUS plants to play a preferred role providing mid-merit generation. This would also provide time for technology to be improved to allow full CO_2 capture for short running periods, and for T&S infrastructure to have been established, and hence T&S risks to reduce. It would also allow time to establish with greater certainty the role that new nuclear is likely to play and the direction of heat decarbonisation.

Finally, we note that the Cornwall Insight and WSP report finds that there is no provision for the metering of carbon in the current CfD rules, and that a carbon capture quality standard may need to be put in place (see pages 32, 37 and 40). We agree that it is essential for a standard approach to be developed to measure and report on capture levels.

11. In your view, should any potential funding model(s) be applicable across all power CCUS technologies (including but not necessarily limited to CCGT with post-combustion capture, BECCS, and pre-combustion capture or hydrogen turbines)?

As we explain in our answer to Question 10, BECCS plants are more suited to a baseload CfD, and gas-fired plants with CCS (pre- or post-combustion) are, over time, probably more suited to a flexible CfD with a capacity payment.

Private wire CfDs should also be allowed for CCUS, as they are for renewable electricity generation. This could help to encourage industrial decarbonisation.

If hydrogen production is only used for power generation, then a CfD (baseload or flexible) should include the hydrogen production element. Essentially, the choice would be either to run a gas-fired CCUS plant, or to run an advanced methane reformer with CCUS, and then use a hydrogen turbine to produce power. Business model design should be agnostic about which route is chosen, and encourage the most flexible and cost-effective to win out.

If hydrogen production is also used for other applications, or if hydrogen is produced from electrolysis, then it complicates matters. Further consideration would need to be given to how a CfD for hydrogen production would interact with any support mechanisms for hydrogen injection into the grid or use in downstream applications, such as transport. For electrolysis hydrogen, consideration would also need to be given to the interaction with CfDs for renewable electricity. It is worth noting that this scenario is much more likely, particularly for hydrogen produced from natural gas – given the benefits of keeping a hydrogen production plant running for most of the time, the hydrogen produced will be used for other applications as well as electricity.

12. Are there any models that we have not considered in this consultation which you think should be taken forward for power CCUS, and why?

No.

13. Have we considered the most important challenges in considering the development of CCUS for industry?

In addition to the challenges mentioned in the consultation document, we would emphasise:

- **Offshoring of emissions:** The risk of further offshoring of emissions needs to be considered in more detail. To date, we have seen far too much decarbonisation through offshoring of industry. Between 1997 and 2016, the UK's production of emissions fell by 35%, but the emissions embodied in the goods and services we *consume* in this country only fell by 9%,[6] as manufacturing declined dramatically.[7] To give one example, the closure of Redcar steelworks in late 2015 led to 2,000 job losses, but caused nearly half the fall in industrial emissions in 2016.[8] This is not a sustainable position for the UK, is not compatible with the Clean Growth Strategy, and may actually increase emissions globally as industry in many countries is far more dependent on coal. Therefore, it is crucial not to add extra costs onto industry, where global competition is strong and margins are thin, as it will simply provide an incentive to relocate.

- **Subsidy-free:** We agree that the end goal should be for carbon capture in industry to become subsidy-free. We would, however, emphasise that it will take time for sufficient low carbon product demand and a high enough carbon price to be in place.

14. Of the models we have considered for industry CCUS, do you have a preference, and why?

Our first point is that the end-goal is industrial decarbonisation, and that CCUS is an important means to that end, but is not an end-goal in itself. It is important, therefore, to try to implement a level playing field for various technologies to reduce emissions from industry, including but not limited to CCUS.

We don't think that a CCS certificate plus obligation model is the best approach. It ignores other non-CCUS technologies, and if levied on industry provides an incentive to offshore production. Putting in place additional incentives to avoid offshoring would then add further complexity.

Our preference is for a **hybrid grant/CfD model**, as recommended by the CAG, with the grant covering capital costs and the CfD operational costs, for two reasons:

- Having a grant for capital costs overcomes a major initial hurdle to deploying CO_2 capture technology, especially for early projects. Existing schemes such as the £170 million industrial cluster decarbonisation challenge within the Industrial Strategy Challenge Fund (ISCF), and the £315 million Industrial Energy Transformation Fund (IETF) are possible avenues for providing initial capital grants, although they are not enough on their own.

- CfDs are a well-understood investment mechanism, and with the right implementation to the context of industrial CO_2 capture, should be able to attract investment. A successful mechanism for funding operational costs will in turn make it easier to fund initial capital investment, especially if industry match-funding is required.

There are several important design considerations:

- **CO_2 price:** We agree that the CO_2 strike price will vary between and within industrial sectors. In order to manage this, an approach that delivers the lowest hanging fruit first would be helpful. This could be done through a competitive auction for the first few million tonnes, ensuring that the lowest-cost industrial capture was developed first and providing some certainty on CO_2 volumes for developers of the first T&S infrastructure. Subsequent auction rounds would encompass sectors that cost more to decarbonise, and hence a rising CO_2 strike price would have to be accepted.

- **Technology-neutral:** As stated above, CCUS is not the only technology to decarbonise industry, and so a CfD could be based on CO_2 *abated*, rather than CO_2 *captured*. This adds complexity, especially in establishing the baseline for emissions, although the EU ETS mechanism could be adapted. Including other technologies would also encourage, for example, fuel switching to hydrogen or bioenergy, low carbon electrification, and energy efficiency, with the most cost-effective solutions winning out.

- **Regional auctions:** As we stated in our answers to earlier questions, a government strategic plan on the desired levels of CO_2 capture in each region, with a willingness to contract for the desired amounts, would provide certainty to T&S developers. For industry based in clusters, regional CfD auctions could be held for a specific level of capture, which would provide certainty for T&S developers, and hence certainty for capture plant developers.

- **Non-cluster industry:** Significant industrial emissions are produced by facilities not based in clusters. CCS will inevitably cost more, as the transport of CO_2 to storage facilities will be more difficult and expensive. This factor will need to be considered in CfD auctions. Equally, it may be most sensible to focus on CO_2 utilisation for non-clustered industry, although there is a risk that most utilisation facilities may themselves be in clusters.

Finally, on the question of whether to have a CfD for CO_2 capture only, or for technology-neutral CO_2 abatement, there are pros and cons of both approaches:

- For a CfD on wider abatement, it would be possible to hold an auction for, say, 3 million tonnes, and only, say, 1 million tonnes are awarded for CCS. This would mean uncertainty for T&S developers.
- For a CfD on CO_2 capture only, there would be greater certainty for T&S developers, but other ways to decarbonise industry cost-effectively could be missed.

15. Are there any other models that we have not considered in this consultation which you think should be taken forward for industry CCUS, and why?

No, although we would emphasise the merits of holding regional auctions for industrial CO_2 capture, in the main industrial clusters. This would ensure that CCUS infrastructure is being built in multiple clusters – as we state in our answer to Question 1, at least five clusters will need CCUS infrastructure by 2050.

16. In your view, are there any models which best work across all industrial sectors where CCUS could have a role to play?

As stated in our answer to Question 14, a hybrid grant/CfD would overcome capital cost hurdles across industrial sectors. CfD auctions, including at a regional level, would help to ensure the lowest-cost sectors go first, and then higher-cost sectors can develop CO_2 capture plant in subsequent auction rounds, although a rising CO_2 strike price would have to be accepted.

17. What actions should Government and industry take to help establish demand for low-carbon industrial products?

There are two actions that would help to increase demand for low-carbon industrial products, although we do not claim that they would be enough on their own:

- Procurement: Public procurement for infrastructure projects could include a certain percentage of low carbon materials. This is likely to be easier for some projects than others, and so could be implemented on a project-by-project basis.

- Low carbon industrial product quality mark: A new low carbon industrial product certification and quality mark should be developed, similar to Fairtrade or FSC kitemarks, as recommended by the CCUS Cost Challenge Taskforce. It should be backed by government and supported by industry, and ideally agreed internationally, although a UK brand would be a starting point. It would take time to get right, as the carbon footprint of input raw materials from other countries would also need to be considered, and other sustainability measures (e.g. land use) should also be incorporated.

18. Do you agree that a future business model should focus on hydrogen production costs? If not, what are the benefits of considering other parts of the hydrogen value chain in the next phase of our work?

Although it may be most straightforward to include hydrogen production costs only at this stage, there are a number of other issues that require consideration, including:

- The transport of hydrogen in pipelines may be funded by additional network charges.
- The use of hydrogen in transport may be funded by the Renewable Transport Fuel Obligation (RTFO) – although this should be expanded to cover all forms of low carbon hydrogen production.
- If hydrogen is used for fuel switching in industry, it could be covered by an industrial emissions abatement CfD, as stated in our answer to Question 14.
- We believe that hydrogen in domestic heating is vital to decarbonising homes, and consideration of how best hydrogen conversions and hydrogen fuel should be paid for is critical, to avoid placing too heavy a burden on households. Network charges could be a key mechanism for paying for hydrogen use in domestic households.

How hydrogen production business models interact with these wider issues is crucial in ensuring the widespread adoption of hydrogen across different parts of the economy.

We also think it is important to develop hydrogen production in multiple industrial clusters at the same time, not just in one winning cluster. The International Energy Agency's recent review of the future of hydrogen concluded that ports with concentrations of refining and chemicals production would be ideal locations to scale up the use of low-carbon hydrogen, since hydrogen produced from fossil fuels without CCUS is already being used in these areas.[9] And there are several such industrial port areas in the UK. Further, it would be logical to ensure that hydrogen projects based around clusters or anchor customers are structured to take advantage of future potential for expansion, for example for blending additional hydrogen in the local distribution network once regulation allows.

Finally, hydrogen storage is also an important element, which is vital for hydrogen production to play a flexible role in the wider energy system. Hydrogen storage should therefore be in scope when considering hydrogen production business models.

19. Do you have views on whether the model should seek to support both CCUS-enabled hydrogen production and renewable production methods? If so, how might this work?

As we stated in our answer to Question 14, the objective is decarbonisation, and we will need hydrogen from both methane reformation with CCUS and electrolysis to decarbonise effectively. Therefore, both routes should be supported, and a level playing field for all low carbon hydrogen production technologies should be created. By the same token, it is important to consider the interactions with other decarbonisation mechanisms. For instance:

- As stated in our answer to Question 11, if hydrogen is produced via electrolysis, then the CfD for renewable power generation also needs to be considered.
- If hydrogen is used for fuel switching in industry, then if set at the right level, an industrial CfD based on wider CO_2 abatement could include hydrogen production from both methane reformation and electrolysis.
- A CfD for power generation, if set at the right level, could include hydrogen production, if the hydrogen was only used for power generation. For CCUS methods of hydrogen production, the choice would be either to run a gas-fired CCUS plant, or to run an advanced methane reformer with CCUS, and then use a hydrogen turbine to produce power. Business model design should be agnostic about which route is chosen, and encourage the most flexible and cost-effective to win out. But as we noted in our answer to Question 11, it is likely that hydrogen production facilities will run most of the time, and hence the hydrogen produced will be used for other applications in addition to power generation.

20. Have we identified the most important challenges in considering the development of a business model for hydrogen production?

We agree that the higher cost of hydrogen relative to high-carbon fuels, in the absence of high carbon prices, and the need to ensure that low carbon hydrogen production facilities are investible are key challenges – indeed, they are the most significant issues. Given that hydrogen costs more than natural gas, there is a genuine risk that hydrogen production is built, with no demand following.

However, we are not convinced by the third challenge, about ensuring that hydrogen is only deployed where it can make most contribution towards our decarbonisation goals. Determining this precisely in advance risks overcomplicating any support mechanism for hydrogen, and risks the wrong choices being made. As we explain above, moving to auctions for power and industrial CCUS CfDs, and potentially opening up the industrial CfD to other decarbonisation technologies, allows for the market to determine the most cost-effective solutions. The same principle should also be applied to hydrogen production and use.

It would be possible, however, to consider competitive mechanisms for both hydrogen production and use in different sectors, which would see differential pricing developed through market mechanisms. For example, expanding the RTFO to cover all forms of low carbon hydrogen would provide a mechanism for establishing a hydrogen price in transport, and a CfD for hydrogen production, with the natural gas price as the reference price, would establish prices for hydrogen in industry and in the gas grid. Focusing on higher-margin markets to start with can also help to support the business case for other sectors, as it gets hydrogen production established.

21. What reflections do you have on the approaches we have identified to address the main challenges in designing the model?

We agree that the priority for early projects is to minimise risks to investors through reliable revenue streams.

We agree that hydrogen should be deployed in multiple sectors, although as stated in our answer to Question 20, we would caution on determining precisely which sectors. And as stated in our answers to previous questions, we also think that hydrogen projects based around clusters or anchor customers should be structured to take advantage of future potential for expansion, for example for blending additional hydrogen in the local distribution network once regulation allows.

We also agree that the avoided carbon price should be accounted for, and that it would be most sensible to take account of a more stable carbon price.

22. Do you have views on which business models we should evaluate in the next phase of our work?

Given the wide variety of possible uses for hydrogen, it may be most straightforward to establish a **hybrid grant/CfD for hydrogen production**, with grants to cover capital outlays and the CfD covering operational costs. The reference price would be the natural gas price, plus a CO_2 price for those sectors that currently pay CO_2 prices on natural gas consumption. Such a structure would have similar advantages to those described in our answers to earlier questions on power and industrial CCUS.

For transport usage, the RTFO should also be expanded to include all forms of low carbon hydrogen production, and UK hydrogen production only could be supported, to avoid the issue identified by the CAG that renewable transport fuels delivered to date have been largely imported.[10]

This would, however, essentially mean that there would be up to four mechanisms to fund the production of low carbon hydrogen:

- RFTO, if it was expanded to all forms of low carbon hydrogen;
- Power CCUS CfD, if hydrogen production was allowed within the CfD and hydrogen was solely used for power generation;
- Industrial CfD, if wider CO_2 abatement was included, therefore covering fuel switching;
- Hydrogen production CfD.

It would be important to avoid double-subsidies, and this could be achieved, for example, by only allowing one of these mechanisms to be used for each unit of hydrogen produced. For example, if a hydrogen production plant produced 100 units of hydrogen, 50 of which were used for transport and the other 50 for industrial fuel switching, then the RTFO could be applied to the first 50 units and the industrial CfD to the other 50. In this way, the appropriate mechanisms would be employed, depending on the uses of the hydrogen, up to the capacity of the plant.

For transport of hydrogen, an extension to the existing RAB-based network charging regime is most appropriate, ensuring a low cost of capital and using an existing well-understood and successful mechanism. This of course will also require changes to GS(M)R to allow higher hydrogen blends in the gas network.

An interesting alternative to be considered is a RAB-based model for hydrogen production and transport (and in some cases use), as developed in the H21 North of England study. This may depend on the sectors using hydrogen, and its interaction with other CCUS or CO_2 abatement models in power and industry would need to be carefully considered.

23. What capabilities are needed for the delivery of CCUS in the UK?

In terms of the **capabilities required** for the delivery of CCUS, the list provided in the consultation document is generally good, although we would add the following:

- Implementing the legislation and other mechanisms needed to put the chosen business models into practice;
- Setting out a strategic plan for the levels of CCUS desired in different regions;
- Agreeing the amount of CCUS (i.e. how many millions of tonnes of CO_2) to auction in each round, including at regional levels;
- For the first CCUS projects, including capture and T&S, before auctions are put into place, agreeing negotiated prices and other terms and conditions;
- Agreeing levels of capital grant and required match funding for T&S, capture and hydrogen production projects, and agreeing capacity payment levels for flexible power CCUS projects;
- Ensuring that the planning and regulatory permit requirements are obtained in a timely manner, without delays in planning decisions.

These six capabilities are critical to ensuring that projects are delivered in a timely way in practice.

In terms of a **potential delivery body**, whether there is a delivery body or not, policy certainty is critical, and so an overall strategic aim for CCUS developed by government, with implementation de-coupled from politics, would help to provide more continuity.

Any delivery body would need to be properly independent, but we don't believe that expanding the remit of existing independent regulators would be effective. For example, looking at the capabilities required in our list above, the Oil and Gas Authority could provide a strategic area plan for CO_2 storage, but would not have the capability to agree levels of capital grant and match funding required for T&S development. And Ofgem would not have the capability to develop a strategic plan to determine desired levels of CCUS in key industrial clusters.

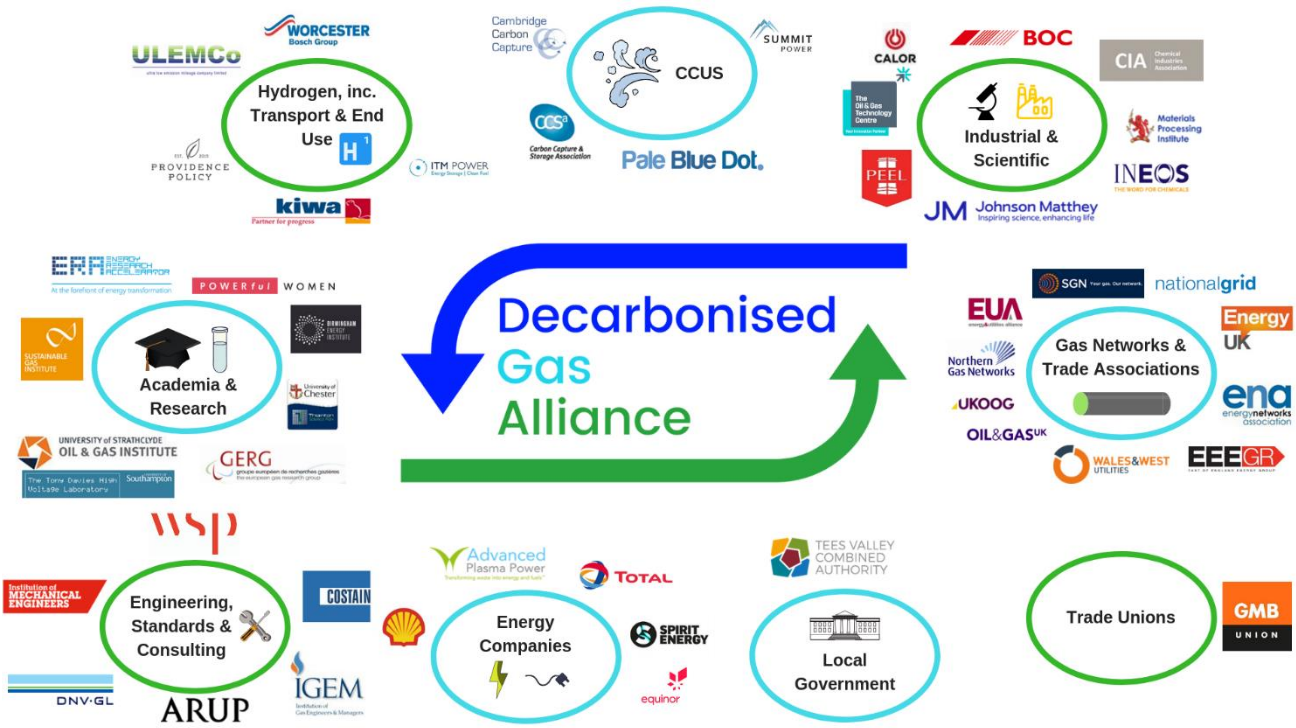
Appendix: About the Decarbonised Gas Alliance

The Decarbonised Gas Alliance (DGA) is an alliance of almost 50 gas producers, transporters, suppliers and users, hydrogen and carbon capture experts, alongside R&D, supply chain, trade union and local government specialists whose knowledge and expertise will be vital in decarbonising the UK's gas system and improving poor air quality.

Our aim is to work with all levels of government and with other expert organisations to use the gas system as a whole to help deliver our emission reduction and air quality goals. We believe that decarbonising gas – including biogases and hydrogen from a variety of low carbon methods – would make best use of our existing infrastructure and lower the overall costs of decarbonisation.

The DGA is a broad-based alliance, established in late 2016, and has now expanded to 48 signatory organisations, which are listed in full in the diagram below. The DGA secretariat is managed by DNV GL, a global specialist firm which provides advisory, certification and other technical assurance solutions covering a range of energy sources.

We welcome the opportunity to provide our views on the design of business models for CCUS, and we are happy to provide further detail, if this would be useful to BEIS.



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