Department for Energy Security & Net Zero

Hydrogen transport and storage infrastructure: minded to positions

Minded to government positions on business model designs, regulatory arrangements, strategic planning and the role of blending

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Disclaimer

This document sets out our minded to positions corresponding to chapters in the consultation on hydrogen transport and storage infrastructure, covering our proposed policy, current thinking and next steps in each area. Our minded to positions are indicative only and do not constitute an offer by government and do not create a basis for any form of expectation or reliance. The proposals are not final and are subject to further development by government, as well as the development and Parliamentary approval of any necessary legislation, and the completion of necessary contractual documentation. We reserve the right to review and amend all proposals set out within this document.

Chapter 1: General information

Why we consulted

Hydrogen can support the decarbonisation of the UK economy, particularly in ‘hard to electrify’ UK industrial sectors, and can provide greener, flexible energy across power, transport and potentially heat. Hydrogen produced in the UK could create thousands of jobs across the country, and provide greater domestic energy security, lowering our reliance on energy imports. Analysis by the department for Carbon Budget 6 suggests 250-460TWh of hydrogen could be needed in 2050[1], making up 20-35 per cent of UK final energy consumption.

For these reasons, in the British Energy Security Strategy (BESS) government doubled its ambition to build up to 10GW of new low carbon hydrogen production capacity by 2030, subject to affordability and value for money, with at least half of this coming from electrolytic hydrogen production.

Hydrogen transport and storage infrastructure will be critical to enabling this 10GW ambition, and the related economic benefits. It will connect producers with consumers, and balance misalignment in supply and demand. However, lengthy development lead times, high capital costs and uncertain financial investment returns in a nascent market means this infrastructure is unlikely to materialise without a supportive policy framework.

In the BESS, Government committed to designing new business models for hydrogen transport and storage infrastructure by 2025. We consulted on this from 31 August 2022 to 22 November 2022, seeking views on design options for these business models in order to meet this commitment and enable the hydrogen economy to deliver its substantial potential carbon and economic benefits. In addition, we sought views on the need for a strategic planning function for the rollout of hydrogen transport and storage infrastructure, approaches to wider regulation and implications for blending. This document is the next step in meeting our BESS commitment.

Overview of responses

The minded to positions take into account responses to the consultation on hydrogen transport and storage infrastructure from 31 August 2022 to 22 November 2022, as well as feedback provided by stakeholders through engagement that has taken place since publication of the consultation. We have summarised responses to the consultation and our government response to each of the 63 questions in a separate document[2] that we intend to be read alongside this one.

We thank respondents for engaging with this consultation. The responses received will be very useful in informing our ongoing work. We will continue to work closely with industry and

[1] Department for Business, Energy and Industrial Strategy (2021), ‘Carbon Budget 6 Impact Assessment’.

[2] Hydrogen transport and storage infrastructure: government response to consultation

regulatory bodies to consider the issues raised and the suggestions put forward regarding hydrogen transport and storage infrastructure.

The Department for Energy Security and Net Zero will also continue to engage with the devolved administrations to ensure the proposed policies take account of devolved responsibilities and policies across the UK.

Executive summary

Chapter 2 - Hydrogen transport infrastructure

The minded to positions in this chapter provide a direction of travel for the hydrogen transport business model design. The minded to high-level design is a Regulated Asset Base (RAB) alongside an external subsidy mechanism, in the form of private law revenue support contracts. In addition to business model design, we will also develop our position on allocation, as well as the accompanying market framework for early projects. We intend to continue to work with industry as we progress towards the final business model design.

Chapter 3 - Hydrogen storage infrastructure

The minded to positions in this chapter provide a direction of travel for the hydrogen storage business model design. We propose a revenue ‘floor’ to mitigate demand risk for storage providers; an incentive to maximise sales to users and a mechanism to give the subsidy provider a potential share of the ‘upside’. We anticipate the initial focus for support to be geological storage, though we are minded to retain optionality to support above-ground storage where it faces similar market barriers. We consider the model best delivered through a private law contract lasting at least 15 years. We will move into the next level of design detail of the business model and the contract, as well as developing our position on allocation of the contract to potential storage projects. We intend to continue to collaborate closely with industry as we progress towards the final model design.

Chapter 4 - Strategic planning

The minded to position in this chapter sets out that some form of strategic planning, potentially combined with elements of a market-led development, is necessary to enable the efficient, cost-effective and timely roll-out of transport and storage infrastructure. It is our view that the build-out of hydrogen transport and storage infrastructure, and in particular larger scale or systemically important assets, should be guided by centrally coordinated, locally sensitive, strategic planning that is integrated across energy and other relevant systems. Our intention is that the Future System Operator (FSO) take on a central strategic planning role at an appropriate time following its establishment, within the statutory framework provided for by the Energy Bill. In the interim, we believe it is necessary for UK government, working closely with Ofgem and industry, to take a leading role in providing early strategic direction for the build out of hydrogen T&S infrastructure. Therefore, we will publish a ‘hydrogen networks pathway’, to set out the next steps in our vision for the development of hydrogen T&S in the UK.

Chapter 5 - Regulatory framework.

In Part 1 of this chapter (market framework) we set out that it is government's intention to keep the market framework and industry commercial arrangements under review with a view to introducing timely amendments where they are warranted. This review will include ongoing work taking place through the Hydrogen Advisory Council's Transport and Storage working group in the first instance but is likely to encompass further engagement with stakeholders via a call for evidence and/or consultation on more specific proposals.

In Part 2 of this response (non-economic regulation) we set out that we will continue to work closely with industry and relevant regulatory bodies to consider and examine the issues raised and the suggestions put forward on the suitability of existing non-economic regulatory frameworks for hydrogen, with a view to introducing timely amendments where they are warranted.

In April 2023, we published the Offshore Hydrogen Regulation Consultation, which closed on 22nd May 2023. The consultation set out initial proposals for offshore hydrogen pipelines and storage facilities, requiring secondary legislation whilst ensuring the environmental impacts of early hydrogen projects are duly considered and that activities are conducted with proper regulatory oversight. We aim to publish our response to this consultation alongside a summary of the responses received in Q3 2023.

Chapter 6 - Blending.

Alongside the potential benefits and risks explored in this chapter, we are considering the potential means to deliver blending, if blending is enabled by government. This includes the assessment of technical delivery models for blending, market and trading arrangements, interactions with gas billing and potential commercial support mechanisms.

We are aiming to publish a consultation shortly on hydrogen blending that sets out some of our minded-to policy positions ahead of the intended 2023 policy decision. In this consultation, we also plan to set out the nature of our intended 2023 decision on blending into gas distribution networks given broader strategic, economic and safety considerations. We invite readers to engage with this next consultation, once published.

The **hydrogen transport and storage: government response to consultation** document summarises the stakeholder responses received to each of the 63 questions in our consultation and sets out government's view on each.

Chapter 2: Hydrogen transport infrastructure

Introduction

In the British Energy Security Strategy (BESS), government committed to design new business models for hydrogen transport and storage infrastructure by 2025. In August 2022, government sought stakeholder feedback on the high-level design of these business models. This chapter sets out government's minded-to positions on the high-level design of the hydrogen transport business model. These are based on stakeholder feedback from the consultation. The annex sets out the stakeholder feedback to each individual question outlined in the consultation.

In total, the consultation received 90 responses. Given the breadth of the consultation, not all stakeholders answered every question. Nonetheless, for the hydrogen transport business model chapter, responses were received from a broad set of stakeholders including natural gas network owners and operators, potential hydrogen storage owners and operators, hydrogen producers, hydrogen end-users, and energy-related trade associations.

The consultation set out that government's initial focus for the hydrogen transport business model would be onshore pipelines transporting hydrogen as a gas. From this, government asked a series of questions on the high-level design, market barriers, and other considerations, such as compatibility with the natural gas network price control.

Although the consultation set out the focus for onshore pipelines transporting hydrogen as a gas, the consultation did also seek stakeholder views on other infrastructure and methods of hydrogen transportation, such as offshore pipelines, pipelines transporting hydrogen as ammonia, and vehicular transportation of hydrogen.

Minded to position

We have established the following minded to positions for the high-level design of the hydrogen transport business model:

- The initial focus for the business model will be on **large-scale pipeline infrastructure, which transports hydrogen as a gas**;
- A **Regulated Asset Base (RAB)** will form the basis of the business model;
- An **external subsidy mechanism will be created** alongside a RAB to ensure that charges to users of the pipeline(s) and/or network(s) are not prohibitive, whilst allowing hydrogen transport providers to make a reasonable return on their investment;
- The external subsidy mechanism will be delivered through private law revenue support contracts between a counterparty and a hydrogen transport provider receiving the subsidy;

- The external subsidy mechanism can be used in conjunction with or separately to a RAB;
- The business model needs to be **compatible with the future natural gas network price control**, and will be designed as such; and
- **Strategic planning will form the basis of our allocation process** for the business model, and it will help inform the nature and timing of support for early hydrogen transport projects.

Given the already ambitious nature of designing a business model by 2025, an additional interim business model may cause delay and add complication to delivering an enduring hydrogen transport business model as soon as possible. An interim business model could not be designed in parallel to be operational significantly earlier and, as such, would not alleviate the concerns of stakeholders who expressed a need for more urgent government support.

We are developing our approach to strategic planning for hydrogen transport and storage (T&S) infrastructure as a priority to help identify and prioritise early strategically significant projects. This strategic planning will form the basis of the business model allocation process, and it will help inform the nature and timing of support for early hydrogen T&S infrastructure projects.

Section 1: Strategic objectives

Need for a business model

There are a number of market barriers associated with investing in and developing hydrogen transport infrastructure, including high upfront capital costs and uncertain financial returns. A business model is required to help overcome these market barriers.

As illustrated below, hydrogen transport infrastructure will be important in supporting the hydrogen economy. This is why in the BESS, government committed to designing a business model for hydrogen transport infrastructure by 2025.

Objectives

The government has a 10GW hydrogen production capacity ambition by 2030 (subject to affordability and value for money). The early objective of this business model will be to encourage the development, construction, and operation of hydrogen transport infrastructure to support this ambition. This is because increasingly large transport infrastructure will be needed to link hydrogen producers with consumers (e.g. in industry, power, transport and potentially heat) and storage facilities.

Beyond the 10GW hydrogen production capacity ambition (subject to affordability and value for money), a thriving hydrogen economy is likely required to support wider decarbonisation and help meet net zero targets. Additionally, a hydrogen economy can contribute to energy security and allow the UK to take full advantage of home-grown energy. The development of hydrogen transport networks aids the transition towards a large, mature and competitive hydrogen market synonymous with a thriving hydrogen economy.

Additionally, the cost of transporting hydrogen via road is estimated to be higher than the cost of transporting hydrogen via pipeline, especially over longer distances. According to analysis by Frazer-Nash, published in 2022, the levelised costs for transporting hydrogen via road approximately costs £1.23/kg and transporting hydrogen by pipeline approximately costs £0.17/kg.[3] This cost is based on the distance hydrogen is expected to be transported, established through Frazer-Nash's research. Whilst there will be a range of transport methods that will play a role in the emerging hydrogen economy, we consider pipelines to be the most cost-effective way of scaling-up.

This business model will encourage investment in and the development of hydrogen transport infrastructure. The growth of this infrastructure can help to support the market transition from a highly fragmented initial stage to a more integrated end state. We think this end state should be able to compete against other technologies without support and allow it to form part of an integrated energy system, working alongside and concurrently with electricity and natural gas.

Government has committed to taking strategic decisions in 2026 on the role of hydrogen in decarbonising heat, which will have important implications for the scale, location and nature of any hydrogen network. We consider that the overall need for a large, integrated, and resilient network to link multiple producers and consumers, and connect to storage, is not contingent on the use of hydrogen in heating.

Nonetheless, as we design a business model by 2025, we will need to consider whether this business model is suitable for supporting infrastructure needs for hydrogen for heating, should this be required following decisions in 2026.

Focus for the business model

We will initially target our support to large-scale pipeline infrastructure, which transports hydrogen as a gas.

Based on stakeholder feedback, we think the initial need for the hydrogen economy is for the transportation of hydrogen as a gas, predominantly onshore. Early projects are expected to produce and use low-carbon hydrogen as a gas and are largely located onshore.

Early strategic pipelines will enable the growth of the hydrogen economy. They will help to provide resilience for the future market by diversifying supply, encouraging hydrogen producers into the early market by increasing the certainty of having future hydrogen transport infrastructure, and enticing end-users to switch to hydrogen in the long term.

For initial producers and end-users of hydrogen that require limited hydrogen transport infrastructure, the hydrogen production business model provides an avenue to support the development of this limited infrastructure. Although to note, the hydrogen production business model will only offer capex support as opposed to opex support. This allows the hydrogen transport business model to focus on larger scale infrastructure.

[3] https://www.gov.uk/government/publications/hydrogen-infrastructure-requirements-up-to-2035

Given the potential for offshore low-carbon hydrogen production, we are also seeing first-of-a-kind (FOAK) offshore pipeline projects coming forward. Vehicular transport will also play a role in the near term, as well as in any enduring regime, most likely by supporting dispersed end-users that do not have nearby pipeline. As such, offshore pipelines transporting hydrogen as a gas, as well as vehicular transportation, may need support, and we will be undertaking work to understand this need.

Following feedback, government understands the potential importance of other infrastructure or methods of transportation that will support the development of the hydrogen economy. This feedback has been beneficial to aid government's understanding of how other infrastructure and methods of transportation may develop and also aids in analysing whether support is needed and if so, the type of support that may be required. The government will keep this under review, most notably as part of the strategic planning workstream. Further information is provided in the 'Other Infrastructure section below.

Section 2: High-level design of the business model

Key design principles

There was broad agreement to the key design principles for the hydrogen transport business models outlined in the consultation. However, following stakeholder feedback, we have made some changes to the key design principles.

Table 2.1: Key design principles for the hydrogen transport business model

No.	Key Design Principle	Description
1	Investable	- The business model should provide sufficient predictability over revenue and return to investors and mitigate risks that investors are not best placed to bear
2	Promotes market development	- The business model should incentivise transport providers to optimise the use of their infrastructure - The business model should encourage the development of a market, through cost reductions and certainty for users, that does not require on-going support (external subsidy mechanism)
3	Compatible	- The business model should be compatible with other policies across the value chain, including other hydrogen related business models, and should not result in double subsidisation - This business model should be compatible with the natural gas network price controls, this should help facilitate repurposing, asset valuation, and risk management

		- The business model should also be compatible with different stages of development and hydrogen market maturity over time, while being adaptable to this change
4	Avoids unnecessary complexity	- The business model should avoid unnecessary complexity for government to design and implement in a timely manner - The business model should avoid unnecessary complexity to allow hydrogen transport providers to understand and comply with over time
5	Reduces support over time	- The business model should allow for support to reduce over time by being responsive to market conditions, the changing risks as the hydrogen economy grows and by incentivising learning and innovation to drive cost reductions over time - The business model should aim to be transparent in its reduction in support over time so as to not create additional revenue risk
6	Suitable for future pipeline	- The business model should be fit for purpose for FOAK projects as well as nth-of-a-kind (NOAK) projects
7	Value for money	- The business model should be effective in achieving its intended purpose at the lowest possible cost to the government and prevent excessive returns to developers

These principles will continue to inform our policy development and will be used to evaluate different options and features of the detailed design of the business model.

Regulated Asset Base

Our minded-to position for the high-level design of the hydrogen transport business model is that it will feature a RAB.

Stakeholder feedback confirmed that a RAB business model design is well supported in a growth phase. Many stakeholders pointed to the fact that the RAB model was well-known to those likely looking to invest in large-scale hydrogen transport infrastructure and would effectively de-risk investment.

Stakeholders also noted the flexibility of the RAB being beneficial given the anticipated transition from a nascent market to a mature market, and the different risks and rewards a business model will need to cater for to encourage private investment as the market transitions. A RAB offers a well-known framework but one that can also be adapted to cater towards different and changing circumstances, providing investors with a degree of certainty as to the business model design whilst also allowing government or a regulator to set the appropriate risk and reward to encourage investment at different points in the growth of the hydrogen economy. This transparency and flexibility are the main reasons we consider a RAB design to be optimal for both a growth and a steady state phase.

Stakeholder feedback agreed with the government's view that a RAB would be the most appropriate model in a steady state phase. This is primarily because:

- The RAB framework is familiar to both government, regulators and industry – and has successfully incentivised investment into natural gas, electricity and water infrastructure;
- It addresses the barriers and challenges associated with large-scale infrastructure – including high upfront capital costs and difficulties in recovering revenues over a long period of time; and
- A RAB-style price control framework provides user protections against risks associated with monopolistic or strategically important assets.

Stakeholder feedback also flagged that an external subsidy mechanism would be required alongside a RAB framework in order to avoid high upfront costs falling on an initially small user base in a growth phase. This is covered in further detail below.

External subsidy mechanism

A benefit to those receiving a RAB is the revenue certainty it provides, through the provision of regulated returns - commonly referred to as, or helping to make up, the "allowed revenue". A RAB usually operates under a, 'user pays principle' – in the sense that the "allowed revenue" is recovered from users of the infrastructure through network charges.

We anticipate that during the growth phase of the hydrogen economy, the number of users will initially be low, due to the nascency of the market. Therefore, relying solely on these users to recover costs will result in prohibitively high charges for these users. We could solve this problem by capping user charges, so they're not prohibitive. However, this would then result in the transport provider being unable to recover all of the allowed revenue.

To overcome this, an external subsidy mechanism will likely be required in the initial stages of the hydrogen economy. This could, in effect, top up the difference between the allowed revenue and the amount that can be recovered through fair user charges. This would mean transport providers can recover their allowed revenue, whilst ensuring users do not face prohibitive charges.

The use of an external subsidy mechanism was supported by the stakeholder responses to the consultation. They noted the importance of minimising the first mover and/or early user disadvantage associated with building new high capital cost pipeline(s) and/or network(s).

The use of an external subsidy mechanism should help meet our objective of supporting government's hydrogen production capacity ambitions, by minimising the financial barriers faced by users who want to switch to low carbon hydrogen.

It is important that a RAB and the external subsidy mechanism can be used independently as well as in conjunction with each other. This is because not all strategically important pipeline projects will necessarily be appropriate for a RAB, but we may still want to support projects via the external subsidy mechanism.

Section 3: Stakeholders

Recipients of the business model

Our current assessment is that this external subsidy mechanism should be allocated to a hydrogen transport provider, rather than users. This is because:

- It is transport providers that are exposed to the high upfront capital costs and associated revenue risks;
- The number and diversity of potential network users means it will likely be simpler to target transport providers; and
- It offers familiarity as government has taken a similar approach to supporting other large-scale infrastructure – such as carbon capture, usage, and storage transport and storage (CCUS T&S), and so we expect it to further de-risk investment.

In the consultation, we asked stakeholders about the most suitable ownership model for infrastructure supported under this business model. We have noted the feedback we have received, and these responses will continue to inform the detailed business model design process.

Needs of key stakeholders

We have considered the needs of the main stakeholders with an interest in the hydrogen transport business model, namely hydrogen transport providers, users and government. The hydrogen transport business model must consider and balance the needs of these stakeholders within the hydrogen transport value chain. Our initial assessment of these needs are set out below:

Government:

- Support the 10GW production capacity ambition and support the hydrogen economy more widely (enabling wider decarbonisation for industry and transport as well as the power sector);
- Facilitate investment into hydrogen transport infrastructure;
- Ensure allocation of the business model is value for money and maximises benefits for the hydrogen economy;
- Keep subsidy to a minimum and work with industry to become subsidy free and ensure subsidy control limits are met;

- To ensure security of supply is maintained to an acceptable level for the hydrogen economy to continue to grow; and
- To ensure the development of hydrogen transport is well integrated within broader energy security objectives of government.

Hydrogen transport providers:

- Confidence that hydrogen transport infrastructure will generate sufficient revenue;
- Transparency and predictability of returns on investment;
- Ability to price competitively to attract users; and
- A stable and proportionate regulatory regime (economic and otherwise).

Hydrogen transport users:

- Affordable hydrogen transport infrastructure;
- Accessible hydrogen transport infrastructure; and
- Security of supply for hydrogen.

Section 4: Regulated Asset Base

Regulator

A RAB needs an independent regulator to administer the framework and regulate the companies that operate the pipeline(s) and/or network(s). Hydrogen is a gas within the Gas Act 1986 (the “Gas Act”). Under the Gas Act, Ofgem is already the independent regulator for hydrogen.

The natural gas and electricity networks operate under a RAB-style price control, and Ofgem is currently the independent regulator for these sectors. Subject to the will of Parliament, Ofgem will also be the independent economic regulator for CCUS T&S infrastructure which is to be established by the Energy Bill.

Regulation, supported by an independent regulator, is beneficial for large-scale infrastructure such as large-scale pipeline(s) and/or network(s) as this infrastructure is often operated as natural monopolies. Large-scale energy infrastructure can often exhibit monopolistic features, which can create market barriers. These potential market barriers are (not an exhaustive list):

- Vertical issues – pipeline/network providers prevent users from joining the pipeline(s) and/or network(s) or reduce access to users;
- Horizontal issues – pipeline/network providers set excessive charges for users; and
- Performance issues – poor handling in terms of customer service, not investing efficiently in the pipeline(s) and/or network(s), and not willing to innovate.

It is the responsibility of the independent regulator to issue licences. The licensing framework is used to implement the price control settlement. The licensing framework also ensures that the independent regulator can place requirements, subject to further regulation in some cases, on the licence holder for receiving a RAB, such as the ability to require third party access.

The regulator develops a price control to set performance targets and the allowed revenue for the licensed company. An allowed revenue sets out how much revenue a licensed company can recover from its users. In the case of natural gas, the natural gas network provider can charge users of their network(s) for the service of transporting natural gas to end-users.

An allowed revenue aims to ensure pipeline/network providers can recover costs and earn a fair rate of return whilst controlling the end cost for users or customers. The allowed revenue is reflective of costs incurred by the provider for activities such as operating, maintaining, and developing the network, as well as a fair rate of return. The allowed revenue ensures that any revenues recovered by the providers balance the relationship between investment in the pipeline(s) and/or network(s), company returns and the amount that they charge customers for use of the pipeline(s) and/or network(s).

This helps to manage the market barriers associated with this type of infrastructure. It also illustrates the importance of an independent economic regulator as part of the RAB design and helping to overcome these market barriers.

Legislative framework

Currently RABs for natural gas networks are allocated and implemented through gas transporter licences granted under the Gas Act.

Whilst we recognise that the emerging hydrogen market will not be exactly like natural gas, we think relying on the existing framework under the Gas Act, which also applies to hydrogen, where we can, will allow us to progress quickly and get initial large-scale projects off the ground. As such, we propose to continue to use the mechanics of the Gas Act for now, including implementing a RAB for hydrogen pipelines through gas transporter licences.

Allocation and licensing

Currently, Ofgem grants and regulates gas transporter under the Gas Act. In the context of natural gas, this means that Ofgem has sole responsibility for the design and allocation of a RAB. We think this is initially unlikely to be an optimal approach for hydrogen.

Hydrogen is a highly nascent market, and given the risks associated with a nascent market, there is a need for government to provide support through subsidy mechanisms. These FOAK projects and their strategic coherence will, for example, likely be intimately tied to decisions on the hydrogen production business model allocation rounds, as well as wider decisions on CCUS cluster sequencing.

There will be complex policy trade-offs when considering which transport projects should be built and by when, and we think that government will be better placed to make these trade-offs in the early stages. This is especially the case when considering how the RAB will be used in conjunction with the external subsidy mechanism.

To provide a role for government in the allocation of RABs to these early hydrogen pipeline projects, government is seeking various powers through the Energy Bill, including giving the Secretary of State (SoS) powers to grant, extend, restrict and modify gas transporter licences. These powers will be limited to hydrogen and will not apply more generally to natural gas. We have not yet made any decisions on the actual configuration of roles and responsibilities between Ofgem and government. This will be a key priority area for us in the next stage of this work.

Currently, our focus is on a RAB for pipelines transporting hydrogen as a gas in Great Britain (GB). Government is working with counterparts in Northern Ireland Civil Service and the Northern Ireland Utility Regulator to understand potential hydrogen transport infrastructure development there and any potential requirements around business model support.

Whilst our focus here is on implementing a RAB for hydrogen pipeline projects through gas transporter licences granted under the Gas Act, elsewhere in our consultation we recognised that the existing market framework and industry commercial arrangements that would apply to hydrogen may not be conducive to the emergence of hydrogen transport and/or storage infrastructure. We therefore sought the views of stakeholders on these matters and asked how any perceived shortcomings might be addressed. Stakeholder views and government's intended next steps are set out in the Regulatory Framework chapter.

We appreciate the dependency between the business model and the market framework, especially in giving investors, operators, owners and users confidence. As such, in line with the next steps outlined in the Regulatory Framework chapter below, we'll consider how the market framework can work effectively alongside the business model from day one.

Section 5: External subsidy mechanism

Counterparty

Our intention is that the external subsidy mechanism, whether accompanied by a RAB or not, will be delivered via a private law contract (a "hydrogen transport revenue support contract") with the hydrogen transport provider. A counterparty would be needed to administer these hydrogen transport revenue support contracts.

A counterparty would manage the contracts and act a conduit for subsidy funding. This aligns with the approach taken for other schemes, including the Contracts for Difference (CfDs) scheme, for which the Low Carbon Contracts Company (LCCC) acts as the counterparty,[4] and the hydrogen production business model, for which government anticipates the LCCC will be the counterparty,[5] subject to successful completion of administrative and legislative arrangements.

We have tabled amendments in the Energy Bill to underpin the delivery of hydrogen transport revenue support contracts, including providing the SoS with powers to designate a hydrogen

[4] https://www.lowcarboncontracts.uk/contracts-for-difference-cfd
[5] https://www.gov.uk/government/publications/hydrogen-production-business-model

transport counterparty by notice and to direct the counterparty to enter into contracts with a hydrogen transport provider.

A decision has not yet been made as to who government will designate for this counterparty role for the business model - Government will undertake analysis to determine this. Considerations in the decision-making process will include operational independence, the ability to command investor and government confidence, contract management experience, and sector expertise.

Territorial scope of the external subsidy mechanism

The territorial scope of the external subsidy mechanism for the hydrogen transport business model is intended to be United Kingdom (UK)-wide. Although, as mentioned above, the territorial scope of the RAB is intended to be GB-wide in line with the Gas Act.

We will continue to work with the Northern Ireland Civil Service on understanding the potential development of hydrogen transport infrastructure in Northern Ireland and any required support. Meanwhile, the legislative powers we have sought will give us the optionality of supporting hydrogen transport projects in Northern Ireland through subsidy.

Funding the external subsidy mechanism

No decision has yet been taken with regards to how the external subsidy mechanism will be funded, however, options for funding include Exchequer and/or a levy. We will provide a more detailed update on funding the business model in due course. If we make a decision to fund via a levy, we will consult on the design of this - the hydrogen storage business model has a similar position on funding. For the specific hydrogen storage business model position, please see the Hydrogen Storage Business Model chapter.

We are seeking powers in the Energy Bill to enable the external subsidy mechanism to be funded by both Exchequer and/or levy funding, with the decision to be made in the future.

By enabling options for both Exchequer and levy funding, the provisions in the Energy Bill seek to provide two reliable options for funding the business model.

The Energy Bill already includes powers to allow the business model to be funded via the Exchequer. However, to provide the option to fund the external subsidy mechanism via a levy, we have tabled amendments to the Energy Bill to enable the establishment of a levy. For clarity, the powers we have sought expand levy powers which existed in the original draft of the Energy Bill to fund the cost of hydrogen production contracts. The amendments we have tabled include provision for transport within the scope of these hydrogen levy provisions.

Our amendments will provide the SoS with powers to appoint a levy administrator and to make regulations to establish a levy to fund the external subsidy mechanism associated with the business model, and related costs. Levy funding mechanisms are used elsewhere in the energy sector, for example for funding CfDs and the Green Gas Support Scheme (GGSS). Consequently, a levy is well understood by the private sector. As with the hydrogen production business model, revenue generated by this levy would be used by a hydrogen transport counterparty to make payments under hydrogen transport revenue support contracts, and to cover related costs such as those associated with administering the levy or managing the contracts.

Securing primary legislation with provisions for a hydrogen transport levy is not a commitment to using a levy for the hydrogen transport business model. It only enables government to introduce a levy later, if appropriate, through secondary legislation. The decision to introduce any levy will take into account relevant considerations including relevant wider government priorities and policies.

The result is that the powers to fund the business model via Exchequer and/or a levy provide the option to use either of these revenue streams to support the development of hydrogen transport infrastructure, enable the hydrogen economy to grow, and to meet government's ambition of up to 10GW of low carbon hydrogen production capacity by 2030 (subject to affordability and value for money).

Section 6: Allocation and interaction with wider energy system

Whole system planning

As the energy sector becomes more interlinked between electricity, natural gas, and hydrogen government understands the need to ensure any business model can interact well with other business models, policy and regulatory frameworks in the energy sector.

In particular, the hydrogen transport business model will need to work effectively alongside the next natural gas network's price control. This should help facilitate repurposing, asset valuation and risk management.

Business model interaction

We are conscious that we are designing the hydrogen transport business model within a landscape of existing government schemes, including the hydrogen production business model, Net Zero Hydrogen Fund (NZHF) and Renewable Transport Fuel Obligation (RTFO), as well as forthcoming schemes including the hydrogen storage business model. We are also aware of possible market interventions to support hydrogen to power generators and large-scale long duration electricity storage.

We will continue working across government to ensure alignment between these schemes, particularly where there may be overlap in eligibility. In these cases, we will ensure that our design mitigates potential subsidy cumulation. This will form part of the next stage of business model design.

This close working is especially true for the hydrogen production business model given that this business model has the scope to support limited hydrogen transport infrastructure (subject to necessity, value for money and affordability).

Allocation of the business model

An important part of business model design will be the allocation process. As set out earlier, government is seeking powers to have more control over the allocation of the RAB, and this will be complemented with powers for government to designate and direct a counterparty in relation to an external subsidy mechanism.

Our initial view of the allocation of the business model, especially in the short-term, is that it will likely be negotiated bilaterally between the department and prospective hydrogen transport providers – with a key role for the regulator and the counterparty. As we explained earlier in this chapter, we have not yet made a decision on the exact configuration of roles and responsibilities between government and the regulator.

The minded to positions set out in this government response provide a starting point for developers to understand the support framework for potential projects. The next level of detail will be provided through our position on allocation which will be developed as a priority. Ultimately, strategic planning will form the basis of our allocation process, making sure that the business model is allocated to projects in the right location, of the right size and at the right time. This includes business model support being provided to allow for futureproofing of infrastructure to meet future demand as opposed to only meeting current known demand.

In the longer term, it is likely that the Future Systems Operator (FSO) will play a role in providing this strategic planning for the allocation process. See the Strategic Planning chapter for more details on the possible future role for the FSO. In the short-term, we think there is a need for government to play this strategic planning role for the allocation process. We set out our key position and next steps on strategic planning in the Strategic Planning chapter.

Other infrastructure

It is the government's current intention to only design one business model for large-scale hydrogen transport infrastructure. As noted previously, this business model will focus initially on large-scale pipelines transporting hydrogen as a gas.

However, we are aware that other infrastructure and methods of hydrogen transportation will likely be needed to support a thriving hydrogen economy. Government is keen to better understand how this infrastructure is likely to evolve, and what support may be needed. That is why the consultation sought stakeholder views on other infrastructure, such as offshore pipelines, pipelines transporting hydrogen as ammonia, and vehicular transportation of hydrogen.

Government will continue to work with stakeholders to understand how this infrastructure may develop, and what support is needed, including the need for smaller scale infrastructure as the hydrogen economy initially develops.

Interim support

We remain committed to supporting early projects, unlocking the advantages that strategically significant transport infrastructure can bring to the wider hydrogen economy. Our commitment to design a business model for hydrogen transport infrastructure by 2025 is ambitious but essential, and will provide an enduring framework at the right pace to support and accelerate the growth of the hydrogen economy. We are developing our approach to strategic planning as a priority, and this will form the basis of the hydrogen transport business model allocation process and will help inform the nature and timing of support for early hydrogen transport projects.

We have already taken steps to support early projects, for example, in March 2023, 20 production projects were shortlisted through the Hydrogen Allocation Round (HAR) process, and many included early transport infrastructure. The transport infrastructure necessary for the first hydrogen production projects in the clusters is also being taken forward as part of Track 1 of the Cluster Sequencing process. Additionally, devex for some hydrogen projects by existing natural gas network providers, can be supported under Ofgem's RIIO mechanism where the projects provide clear benefits to natural gas consumers. For example, Ofgem recently approved devex funding for the feasibility stage of National Gas' Project Union.[6]

Identifying opportunities to reduce uncertainty and provide a clearer path forward for hydrogen transport infrastructure development is a key priority of our strategic planning work. In the Strategic Planning chapter, we set out our early views on strategic planning for hydrogen infrastructure and the next steps we are pursuing as a priority to help identify and prioritise early strategically significant projects. Our work on planning, regulation and the enduring market framework for hydrogen is also focused on initial solutions that can best support early projects to progress. Supporting these early strategically important projects is a key ambition to enable the growth of the hydrogen economy.

Stakeholders have suggested that there is a need for interim mechanisms between now and 2025 to help support early projects. Given the already ambitious nature of designing a business model by 2025, an additional interim business model may cause delay and add complication to delivering an enduring hydrogen transport business model as soon as possible. An interim business model could not be designed in parallel to be operational significantly earlier and as such, would not alleviate the concerns of stakeholders who expressed a need for more urgent government support.

Next steps

As we have a minded to position on the high-level design of the business model, work associated with the detailed design has begun. We intend to maintain our ongoing engagement with stakeholders across the hydrogen value chain and in particular, those proposing to develop, construct and operate large-scale hydrogen transport infrastructure as we undertake this detailed design work. We will continue to gather feedback on policy development and ensure stakeholders are aware of future opportunities to feed into the detailed design. We plan to publish an update of the progress of the design of the business model at the end of this year.

[6] https://www.ofgem.gov.uk/publications/ngt-project-union-feasibility-phase-decision

Legislation

As discussed, government is currently seeking powers through the Energy Bill to support the implementation of the hydrogen transport business model.

These powers will enable broad options on the design of the business models.

To recap, government is seeking powers for:[7]

- Allocation of a RAB-style price control;
- Designate and direct a counterparty; and
- Appoint a levy administrator and to make regulations to establish a levy.

Next phase of design

After establishing the high-level design of the business model, supported by this legislation, government is now focussed on the detailed design.

Information on progress will be provided through updates, with the first update expected at the end of this year.

Our intention is that the update on the hydrogen transport business model will be issued alongside an update on strategic planning for hydrogen. We intend for early strategic planning to focus on informing the design of the business model allocation process to ensure that allocation is able to take relevant strategic factors into consideration, please see the Strategic Planning chapter for further details on this.

Alongside strategic planning, the market framework within which hydrogen and hydrogen transport infrastructure operates in will be an important consideration for investors as well as owners and/or operators of the pipeline(s) and/or network(s). As set out in the Regulatory Framework chapter, it is government's intention to keep the market framework under review. This review is likely to include further engagement with stakeholders through a call for evidence and consultation on more specific proposals at a later date.

[7] https://www.gov.uk/government/publications/energy-security-bill-factsheets/energy-security-bill-factsheet-hydrogen-transport-and-storage-business-models

Chapter 3: Hydrogen storage infrastructure

Introduction

The government committed to design a dedicated business model for hydrogen storage in the British Energy Security Strategy.[8] In this chapter we outline our minded to position for the high-level design of the hydrogen storage business model. Minded to positions are based on responses to the hydrogen transport and storage infrastructure consultation, engagement with industry and input from advisors.

Minded to position

Section 1 sets out our overall strategic objective for storage infrastructure. We conclude that hydrogen storage should be available to meet the needs of users in an emerging and evolving hydrogen economy by addressing imbalances in hydrogen production and demand. It is important for the business model to secure timely investment in storage, whilst retaining sufficient flexibility to meet changes in size and nature of the hydrogen market.

In section 2, we describe our approach to the design of the model to provide protection against demand risk, which comprises price risk and volume risk. Demand risk differs from other identified risks as it is largely beyond the control of the storage provider and therefore creates a significant barrier to investment.

In section 3, we establish parameters for business model support. We set out our rationale for targeting business model support to storage providers as they have the burden of upfront capital expenditure and demand risk. We anticipate the initial allocation of the business model to focus primarily on geological storage as it better serves government objectives for scale, technology readiness and end uses, compared with above-ground and chemical storage. We are however minded to retain optionality in the business model to support above-ground storage where it faces the same market barriers as geological storage. We have assessed whether there is a case for government to introduce multiple storage business models. Given our already challenging 2025 target, we are minded to design a single, enduring business model which is adaptable to an evolving hydrogen economy.

In section 4, we consider the commercial design of the model and propose proceeding with a minimum revenue floor for storage providers to sufficiently mitigate demand risk, regardless of the extent to which the facility is used. We want to incentivise storage facilities to maximise revenue from users, and so we propose to let the storage provider earn more than the floor if they are able to raise revenue from users. To protect value for money, we are considering including a mechanism to ensure that if user revenues are particularly high, the facility must make payments to the subsidy provider.

We have set out current thinking around duration of support. We are minded to award business models for at least 15 years to reflect the early years where utilisation of storage facilities could

[8] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

be low, whilst enabling the subsidy provider potential to recoup payments in later years. We are also considering incentives for facilities to be built on time, with high levels of availability. We will also consider sculpting the profile of capital repayment across the duration of the contract.

Finally, we propose that the most suitable delivery mechanism is private law contracts between hydrogen storage providers and the subsidy provider as they can be implemented relatively quickly and provide flexibility to support a range of projects.

In section 5, on commercial context, we set out that the initial users of storage could include hydrogen producers, offtakers and/or hydrogen network companies, and in due course intermediaries might also use storage. Our intention is that storage pricing should be driven by supply and demand and reflect the long-run marginal costs of storage facilities. We are mindful of market power, which may be elevated during the early rollout of hydrogen.

In section 6 we outline options for funding the business model, including funding via a levy or via Exchequer funding. No decision has yet been taken on how it will be funded. We will provide a more detailed update on funding the business model in due course. If we make a decision to fund via levy, government will consult on the design of any levy.

In section 7, on allocation of support, we anticipate that the hydrogen storage contract will be negotiated bilaterally between the Department for Energy Security and Net Zero (the department) and prospective storage providers. We are considering whether we would support facilities built in stages, and if so, how multi-staged facilities would be supported by the business model.

The minded to positions set out in this document narrow down the options set out in the consultation and provide a direction of travel for the design of the business model. The next level of detail will be provided through our position on allocation criteria that will be developed in parallel with the development of the business model contract. We intend to continue to be guided by consultation with industry as we progress towards the final model design.

This chapter is supported by annexes which set out rationale for options we rejected for mitigating demand risk, and the costs of a typical geological storage facility.

Section 1: Strategic objectives and context

In this section we outline the need for hydrogen storage and our overall strategic objectives for storage.

Why we need storage

Hydrogen storage will play a vital role in the hydrogen economy and wider energy system.

As the hydrogen economy develops, there will be times when the supply of hydrogen will not align with demand from offtakers which will result in periods of a surplus or scarcity of hydrogen, creating security of supply risks. Storage infrastructure will be key to address imbalances in hydrogen production and demand.

We consider hydrogen storage to be required for the following roles:

- Managing within-day network balancing when there is a mismatch between entry and exit volumes in hydrogen networks.
- Allowing hydrogen producers to better manage the demand and production mismatch, particularly for electrolytic producers, and energy security more broadly as hydrogen becomes more important in the wider energy system.
- Supporting decarbonisation of the power system and the 2035 net zero power target through avoiding curtailment of renewables via electrolytic hydrogen production and hydrogen-fuelled power generation.
- Potentially reducing overall hydrogen production capacity requirements by maximising supply and allowing production facilities to optimise their output.

Overall strategic objective

Our overall strategic objective is to ensure hydrogen storage infrastructure, as a part of wider system architecture, is available to meet the needs of users in the emerging hydrogen economy. We recognise that the needs of users will differ - for example, hydrogen to power generators will need quick access to large volumes of stored hydrogen, whilst hydrogen used for heat (subject to the 2026 government decision),[9] will require interseasonal storage, where large volumes of hydrogen are stored over long durations for security of supply. We can however, broadly categorise all users needs as below:

- Time - when storage is needed,
- Location - where storage is needed,
- Performance characteristics - type of storage needed,
- Cost – affordability.

Under our broad objective to make hydrogen storage available, there are two key priorities:

- Delivery at pace, and
- Enabling low regrets and/or strategically important projects.

The business model needs to be available to deliver revenue certainty to prospective storage providers as soon as possible to enable final investment decisions to be taken promptly on projects which are low regrets and/or those considered to be of strategic importance. These include, for example, projects that provide critical resilience and confidence to producers and offtakers in and around industrial regions.

Delays to the business model could result in delays to the delivery of critical infrastructure which could threaten government's ambition to have 10GW of low carbon production capacity by 2030, and ultimately our net zero target.

[9] https://www.gov.uk/government/publications/heat-and-buildings-strategy

We recognise the role of hydrogen storage and the barriers facing prospective storage providers are likely to evolve as the hydrogen economy matures. It is therefore important the business model design enables the necessary early investments in hydrogen storage infrastructure while also offering sufficient flexibility for potential changes in the size and nature of the hydrogen market, as well as its wider regulatory and market frameworks.

Future of the hydrogen storage market

Our aim is to establish a self-sustaining market for hydrogen storage. We expect this market to have several competing firms. This is because:

- Large numbers of storage facilities are likely to be required, even in net-zero compliant scenarios with comparatively low amounts of hydrogen production and use.[10]
- Storage does not have all the characteristics of a natural monopoly.[11]

Our vision of a competitive market informs our approach to the design of the business model.

Currently, we are open-minded as to whether, in the long run, there will be a need for on-going government intervention(s) in the hydrogen storage market. This might include, for example, intervention(s) to ensure enough hydrogen gas is kept in storage facilities to ensure security of supply. Evidence on issues such as these is currently scarce but we need to de-risk investment in hydrogen storage facilities as soon as possible. We are therefore designing a business model that is compatible with a range of options for the future market framework for hydrogen storage, and which can secure investment in storage facilities notwithstanding the current uncertainties about that market framework. To the extent that we are already able to set out views on the future market framework, we have done so in this chapter (for storage) and also in chapter 5 (for hydrogen more generally).

Interaction between transport and storage

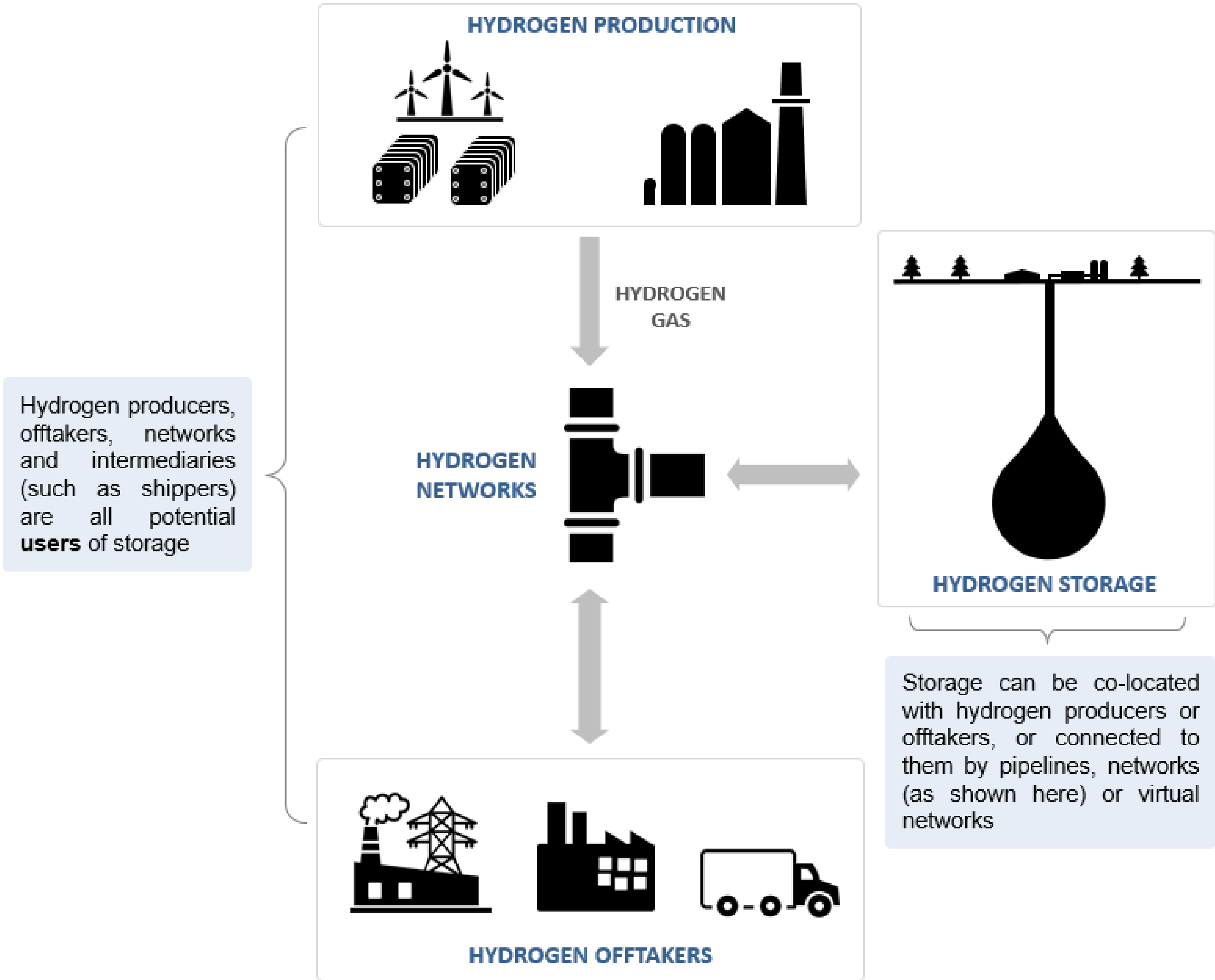
Hydrogen transport and storage will interact with and depend on each other in several ways. Transport infrastructure such as networks will connect storage facilities with storage users such as hydrogen producers and offtakers (see figure 3.1). Storage facilities will help to balance supply and demand for hydrogen gas on networks. Ensuring the development of

[10]For example, in National Grid's Future Energy Scenarios 2022, the "consumer transformation" scenario entails annual storage of at least 11TWh of hydrogen by 2050. This storage requirement may be met by multiple technologies of different sizes but is broadly equivalent to the amount of capacity that would be provided by many salt caverns performing several cycles each year. The "system transformation" scenario entails five times as much hydrogen storage as the "consumer transformation" scenario.

[11] An industry is a natural monopoly if the cost of one firm providing all output for that industry would be significantly less than the cost of two or more firms producing (when their respective outputs are combined) the same amount of output. This situation often arises as a result of very high infrastructural costs, other barriers to entry, and economies of scale, which are typical characteristics of industries such as energy networks, water and telecoms. Although geological hydrogen storage is capital-intensive, start-up costs are not as high as they are for national infrastructure networks, so firms will be able to afford the initial capital outlay to enter the market. Although economies of scale exist for hydrogen storage, these are mostly associated with the capacity of individual storage sites rather than the number of storage sites owned by a single firm. These facts, and the fact that the existing natural gas market has competing firms, indicate that if many storage facilities will be required, hydrogen storage will not be a natural monopoly industry.

transport and storage is coordinated in such a way as to minimise long-term energy system costs while reaching net zero emissions will be complex. Our position on the need for strategic planning to help with this coordination is set out in chapter 4. There are additional issues we need to consider in relation to the interaction between transport and storage, of which, some are covered in the rest of this chapter, and others we will consider as part of future work.

Figure 3.1: Users of hydrogen storage



Need for a storage business model

The development of hydrogen storage infrastructure, particularly as an asset that serves a strategic purpose (i.e. oversized to accommodate potential demand or offers a systemic benefit to the wider energy system) faces multiple challenges. These include:

- Understanding the mix of storage technologies required and the optimum pace of development. Since the hydrogen economy is nascent, there is uncertainty around how and when demand for hydrogen storage will grow, what type of storage infrastructure will be needed in which locations, and the role it might play in providing energy security and resilience.

- Lengthy lead times (up to ten years)[12] and complexity of developing geological storage such as salt caverns and depleted oil and gas fields;
- The need for significant levels of investment (potentially hundreds of millions of pounds of up-front development costs).

The private sector therefore faces multiple market barriers that would adversely affect investment decisions in storage infrastructure and restrict the development of a market for hydrogen storage in line with the British Energy Security Strategy's ambitions.[13]

The key market barrier that developers and investors face is demand risk. This is the risk that the facility is not able to raise enough revenue from sales to storage users to cover its costs (either due to low volumes of sales, or low prices, or both). This means that in the absence of government intervention it is unlikely storage developers would choose to invest in hydrogen storage facilities. Whilst the Net Zero Hydrogen Fund (NZHF) and Hydrogen Production Business Model (HPBM) offer some early investment support with the cost of limited hydrogen storage where it is linked to production projects, this is not sufficient to bring forward investment in geological storage which we expect will be required within the next ten years and beyond. Geological storage is larger, generally more capital intensive, with longer development lead times than above ground approaches, but economies of scale can be achieved. Geological storage in particular is key to the hydrogen economy and will not develop without government support. As a result, we consider a hydrogen storage specific business model is necessary to ensure the timely delivery of geological hydrogen storage infrastructure.

Section 2: Approach to model design

This section sets out our approach to design a business model which meets the needs of the main parties involved in a hydrogen storage project.

Needs of the main parties

The business model must consider and balance the needs of the main parties within the hydrogen storage value chain. These are outlined below.

Storage providers and their investors need:

- Confidence that proposed storage facilities will generate sufficient revenue in order for final investment decisions to be made.
- Visibility and predictability of returns on capital invested to justify investment.
- Ability to price competitively to attract a variety of users.

Storage users need:

[12] It is estimated that salt caverns purpose built for storage have a build time of 5-10 years and converted salt caverns have a build time between 3-5 years. This is based on analysis and research commissioned by the department
[13] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

- Affordable, available and accessible hydrogen storage options which fulfil their functional requirements (e.g. in terms of capacity or cycling rates).
- Security of supply of hydrogen to a level that enables them to continue their hydrogen-related activities.

Government needs:

- To achieve the strategic objectives set out in the UK's Hydrogen Strategy[14] and updated ambition in the British Energy Security Strategy to design new business models for hydrogen transport and storage infrastructure by 2025 and for up to 10GW low carbon hydrogen production capacity by 2030.
- To ensure allocation of support is provided to the projects which maximise the benefits of hydrogen production and align with our strategic objectives.
- To keep any subsidy to a minimum to reduce distortions created by government intervention.
- To ensure the right duration of support to trigger investment and establish a self-sustaining market whilst also allowing an exit route from subsidies.
- Where relevant, to ensure all subsidy control requirements have been met and be comfortable with any balance sheet implications.
- To ensure security of supply to enable the development of the hydrogen economy and its role in the wider energy system.
- To ensure the development of hydrogen storage supports broader energy security objectives of government.

We recognise some parties would take on several roles in the hydrogen value chain and where this is the case any subsidisation would have to appropriately reflect each of these roles.

Key design principles

We have set out our key design principles which will inform the design of the business model. We will use them to evaluate different options and features of the model to assess how well they meet our objectives.

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

Table 3.1 Key design principles for the storage business model

	Design Principle	Description
1	Promote development of a market for hydrogen storage	• Model should encourage both efficient use of storage infrastructure and the development of a competitive market.
2	Investable	• Model should provide sufficient predictability over revenue and return to investors and mitigate risks which investors are not best placed to bear.
3	Value for Money	• Model should be effective in achieving its intended purpose at the lowest possible cost to the government and prevent excessive returns to developers.
4	Reduce support over time	• Model should allow for government support to reduce over time, and eventually transition to a merchant model. This should be achieved by being responsive to market conditions, the changing risks as the hydrogen economy grows and by incentivising learning and innovation to drive cost reductions over time.
5	Avoid unnecessary complexity	Model should avoid unnecessary complexity: • for government to design and implement in a timely manner, and • for storage providers to understand and comply over time
6	Compatible	• Model should be compatible with other policies across the value chain and should not result in double subsidisation. • Model should also be compatible with and adaptable to different stages of the storage market over time.
7	Suitable for future pipeline	• Model should be fit for purpose for first of a kind (FOAK) projects as well as next of a kind (NOAK) projects.

Key risks and how they will be allocated

The way risks would be allocated for a facility in receipt of a hydrogen storage business model is set in the table below. In allocating risks, we are guided by our design principles, including:

- Value for money, which implies risks should usually be allocated to the party best placed to manage them, as this helps to minimise the impact of risks on overall costs.
- Investability, which implies risks should not be allocated to the private sector if the private sector is unable to bear them and/or price them.

- Market development, i.e. our aim to reduce support over time and create a competitive market, which indicates it is generally preferable to allocate risks to the private sector rather than to government, subject to the other principles explained above.

The business model will provide protection against demand risk, which is the risk that facilities will not make enough revenue from sales to users to cover their costs, due to low volumes of sales (volume risk) and/or low prices (price risk). Storage owners will face other risks in addition to demand risk, such as the risks associated with constructing facilities and maintaining them so that they remain available for use. Based on engagement to date, storage facilities have not suggested that the business model should transfer these risks to the government. In our assessment, the party best placed to manage these risks is the owner of the storage facility.

Demand risk is different insofar as it is largely beyond the control of the developer/owner and not a risk they can afford to bear, and therefore creates a significant barrier to investment.[15] Our proposals for addressing demand risk are set out in section 4 (commercial design) and we elaborate on the nature of demand risk and the alternative options we considered for addressing it in annex A. Our proposal for the way risks would be allocated for a facility in receipt of a hydrogen storage business model is set in the table below.

Table 3.2: Risks relating to hydrogen storage projects

Risk	Description	Allocation
Demand risk, including volume risk	Risk that the facility is not able to raise enough revenue from sales to storage users to cover its costs, due to low volumes of sales (volume risk) and/or low prices (price risk)	The subsidy provider will provide a large degree of protection against demand risk, sufficient to de-risk investment in the facility. The operator will still have an incentive to raise as much revenue from users as possible. More detail is provided in section 4 (commercial design)
Construction risk	The risk of construction overruns and, as a result, an increase in capital costs	The developer of the hydrogen storage facility is best placed to manage construction risk through effective risk and financial management, including sufficient allocation of contingency within their budget
Technology risk	Risk that technology related to hydrogen storage does not perform as expected. For	The hydrogen storage facility developer/owner is responsible for adopting technology which it can take

[15] Demand risk is largely beyond the control of storage developers because demand for storage depends on the level of deployment of hydrogen production and end use in the economy. This deployment is influenced to a large extent by government interventions, which storage operators do not have control over.

	example, salt caverns require slower cycling than expected to maintain their structural integrity	sufficient confidence in, and ensuring there are contingency plans if it were to fail or fall short of expectations
Availability risk	Risk that the facility is not available for use due to e.g. issues with technology, maintenance or management of the facility	The hydrogen storage facility is responsible for designing and building the facility and operating it in a way that ensures its agreed level of availability can be met
Change in law, policy or regulatory framework risk	Risk that any change in law, policy or regulation impacts use of hydrogen storage	Since the subsidy provider will be providing protection against volume risk, the storage facility will be protected to an extent from changes in law, policy and regulation that impact the use of hydrogen storage, e.g. changes that accelerate or decelerate the build-out of hydrogen production plant. Beyond this, we will consider whether it is necessary for the business model to include any additional provisions to protect the storage facility from certain unforeseeable and material changes
Decommissioning risk	Risk that decommissioning costs are higher than originally forecasted, or where the storage facility is unable to carry out the decommissioning process	The storage facility is responsible for decommissioning the facility in line with the relevant industry standards

Section 3: Business model parameters

This section sets out parameters for the business model and our minded to position on each. Parameters are factors which affect the scope of the business model and a project's eligibility for support. Parameters enable us to narrow the focus of support and ensure that support is targeted to where it is most needed and to achieve value for money.

Recipient of support

We have considered how best to target business model support to mitigate demand risk. There are two broad approaches:

- Support for storage providers (owners or developers of a hydrogen storage facility), which might entail subsidising the costs of building and operating a storage facility, or

- Support for storage users (parties who utilise storage capacity for a period of time, providing revenue to the storage provider) which could entail subsidising the cost of storage to make it more affordable and encourage more storage customers.

Our minded to position is for storage providers to be the target of business model support. This is in line with our design principles that the business model should be investable, and that it should provide value for money for government. Storage providers need financial reassurance before taking on the upfront capital expenditure and investment costs. Support for providers can kick-start the long lead times required to develop geological storage facilities. Storage providers face demand risk from potentially low volume of sales and/or low prices and therefore require revenue security for facilities to be built.

Supporting users would not sufficiently support the investment cases for storage providers, and therefore would not provide value for money. Initially, there may not be many users of storage and supporting them with the costs of securing storage capacity via a business model may not be sufficient to support prospective storage providers with the significant up-front costs of new hydrogen storage facilities. We have limited sight of who future users of storage will be at this stage, but they are likely to represent a wider group relative to storage providers and, as a result, may have more diverse needs. These users may also vary over time and storage projects cannot secure investment if they are reliant on transient commitment.

Types of storage

Since government resource is limited, we have considered the type of storage the business model should support. This is to ensure that the business model is targeted towards storage solutions that will provide the volume of storage required, whilst also delivering value for money, and helping government meet its strategic objectives to encourage the development of hydrogen networks, in line with our design principles set out in section 2 (approach to model design).

There are three broad types of hydrogen storage:[16]

- Geological storage
- Above-ground liquified or gaseous storage
- Chemical storage (ammonia, methanol, metal hydrides)

This section considers each type of storage and its respective advantages and disadvantages in turn, in order to reach a position on which types should be supported by the business model.

[16] We received stakeholder feedback that the terminology used in the consultation around large-scale and small-scale storage was difficult to define. On this basis we have categorised storage differently for the purpose of the government response and intend to use the terminology going forward.

Geological storage[17]

Table 3.3: Description of geological storage

Factor	Explanation
Description	Underground storage in specific geological formations which have been engineered to store hydrogen such as salt caverns, depleted gas fields, aquifers or lined rock caverns. Cushion gas is required in most cases. Dependent on the deployment of transport infrastructure.
Location	Different geological formations are required for the types of underground storage described above. These geological formations are distributed unevenly across the UK, meaning that different regions may not have equal access to underground hydrogen storage. COMAH regulations apply and may affect the location of geological storage facilities.[18]
Technology readiness	Different types of geological storage have differing technology readiness levels (TRLs). Onshore salt caverns are currently considered most mature for hydrogen storage (they are already used for natural gas storage) and have been demonstrated in Teesside. Lined rock caverns are technically immature and require R&D.
Qualities	Salt caverns, depleted gas fields and aquifers have the potential to store large volumes of hydrogen over a long duration with limited loss of gas but may be susceptible to geomicrobial reactions. Depending on the size of facility, injection and withdrawal rates can be faster (e.g. salt caverns and lined-rock caverns), or slower for larger facilities (e.g. depleted gas fields and aquifers).
Costs	Faces high upfront costs (including the cost of cushion gas) and long lead-times until they are operational but can provide economies of scale since the capacity is larger. Operational costs are relatively low compared to the scale of storage capacity.

[17] Most of the information in these tables is sourced from analysis and research commissioned by the department. This is an overview of storage technologies to provide some context for this government response. It is not an exhaustive commentary on the techno-economics of hydrogen storage. We plan to publish more details on the techno-economics of hydrogen storage technologies in the future.

[18] https://www.legislation.gov.uk/uksi/2015/483/contents/made

Demand	Faces demand uncertainty due to the large capacity and reliance on a variety of users to utilise the capacity.
Existing support	No existing support. Government support will be necessary for projects to take final investment decisions whilst the hydrogen economy is nascent.

Above-ground liquified or gaseous storage

Table 3.4: Description of above-ground liquified or gaseous storage

Factor	Explanation
Description	Liquified or pressurised hydrogen stored in tanks or vessels.
Location	Can be installed in any location, providing that it complies with COMAH regulations.
Technology readiness	High/medium technology readiness level (TRL) – pressurised hydrogen cylinders considered most mature.
Qualities	Smaller scale means smaller volumes can be stored. Liquified hydrogen is stored at very cold temperatures and subject to boil-off over longer durations, whereby some gas is lost. Best suited to fast cycling over short time periods, and in areas where geological storage is limited or areas with lower levels of demand.
Costs	Faces lower upfront costs and shorter lead-times, but typically provides a smaller-scale storage solution which might serve individual producers or users of hydrogen. Operating costs may be relatively high, particularly for liquified hydrogen which must be maintained at a very low temperature and then brought up to temperature before use.
Demand	Where it serves an individual user, it will face lower demand uncertainty. Potential for multiple vessels/tanks to be used to create larger storage volumes, in which case more users could be served.
Existing support	Existing support via the HPBM and the NZHF for limited storage where it is linked to a hydrogen production facility.

Chemical Storage

Table 3.5: Description of chemical storage

Factor	Explanation
Description	Hydrogen undergoes a chemical process whereby its molecules become stored in another chemical compound, e.g. ammonia, methanol, metal hydrides. The chemical process can later be reversed to release the hydrogen.
Location	There are no geographical restrictions on where chemical storage can be located, however it requires process plants to convert the hydrogen to and from the chemical compound. Therefore, it is more suited to industrial areas.
Technology readiness	The production process of ammonia has a high TRL. Other carriers are more novel, with production processes yet to be demonstrated at scale. Critically, the cracking process (whereby chemical carriers are converted back to hydrogen) has a low TRL.
Qualities	Chemical carriers may be well suited for transporting hydrogen over long distances in the absence of pipelines, as well as storing hydrogen. Relatively high energy density, particularly compared to pressurised hydrogen. Compounds can be stored for long durations. Processes for producing / cracking the compounds are less flexible, so may require response times of hours or days for storing or extracting hydrogen. Both compound production and cracking can entail significant energy losses.
Costs	Faces lower upfront costs and lead-times compared to geological storage, however the costs of the cracking process are not well established. Operating costs are yet to be explored in detail, but energy requirements could be significant, and catalysts may be expensive.
Demand	Demand most likely to be for international trade of hydrogen which may entail some demand uncertainty. This is hard to predict during the nascent stage of the hydrogen economy.
Existing support	No existing support for use as hydrogen storage.

We expect initial allocation of the storage business model to focus primarily on geological storage. We have reached this view as we consider that this type of storage is essential to establishing a hydrogen network and hydrogen economy since it can provide greater storage capacity at lowest cost of the options available and best support energy security. This type of storage is unlikely to be built without government support.

As part of our work on allocation criteria (see section 7, allocation of support), we plan to set out a mandatory TRL that projects must meet to be eligible for storage business model support. Some geological storage types may not be eligible initially because of a lower TRL, however, as technologies mature, we expect a wider range of technologies to become eligible for storage business model support. Beyond the TRL, we plan to take a technology-neutral approach, meaning that we will not distinguish between projects based on the geological storage type (e.g. salt cavern, depleted gas field etc), but on the project's overall merits.

Given the lower costs, lower demand uncertainty and support within the HPBM and NZHF, we believe storage business model support is less necessary for above-ground storage. Particularly where above ground storage serves a single producer or offtaker, this may not be a value for money investment for the storage business model and is less likely to facilitate government's strategic objectives.

In general, supporting above-ground storage does not fit with our design principles. However, there may be instances where above-ground storage is used to create relatively large-scale projects, for example, where access to geological storage is limited. In such locations, above-ground storage may be needed to facilitate local hydrogen networks and may represent a value for money option.

To allow for the circumstances described above, we are minded to retain optionality in the storage business model to support above-ground storage where it faces the same market barriers as geological storage: high costs, long lead times and uncertain demand. Above-ground projects applying for storage business model support would need to demonstrate how these barriers apply to them.

At this stage, chemical storage is deemed beyond the scope of the storage business model. Given the low TRL for the cracking process and, it does not currently meet our design principles. Further technological development will be needed before chemical storage becomes eligible to receive storage business model support.

Use cases of storage

Hydrogen storage infrastructure will serve several functions which provide benefits to the wider hydrogen economy. We refer to these functions as 'use cases'. We have identified six unique use cases, each of which:

- provide different benefits to the hydrogen economy
- serve different end users of hydrogen
- are provided by different storage types, and
- have different cycling rates, i.e. how quickly hydrogen can be injected and withdrawn from a facility.

Table 3.6 below outlines our view of the use cases which could emerge with the development of the hydrogen storage economy. The use cases are not mutually exclusive, and we acknowledge a storage facility could provide multiple. The list may not be exhaustive and may be subject to change but represents our work to date.

As part of the development of allocation criteria, government may choose to distinguish between projects on the basis of intended use case (see section 7, allocation of support). This is unlikely to affect initial allocation round(s), since early allocation will be limited by the number of projects coming forward. Stakeholders will be consulted before any final decisions are made.

Table 3.6: Use cases of hydrogen storage

Use Case	Benefit to the hydrogen economy	Beneficiaries		Storage Types	Storage profile	Timing
		Organisational	Off taking			
Strategic Reserves	To provide security of supply and insurance	H2 transmission network operator, government regulator (Ofgem)	H2 to power, H2 for heat	Geological storage	Monthly, seasonal	May be needed over the longer-term
Operating source/sink for unplanned supply and demand changes	To provide storage during irregular weather	Intermittent renewable power generators, electrolytic/CCUS -enabled H2 producers, national grid	H2 to power, industrial sector	Geological storage, above-ground storage & linepack	Intraday, daily, weekly, can require fast cycling and high volumes	Needed in the near-term
Operating source/sink for planned supply and demand changes	To balance network pressure	H2 transmission network operator, H2 shippers, H2 suppliers	Any transmission system off taker (transport industrial, etc).	Geological storage, above-ground storage & linepack	Intraday	Needed in the near-term
Operating Reserves	To ensure continuous supply to the end user	H2 producers	Industrial, transport, operating margins gas (NG)	Above-ground storage	Daily, weekly	Needed in the near-term
Operating source/sink for liquidity	To trade stored H2	H2 shippers, H2 suppliers, H2 traders	H2 for heat, industrial, transport	Geological storage	Daily, weekly, monthly, seasonal	May emerge over the longer-term
Operating source/sink for international trade	To import /export H2	H2 transmission network operator	H2 produced for export, LOHC shippers	Hydrogen carriers	Daily, weekly, monthly, seasonal	May emerge over the longer-term

Number of business models

We have assessed whether there is a case for government to introduce multiple storage business models. These are outlined below, along with our assessment of the case for each one.

First, we considered whether an interim business model is needed before an enduring one can be put in place. We believe it possible to design only one business model by our 2025 target, since this is already a challenging timeline. An interim model cannot be designed sooner than an enduring model and so would not alleviate the concerns of stakeholders who expressed a need for more urgent government support. Per our design principles, we will ensure our enduring model is designed to be compatible with and adaptable to an evolving hydrogen economy and a developing market for hydrogen storage.

Second, we considered whether different business models are needed for different storage types. We are retaining optionality within the model to support above-ground storage where it faces the same barriers to investment as geological storage (see types of storage section above) and therefore can support multiple storage types with a single model. Introducing different business models for different storage types could introduce further complexity into an already complex landscape with multiple other government interventions planned (e.g. hydrogen production business model, hydrogen transport business model, the net zero hydrogen fund and the renewable transport fuel obligation[19], etc). This is in line with our design principles to avoid unnecessary complexity. We also want to reduce distortion created by government involvement, and do not want to inhibit private sector investment in other storage types. We have therefore clearly outlined which storage types are out of scope of the model.

On the basis of this assessment, we are minded to design a single business model for hydrogen storage.

Geographical coverage

Our intention is for the storage business model to be UK-wide. The development of hydrogen storage infrastructure represents the critical next step in the growth of the hydrogen economy across the United Kingdom.

To meet government's ambition of up to 10GW of hydrogen by 2030 will require not just hydrogen production, but also transport and storage infrastructure to be in place. Transport networks for the purposes of distributing hydrogen are crucial to ensuring hydrogen can reach the full range of end users. Storage will provide these end users with confidence that the supply of hydrogen is reliable and resilient to risk of outages in production or periods of particularly high demand.

In this regard, a well-developed hydrogen transport and storage network could be especially valuable for wider energy system resilience and security through enabling 'excess' renewable

[19] The Renewable Transport Fuel Obligation (RTFO) supports the decarbonisation of transport by encouraging the production and use of renewable fuels that do not damage the environment. See: https://www.gov.uk/guidance/renewable-transport-fuels-obligation

electricity - produced at times of high wind or solar generation but low demand - to be used to produce hydrogen. This hydrogen can then be stored over time and be converted back into electricity at times of low generation and high demand or used to decarbonise sectors of the economy such as heavy transport or energy-intensive industry.

We consider that a UK-wide business model for hydrogen storage is required to remove market barriers and stimulate private investment in the necessary infrastructure, to deliver our vision of how hydrogen can play its full role in decarbonising the whole UK economy.

The hydrogen storage business model applying UK-wide is subject to the relevant legislative processes as part of the Energy Bill's passage through Parliament.

Section 4: Commercial design

The barrier to investment the business model must address is demand risk, including volume risk. We believe that other risks should mainly remain with the developer, as explained in section 2 (approach to model design).

In this section we explain how the business model would mitigate demand risk and set out some of the other key features of its commercial design.

Solution to demand risk: revenue floor

We reviewed a wide range of commercial design options and considered industry views on the extent to which these would address demand risk, including volume risk. In our assessment, several of the options we consulted on would not address volume risk, and for that reason are not suitable for use as the main mechanism for securing investment in storage facilities: namely end user obligations, end user subsidies, contracts for difference, co-investment, and long-term financing of cushion gas. Few industry stakeholders suggested we should use these options, and those that offered a critique of the options generally agreed with our assessment that they would not address demand risk.[20]

To provide sufficient revenue certainty despite significant uncertainty around demand, we believe it is necessary for the business model to provide a revenue "floor".[21]

A revenue floor would be a minimum amount of revenue the facility is due, regardless of the extent to which the facility is used. It should be noted that this minimum would however still be subject to other conditions being met, including but not limited to the facility being available for use. We will in due course consider whether other conditions are required.

[20] At this time, we are not ruling out using co-investment or long-term financing of cushion gas alongside the business model. We intend to do further work to assess the case for using these as complementary measures.

[21] Further detail on the nature of the demand risk faced by storage providers, and our assessment of the options for addressing this risk, is in annex A.

If the facility is not used at all, and therefore no revenue is earned from users, a subsidy provider would pay enough subsidy to the facility to ensure their total revenue equals the revenue floor.

If the facility is used and therefore receives revenue from users, less subsidy revenue would be required to keep the facility's total revenue above the floor.

Demand for storage is likely to follow annual cycles so our current expectation is that the floor would probably be defined in terms of an annual minimum revenue. An annual minimum revenue could be paid in several instalments each year.

What the floor will cover

The sum of the minimum annual revenues ensured by the floor over the entire length of the contract would be equal to the total capital costs of creating the storage facility, plus fixed operational costs, plus a relatively low return on capital investment. The low return would be commensurate with the fact that the facility is taking relatively little risk, given that the floor provides extensive protection against demand risk.

By setting the floor at this level, we would ensure that the business model is investable, and the facility is highly likely to remain operational for the duration of the agreement, notwithstanding demand uncertainty.

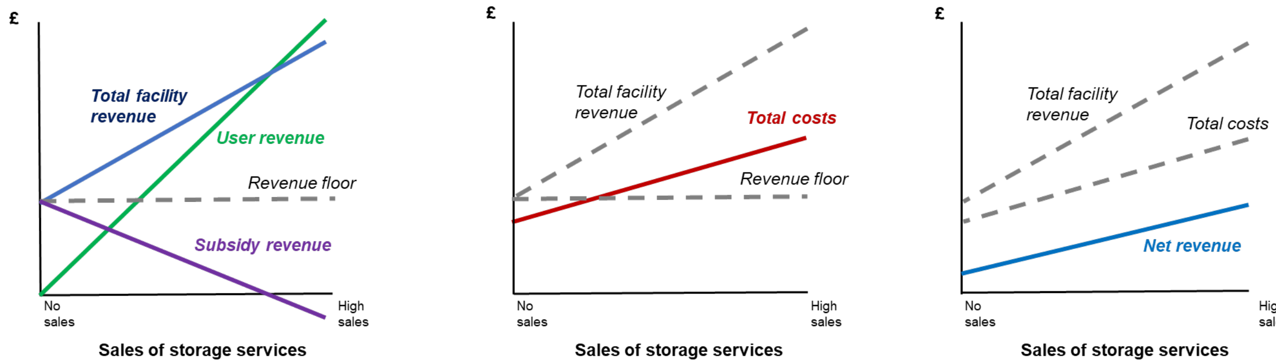
The floor would not cover variable operating costs, such as the cost of using energy to move gas in and out of the storage facility. This is because these costs will only be incurred to the extent that the facility is used, and they can be recovered from users as and when they pay to use the facility. Variable opex costs account for a relatively small proportion of the overall costs of a geological storage facility (annex B describes the cost bases of geological storage facilities).

User revenue and incentive for sales

We want storage facilities to have an incentive to maximise the revenue they earn from users, just as firms in an efficient market would typically engage in revenue-maximising behaviour. This will ensure storage facilities have an incentive to serve users' needs, both during operations, and beforehand, i.e. when the facility is designed.

We aim to achieve this by creating the following relationship between user revenue and the subsidy stream: if the amount of revenue from users goes up, the amount of subsidy revenue will come down (i.e. we are not providing a 'fixed' subsidy payment), but the reduction in subsidy revenue will be smaller than the increase in user revenue. The net effect is that storage facilities will have greater total revenue if they are able to generate more user revenue (figure 3.2). This provides an incentive to achieve sales to users, and by extension will focus the facility developer/owner on the needs of users. The magnitude of the incentive for achieving sales to users will require careful consideration and be subject to affordability constraints and value for money.

Figure 3.2: Revenue floor and sales incentive (illustrative)[22]



We considered an alternative design in which subsidy revenue is fixed regardless of the level of user revenue, and the facility retains both the fixed subsidy revenue and the entirety of its user revenue, however great or small the latter is. This system would have the virtue of being slightly simpler but is also cruder and much less likely to maximise value for money. Given the degree of uncertainty about demand, it would be difficult to estimate with any confidence what level the floor should be set at to ensure investors are likely to earn a return that is fair but not excessive. Therefore, it is likely that if we adopted this design, difficulty in setting the floor at the appropriate level would mean we either fail to attract investment, or ultimately overcompensate investors. A solution to this is to link the amount of subsidy revenue to the amount of user revenue as we have set out above.

Incentive for availability

There will be an incentive for ensuring the facility is available for use.[23] This could take the form of an availability factor: for example, the business model could include a provision that the facility should be available for 95% of each year, and if actual availability falls short of this factor, subsidy revenue would be reduced, for example through reduction of the floor.[24] The more the facility falls short of the availability factor, the greater the reduction in subsidy revenue we would apply, according to an agreed formula.

As a result, although we would normally expect the facility's total revenues to exceed the floor, if its level of availability was particularly poor it could potentially earn less than the floor.

[22] These diagrams not been drawn to scale. The diagram illustrates that the facility might have to share a portion of user revenues with the subsidy provider if we were to introduce a mechanism for sharing in the "upside" demand risk, as discussed in section 4 (commercial design), under the Upside heading. We are considering several options for how this might work and this diagram should not be interpreted as an endorsement of a particular option.

[23] In this context, we would consider a facility to be "available for use" if it was operational and capable of providing storage services to users. If the facility was full to capacity with hydrogen gas, we would still consider it to be "available" as long as it was capable of providing withdrawal.

[24] The figure given here for the availability factor (i.e. 95%) is purely illustrative. The actual availability factor might be higher or lower than this. In the natural gas sector, some underground storage facilities achieve availability rates of 95% or greater, but we are mindful that hydrogen storage may be subject to different engineering or regulatory constraints than natural gas storage.

Incentive for being built on time

It is important for us to ensure the facility is built on time, i.e. at the time we and the developer plan on it being built by when the contract is signed, so that it can serve relevant users who may be reliant on it. We are therefore minded to apply a target commissioning window, which is a mechanism we have successfully used for previous energy infrastructure projects and has been accepted by investors. The target commissioning window would likely depend upon the technology employed by the facility.[25]

Upside

We are minded to include a mechanism that gives the subsidy provider a share of “upside” demand risk, i.e. a mechanism that ensures that if user revenues are particularly high, the facility must make payments to the subsidy provider (reversing the typical flow of payments).

Storage facilities will potentially have very significant user revenues in the long run. We want to avoid a situation in which companies that benefit from a significant amount of support go on to make exceptionally high returns that are not commensurate with the amount of risk they have taken.

If returns are disproportionately high, it is only fair that a portion of these should be returned to the party that was instrumental in making them possible, i.e. the subsidy provider. This would also be consistent with our design principle of achieving value for money: it would ensure that the total costs to the subsidy provider over the lifetime of the business model are minimised.

There are various options for how we might participate in upside, including:

- A cap on revenue: if revenues exceed the cap, any excess must be given to the subsidy provider.
- A gainshare arrangement: the facility must share a portion of its revenues (or net revenues) with the subsidy provider. Gainshare could be applicable only to revenues/profits above a certain level. The proportion shared with the subsidy provider could increase as the level of revenue/profit increases.
- As an addition to either of the above arrangements, the facility could have the option of making a lump-sum payment to the subsidy provider to terminate the contract early (and thereby disapply any revenue cap or gainshare arrangement).
- Government could take an equity stake in exchange for awarding a business model and therefore receive a portion of profits via dividends and/or increases in the value of its shares.

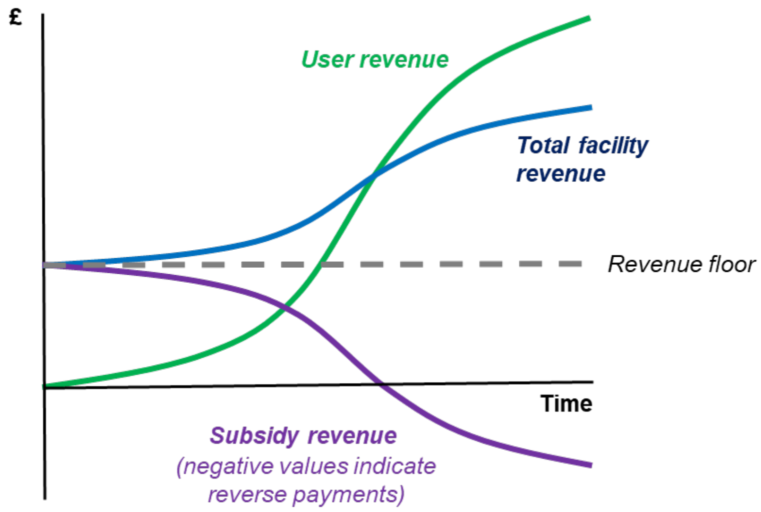
We have not decided which of these mechanisms we would use, and it would be possible for us to use a combination.

[25] For example, target commissioning windows have been used for Contracts for Difference in the low-carbon electricity sector.

An illustration of how a cap or gainshare mechanism might work in combination with the revenue floor and the incentive for sales is provided below. For the purposes of this diagram, we assume:

- User revenue is initially very low, and so subsidy is required to ensure the facility receives the revenue floor it is due.
- Over time, user revenue increases and subsidy payments decrease.
- Eventually user revenues reach a high enough level for the cap or gainshare mechanism to be triggered (the diagram assumes a gainshare), and so the facility makes payments to the subsidy provider.

Figure 3.3: How a cap or gainshare mechanism might work (illustrative)



Duration of support

For geological storage, we are minded to award business models of at least 15 years.

A duration of at least 15 years would make it very likely we support some of the first storage facilities through a number of years where their utilisation could be relatively low. As indicated, through the proposed upside design mechanism it would create the potential for the subsidy provider to recoup (in the latter years of the business model) some of the subsidy payments it makes (in the earlier years). It would also have the effect of making annual subsidy payments lower, because the developer could be given a larger number of lower annual payments compared to a shorter contract.

Given that the useful economic life of a geological storage facility could be 30 years or more, business models lasting for more than 15 years are conceivable. Longer lengths would offer potential for even more upside for the subsidy provider.

A longer contract duration also makes it possible for the subsidy provider to spread out the repayment of capital for the investor over a longer period, and therefore make lower annual payments. A potential downside of spreading capital payment out over a longer period is that the total cost to the subsidy provider over the lifetime of the contract may be higher, due to the cost of finance. It would also potentially mean that we are subsidising facilities for longer and potentially leads to longer government intervention in the market than is needed. Whether either of these things happens depends in part on the extent to which facilities are able to cover their costs without the need for subsidy payments during the latter years of the contract (i.e., the outcomes will depend on user demand) which is uncertain.

Capital repayment profile

We are considering sculpting the profile of capital repayment that the business model provides: the level of the revenue floor does not necessarily have to be the same every year; it could be somewhat higher in earlier years and provide for a more front-loaded profile of capital repayment. Different profiles of capital repayment have been used for different types of energy infrastructure; for example, energy network price controls historically provided a flat profile of capital repayment but in more recent years have made greater use of front-loading.[26]

There are examples of government aiming to remunerate capital investment gradually over the entire course of a business model contract (for example the hydrogen production business model, or contracts for difference for low-carbon power) and examples where business models allow for capital to potentially be repaid well before the end of the contract (the industrial carbon capture business model or the waste industrial carbon capture business model). We will consider the interplay between the profile of capital repayment, the overall duration of the business model, and other key elements of the business model which affect risk and reward, such as the mechanism for sharing in the upside.

In deciding these matters, we will need to consider value for money and affordability for the subsidy provider, and investor risk.

Delivery mechanism

There are a range of options for the business model's delivery mechanism:

- Private law contracts
- Public law based schemes:
    - A policy-based scheme
    - Economic regulation also known as regulated returns

In principle, our intended design (a revenue floor) could be delivered by any of the mechanisms listed above. However, we consider that the most suitable delivery mechanism for our purposes is private law contracts because they can be implemented relatively quickly and give us enough flexibility to support a range of projects.

Using private law contracts means creating bilateral contracts between a storage provider and the government (or a counterparty nominated by the government). As with any contract, these agreements would be legally binding and subject to contract law. They would likely be signed before construction of the asset, and detailed terms and conditions in the contract would help

[26] This was done by changing the profile of regulatory depreciation from straight-line to a more front-end-loaded profile.

to provide investor certainty where appropriate and thereby secure investment and help to keep the cost of capital low.

Our reasons for rejecting the other approaches are set out below.

Rejection of a policy-based scheme

In a policy-based scheme, the level of subsidy is set out in rules and guidance.

Although a policy-based scheme could be set up to provide a revenue floor with the characteristics we have set out above, one of the risks is that it can be difficult to foresee at the time the scheme is designed whether the scheme rules will be compatible with the full range of projects the government ultimately decides to support. In the context of hydrogen storage, this is a concern because there are currently relatively few projects being proposed and therefore inadvertently ruling projects out during the policy design stage could have an adverse impact on the development of the market. By contrast, private law contracts give us some flexibility to accommodate the idiosyncrasies of different projects (although ideally we will have as little variation as possible in the contracts we award, and in any case we cannot use variation in contract terms to provide preferential treatment to particular projects).

Compared to policy-based schemes, contracts are more flexible because changes can be agreed bilaterally and implemented quickly, whereas changes to policy schemes require legislation, which is more time-consuming and complex.

Rejection of economic regulation

Economic regulation entails an independent regulator determining the prices a company can charge or the revenue it is allowed to earn.[27]

Often the regulator will use a regulatory construct known as a Regulated Asset Base (RAB) to determine the company's allowed revenue or the prices it is allowed to charge. The regulated asset base is essentially a catalogue of the company's assets, and the regulator will set allowed revenues or prices at a level that allows the company to recover the costs of these assets plus a fair return on investment. In some economic regulation regimes, regulated asset bases may only partly determine, or play no role in determining, the allowed revenue or the prices the company is allowed to charge: for example, allowed revenues might instead be linked to performance targets or principles the regulator judges the company against. Either way, the return the company makes is determined through regulation by an economic regulator, and therefore economic regulation can also be described as a "regulated returns" regime.

For companies in some industries, there may be a shortfall between the amount of revenue the regulator decides the company should receive in order to make a fair return, and the amount of

[27] For example, for the regulated energy networks, the regulator determines the amount of *revenue* the regulated companies can earn. By contrast, for certain services in the telecoms sector, the regulator determines the *prices* that the regulated company can charge, rather than the overall amount of revenue they can earn. In these regimes, the amount of revenue the company can earn will depend *inter alia* on the volume of sales to users.

revenue the company is able to recover from users. In these cases, the company can be provided with an external subsidy stream to make up this shortfall in revenue.

Industry, and specifically prospective developers have set out that they need a high degree of certainty as to future revenue, but not necessarily for that revenue to be determined by an economic regulator rather than agreed as part of a contract. An appropriately designed private law contract is just as capable of providing a high degree of revenue certainty as a regulated revenue model, and therefore we believe it is capable of meeting the needs of developers and investors.

Where economic regulation has been used to deliver infrastructure in the past (rather than another delivery mechanism such as a private law contract), this is typically either:

- to help an economic regulator determine a price or revenue cap for an enduring price control for a regulated monopoly (for example the regulated gas and electricity networks); and/or
- to use RAB-based remuneration as a way of providing some protection against significant asset- and construction-related risks (for example the New Nuclear and Thames Tideway Tunnel hybrid RABs, or the CCUS RAB)

In our assessment, neither of these aims currently applies to hydrogen storage: we are not aiming to provide protection against construction-related risks (see section 2, approach to model design). Nor do we plan on setting up an enduring price control at this time (section 5 commercial context). Therefore, we consider use of a regulated asset base to be unnecessary. Although there is a degree of uncertainty about how the market will develop in future, this does not justify starting off with economic regulation, given our design principle of avoiding unnecessary complexity.

In addition, some of the typical features of economic regulation might not be completely aligned with our design principles. For example, in RAB regulation, it is typical for asset owners to be remunerated for their capital investment slowly and steadily over the lifetime of the asset, which in the case of energy infrastructure is often several decades. If we applied this to hydrogen storage, it could mean asset owners would receive support for as long as 40 years, as this is the lifetime of a salt cavern. Providing support for such a long period of time would appear to be in tension with our design principle of “market development” (i.e. our aim of reducing support over time and eventually transitioning to a merchant model) and our vision of establishing a competitive market for hydrogen storage.

Counterparty

Our business model will be supported by an external subsidy mechanism, which itself will be delivered through revenue support contracts. These revenue support contracts will be private law contracts between a hydrogen storage provider and a government-appointed counterparty. The government-appointed counterparty will manage the contracts and act as a conduit for subsidy funding. This aligns with the approach taken for other schemes, including the Contracts for Difference scheme, for which the Low Carbon Contracts Company acts as counterparty[28], and the hydrogen production business model, for which government anticipates the Low Carbon Contracts Company will be the counterparty[29], subject to successful completion of administrative and legislative arrangements.

We have tabled amendments in the Energy Bill to provide the Secretary of State with powers to designate a hydrogen storage counterparty by notice and to direct the counterparty to offer to enter into contracts. The amendments will allow an operationally independent counterparty to manage the revenue support contracts, whilst allowing the Secretary of State to oversee the contractual process.

A decision has not yet been made to confirm whom government will designate for this role. Government will undertake analysis to determine the organisation best suited to the role of counterparty for the business model. Considerations in the decision-making process will include operational independence, the ability to command investor and government confidence, contract management experience, and sector expertise. The designation of a body as counterparty will be subject to completion of legislative and administrative processes.

Compatibility with other subsidy regimes

We are conscious that we are designing the storage business model within a landscape of planned government schemes, and forthcoming schemes. Additionally, government is exploring the need for interventions across the wider energy system:

- Government intends to consult in 2023 on the need and potential design options for market intervention to support hydrogen to power generation.
- In Powering Up Britain[30] we committed to putting in place an appropriate policy framework by 2024 to enable investment in large scale long duration electricity storage, with the goal of deploying sufficient storage capacity to balance the overall system.
- In Powering Up Britain we also committed to provide an update ahead of this autumn on the future role that natural gas storage, and other sources of flexibility, can play in gas security including the long-term role of natural gas storage in providing energy security.

We will need to consider how the storage business model interacts with each of these possible interventions.

We will continue working across government to ensure alignment between these schemes, particularly where there may be overlap in eligibility. In these cases, we will ensure that our design mitigates potential subsidy cumulation. This will form part of the next stage of business model design.

[28] https://www.lowcarboncontracts.uk/contracts-for-difference-cfd
[29] https://www.gov.uk/government/publications/hydrogen-production-business-model
[30] https://www.gov.uk/government/publications/powering-up-britain

Section 5: Commercial context

In this section we set out our current views on the market framework for hydrogen.[31]

Ownership and unbundling

We are aware of several prospective geological storage projects and we have been engaging with the companies involved with these. They include companies from the upstream oil and gas sector, the chemicals sector, and the natural gas storage sector. In future, geological hydrogen storage may be owned and operated by companies like these, among others.

Although we welcome investment in storage from companies that have other interests in the energy sector, we may create rules to ensure the operational independence of geological storage facilities from some of those other interests. We note that similar rules exist in the natural gas storage sector today, although we would not necessarily replicate them exactly for hydrogen storage.

Some stakeholders suggested regulated network infrastructure companies should make capital investments in geological storage facilities using their regulated revenues. We are minded not to permit this: our aim is to create a competitive market for storage, and we consider giving control of facilities to regulated monopoly companies would not be an effective way of doing this, and could also create conflicts of interest.[32] Networks might, however, pay for the use of storage facilities, like other users.

Users and charging structure

The users of storage are likely to include hydrogen producers and offtakers, as well as hydrogen network companies (potentially including a network/system operator). In due course, in some circumstances there may be intermediaries that act on behalf of these users and contract with storage facilities for them.

Users would likely provide storage facilities with:

- payment for the option to use storage capacity;
- payment for the options to use injection and withdrawal capacity;
- usage fees, paid when these options were taken up, reflecting the operating costs of using the storage.

This would ensure that user fees reflect the structure of costs facilities face.

We anticipate that storage facilities would initially sell “bundles” that combine each of the products above, but as total demand increases there may be greater demand for unbundled products.

[31] In the August 2022 consultation, we highlighted market framework issues for hydrogen storage under the heading of “commercial uncertainties”.
[32] We are nonetheless content for the ultimate owner of a storage facility to also be the ultimate owner of a regulated network company, subject to the rules on operational independence mentioned above.

Pricing

Ultimately our intention is that storage pricing should, as far as possible, be driven by supply and demand in a competitive market and tend to reflect the long-run marginal costs of storage facilities, so that facilities make a fair return on investment and private investment will be forthcoming when new facilities are required.

The aim of the business model is not to lower the price of storage (although it is likely to have at least a marginal effect on prices, by reducing the cost of capital); it is to ensure that investment in facilities is unlocked. Accordingly, the design of the model incentivises facilities to maximise the revenue they recover from users, including through pricing (see section on user revenue and incentive for sales, above).

We do not want facilities to charge users excessive prices (i.e. prices far in excess of long-run marginal costs) as this would not be an economically efficient outcome. Competition between storage facilities (including market entry) ought to prevent this.

We expect that prices of storage services will fluctuate over time, and may be affected by:

- changes in the supply of storage, and alternatives to storage such as hydrogen imports
- changes in the quantum and typical profile of demand for hydrogen
- changes in hydrogen gas prices, and the emergence of a benchmark price of hydrogen gas
- increasing depth and liquidity in hydrogen markets, increasing network connectivity, and the potential emergence of a national balancing point for hydrogen gas

We intend to examine further how the price of storage might be set and change over time, and how operators might charge for their services, in light of the factors listed above and the interaction between revenue from storage users and revenue from the business model (including the revenue floor and the sales incentive). Our current view is that the price of hydrogen storage is difficult to forecast (like many other prices in the energy market), and one of the benefits of the revenue floor is that it will provide significant protection against price risk for storage operators.

Protecting users of storage

We want to unlock investment in storage because we consider it to be critical for growing the hydrogen economy by providing a vital service to the users that rely on it.

Users will need storage to be affordable and accessible (section 2, approach to model design), among other considerations. We are exploring what steps we should take to ensure this will be the case, especially early on when limited amounts of geological storage will be available.

It is possible that we may act to promote the interests of storage users by attaching conditions to the hydrogen storage business model that help to ensure storage will be available and affordable for users. Another possibility would be to use legislation and regulation as the means of implementing such rules. At this time, we are open-minded as to whether we would use legislation/regulation, conditions attached to the business model, or both.

Any such conditions or rules would only be imposed if we decided they were a necessary and proportionate means of protecting users. We would not attach any conditions that jeopardise investment in storage, given that it is in the interests of users for storage to be built.

As an example of the conditions we might attach, we might require facilities supported by the business model to operate independently of other energy system interests and to provide non-discriminatory third-party access, so as to prevent them from being dominated by a single user that may be closely affiliated with the facility.[33] We note that rules like these are already features of the regulatory regime for current gas storage market, albeit in practice, several gas storage facilities are currently exempt from these rules.[34] We are minded to adopt a default position that hydrogen storage facilities receiving business model support should provide third party access, but we are currently open-minded as to whether any exemptions need to be granted to this general rule.

A more interventionist approach to protecting users' interests would be to set up an enduring regime of regulating the prices storage facilities can charge, i.e. economic regulation.[35] This might be appropriate if we thought that storage providers were likely to have significant market power throughout their lifetime, but our current assessment is that this is not the case – we expect a competitive market to emerge. Therefore, we think economic regulation would be a disproportionate approach.

Section 6: Funding the business model

As it utilises an external subsidy mechanism, the hydrogen storage business model will need to be funded. No decision has yet been taken on how it will be funded. Options for funding the hydrogen storage business model include a levy and Exchequer funding and both provide two reliable options to fund the business model. We are seeking powers to enable the external subsidy mechanism to be funded by both Exchequer funding and levy funding, with the decision to be made in the future. These powers are being sought through the Energy Bill. We will provide a more detailed update on funding the business model in due course. If we make a decision to fund via a levy, government will consult on the design of any levy. The position on funding the hydrogen transport business model is similar. For the specific hydrogen transport business model position, please see chapter 2.

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[33] This dominance could be detrimental because it could mean that some potential users of storage are denied access to the facility, inhibiting growth in the hydrogen economy. It could create market distortions by giving the only user with access to the facility an unfair advantage.

[34] The rules are set out in sections 8R (independence of storage facilities) and 19B (Acquisition of rights to use storage facilities) of the Gas Act 1986, and in Ofgem guidance pursuant to those legislative provisions. Gas storage facilities can apply to Ofgem for exemptions from these rules if they are "minor facilities," i.e. facilities that are not technically or economically necessary for the functioning of the gas market. We intend to do further work to consider how these rules might be interpreted in the context of the hydrogen market and whether they would be appropriate.

[35] A more detailed definition of economic regulation is given in section 4 (commercial design), under the heading rejection of economic regulation.

The Energy Bill already included powers to allow the business model to be funded via Exchequer funding. However, to provide the option to fund the external subsidy mechanism via a levy, we have tabled amendments to the Energy Bill to enable the establishment of a levy. For clarity, the powers we have sought expand levy powers which existed in the original draft of the Energy Bill to fund the cost of hydrogen production contracts. The amendments we have tabled include provision for storage within the scope of these hydrogen levy provisions.

Our amendments will provide the Secretary of State with powers to appoint a levy administrator and to make regulations to establish a levy to fund the external subsidy mechanism associated with the business model, and related costs. The provisions for the levy are UK-wide, which reflects the intended territorial scope of the business model.

Levy funding mechanisms are used elsewhere in the energy sector, such as through Contracts for Difference and the Green Gas Support Scheme. Consequently, a levy is well understood by the private sector.

As with the hydrogen production business model, revenue generated by this levy would be used by a hydrogen storage counterparty to make payments under hydrogen storage revenue support contracts, and to cover related costs such as those associated with administering the levy or managing the contracts.

Securing primary legislation with provisions for a hydrogen storage levy is not a commitment to using a levy for the hydrogen storage business model; it only enables government to introduce a levy later, if appropriate, through secondary legislation. The decision to introduce any levy will take into account relevant considerations including relevant wider government priorities and policies.

The result is that the powers to fund the business model via a levy or Exchequer funding provide the option to use either of these revenue streams to support development of storage infrastructure, enable the hydrogen economy to grow, and to meet government’s ambition of up to 10GW of low carbon hydrogen production capacity by 2030 (subject to affordability and value for money).

Section 7: Allocation of support

We anticipate that hydrogen storage contracts will be negotiated bilaterally between the department and prospective storage providers, rather than a price competitive process (e.g. via auctions). This is primarily due to the relatively small number of storage projects we expect to come forward.

The minded to positions set out in this document provide a starting point for storage providers to understand which types of projects will be eligible for the first awards of the storage business model. The next level of detail will be how we envisage contracts being allocated to prospective storage developers which we will set out through allocation criteria that will be developed in parallel with the development of the storage business model contract. Allocation criteria will provide more clarity to market participants about the evidence they will need to provide to gain government support.

A number of topics raised in this document will be addressed further through our work on allocation criteria. These include but are not limited to:

- Use cases of hydrogen storage – we will decide whether to distinguish between projects based on use case, and if so, which use cases will be supported.
- A minimum technology readiness level will be set to ensure government supports projects that are technologically viable and ready for commercial scale deployment.
- Location – we will decide whether and how to prioritise allocation based on location of a project, including proposed hydrogen transport links with the surrounding network
- Projected users / demand – facilities will need to be able to demonstrate reasonable likelihood[36] of demand emerging for their storage facility. We will decide whether and how to prioritise allocation based on the projected users of a storage facility and any agreements storage facilities have been able to secure with members of their surrounding network.

We envisage a coordinated allocation process with the hydrogen transport business model to ensure that hydrogen networks develop in a cohesive way. Strategic planning will play a role in how support is allocated, and we expect the Future System Operator will take on a role in strategic planning activities for hydrogen, at an appropriate time following its establishment. We set out our initial view and next steps on strategic planning in chapter 4. We aim to set out further details on how the hydrogen storage contract will be allocated in by the end of 2023 as part of the hydrogen networks pathway.

Support for expansion of facilities over time

There may be an economic case for building some storage facilities in stages. For example, in the case of a storage site comprising several caverns, the developer might take the following approach:

- In the first stage, five caverns are built, along with the necessary above-ground infrastructure to mine and operate those caverns.
- In the second stage, three additional caverns are built. These can be mined and operated using the above-ground infrastructure that was built in the first stage, thereby saving costs. However, this requires that the above-ground infrastructure built to operate the caverns from the first stage must be somewhat larger than it would otherwise need to be.

Building storage sites in stages like this allows facilities to benefit from economies of scale (i.e. the re-use/sharing of the above-ground infrastructure across the various caverns), while limiting the extent to which assets are under-used due to being constructed too far in advance of demand.

[36] To be defined as part of our future work to set out allocation of funding

We are considering whether we would support facilities built in stages, and if so, how multi-staged facilities would be supported by the business model.

If we did support multi-staged facilities, we are minded to not start remunerating the developer for latter stages of the facility until they have been constructed. This will remove the risk of us paying for assets that are never actually delivered and improves value for money by deferring subsidy costs. We would implement this in the following way:

- A single contract signed prior to construction of the first stage would set out terms for both stages of the build.
- After the first stage was built, the floor would cover the fixed costs associated with all the infrastructure built at this stage, i.e. the initial set of caverns and all of the above ground infrastructure.
- If the second stage is built, the floor would rise, to provide coverage of the fixed costs (plus a return) associated with the caverns and any other infrastructure built in that stage. In calculating the increase in the floor, we would take into account that the second set of caverns will use above-ground infrastructure that has already been subsidised.

It is important to note that building sites in stages does not eliminate the risk of stranded (i.e. unused or under-used) assets: there is always a possibility that the above-ground assets built in the first stage – which would be built at a size that enables them to serve the caverns built in both the first and second stages – would be under-used if the second stage was never built.

If we did provide support to sites built in stages, we would also need to consider what obligations the contract should place on both parties in relation to the second stage at the point of contract signing. For example:

- Option 1: The contract would not provide any support for the second stage unless and until both parties agreed that the second stage should be built, or
- Option 2: Set out in the contract an objective metric (such as a certain level of utilisation of the first stage) which would trigger an obligation on the developer to build the second stage and an obligation on the subsidy provider to support it.

We will need to consider how these options would affect the risks the subsidy provider and the storage provider are exposed to. For the government, one of the risks under option 1 above is that the developer extracts more generous terms than are necessary in return for agreeing to build the second stage, or unnecessarily abandons its plans to build the second stage and effectively leaves part of the initial investment in the first stage stranded. By contrast, option 2 could prevent the developer from holding the second stage to ransom in this way, but it may require government to provide the developer with more extensive protection against risks associated with the second stage when signing the contract.

Next steps

Our approach to designing the business model will continue to be informed by our ongoing discussions with stakeholders. We intend to maintain our engagement via our Business Model Design Group, the Hydrogen Delivery Council Transport and Storage Working Group, and bilateral meetings with prospective storage providers.

We intend to provide regular updates to stakeholders on our progress, with an update planned for publication by the end of 2023.

We have tabled amendments in the Energy Bill to enable the hydrogen storage business model. Given the contractual nature of the business model, these powers will enable government to designate and direct a counterparty to manage hydrogen storage business model contracts, and, subject to further design of the business model and consultation, enable the potential funding of the hydrogen storage business model via levy.

We are working to determine the secondary legislation needed ahead of entering into hydrogen storage revenue support contracts. We are planning to make revenue support regulations to define who will be eligible to enter into hydrogen storage revenue support contracts.

Annex A: Rejected options for mitigating demand risk

The barrier to investment we are aiming to address

We continue to believe that the barrier to investment the business model must address is demand risk, including volume risk:

- Geological storage facilities take several years to build: for example, a salt cavern will take a minimum of around three to five years to solution-mine.[37] This is somewhat longer than it will take many prospective users of hydrogen storage to build or convert their own plant and equipment for use with hydrogen. It is therefore difficult for the developer of a storage facility to accurately predict, at the time they start construction on the facility, how many users it will have when it commissions.
- Moreover, it is economically rational for facilities to be intentionally built with significant 'spare' capacity to begin with because demand for hydrogen storage is expected to increase over time, and geological storage has economies of scale.
- It is therefore likely that geological storage facilities will have significant amounts of spare capacity when they commission, and although we expect their utilisation to increase over time, it is not clear at what rate this will happen, or when the facility will be operating at or close to its long-term intended level of utilisation.

[37] It is estimated that salt caverns purpose built for storage build time of 5-10 years and converted salt caverns have a build time between 3-5 years; the Hydrogen Production costs report assumes a three-year build time for hydrogen production plants, see: https://www.gov.uk/government/publications/hydrogen-production-costs-2021.

Because of this demand risk, in the absence of government intervention, investors are extremely unlikely to invest money in geological storage facilities on the timescale that we need them to.

Assessment of potential solutions

In the consultation document, we described a wide range of business model options. In our assessment, most of these would not adequately address the demand risk faced by prospective developers of geological storage facilities. A summary of our assessment is set out in table A.1.

In the table, we refer to the idea of a business model that uses subsidy to ensure the facility receives a minimum level of revenue regardless of the extent to which the facility is used (a revenue "floor"). This is the only option we believe is likely to address demand risk successfully.

A revenue floor could be implemented in a number of ways, including:

- A government offtake frontstop, i.e. an option in which government contracts with the facility for use of its storage capacity, and then resells that capacity to other users.[38] The floor in this case would be the amount the government pays to reserve that capacity.
- Another type of private law contract that provides a floor (and does not necessarily result in the government owning a storage product), for example, a cap and floor contract
- A government scheme (rather than a private law contract) that provides participants with a revenue floor
- A regime of economic regulation in which the facility has an "allowed revenue" set with reference to a regulatory asset base. The floor would be related to the allowed revenue.

In the commercial design chapter, we set out our views on how the floor should operate, and explained why we are minded to use private law contracts rather than economic regulation or a policy-based scheme to implement the floor.

Table A.1: Extent to which different business model design options would address demand risk for hydrogen storage

Option	What the option would do in relation to demand risk	Why the option would not work for hydrogen storage
Merchant model	Does not do anything to address demand risk; by definition the private sector assumes all demand risk in this model	Does not reduce demand risk.

[38] The government could either resell the capacity to other users directly, or use a remarketing agreement with the storage facility to allow the facility to perform the reselling.

Co-investment	Does not reduce demand risk but does reduce the impact of that risk on private sector investors, by allocating a share of the risk to government instead	Does not reduce demand risk.
Long-term financing of cushion gas	Does not reduce demand risk but does reduce the need for the private sector to raise its own finance, specifically for cushion gas	Does not reduce demand risk.
End user obligation	Creates demand by obligating users to use the facility, but this only mitigates demand risk for the facility if there are enough users who can afford to comply with the obligation	There are currently no users of hydrogen storage and there will be relatively few users during the early years of operation of the first storage facilities. Even a very large obligation on these users to store hydrogen gas may still not create enough demand to provide the facility with enough revenue to covers its costs, and there are limits to how large the obligation can be made before it threatens the financial viability of users. At the point of the Final Investment Decision, the developer will not know how many users will exist when the facility comes online and therefore there will be no certainty as to whether the obligation will create enough demand. Therefore, from an investor perspective, an end user obligation would not mitigate demand risk sufficiently to unlock investment. There are also likely to be implementation issues (as we set out in the consultation)
End user subsidy	Potentially increases demand by reducing the costs to users of using the facility	May still not create enough demand – there is no guarantee that subsidy will create any demand, as potential users still have the option of not using any storage (volumes could still be nil, and therefore there is still very significant remaining volume risk)
Contract for Difference	Removes price risk for the facility by ensuring it is paid an agreed price, and if necessary topping	Addresses price risk, but not volume risk: notwithstanding the price support that a Contract for Difference offers, volumes could

	this up from a reference price (which might be the price users pay)	still be nil, and therefore there is still very significant remaining volume risk for the facility
Minimum level of revenue ensured by a subsidy stream (aka a revenue “floor”)	Ensures the facility is due a minimum amount of revenue regardless of the extent to which the facility is used	With this option it should be possible to remove demand risk, including volume risk, entirely, if so desired. The challenges will be around designing and calibrating the floor to ensure it maximises value for money for the subsidy provider while still securing investment

Price risk

Our consultation document emphasised the issue of volume risk, i.e. uncertainty about the volume of storage services users will demand. Another aspect of demand risk is price risk, i.e. uncertainty about the prices storage services users will pay. Although we have focussed on volume risk in order to narrow down our options for the business model, we note that the option we are minded to adopt (a revenue floor) would provide protection against price risk as well as volume risk.

Annex B: Typical costs of a geological storage facility

Geological storage facilities are capital-intensive. Even relatively small salt cavern sites are likely to have capital costs in excess of £100m and larger sites (comprising many salt caverns) may cost several times this amount. Depleted gas fields or aquifers may be larger still and could have capital costs greater than £1bn.

For salt caverns, depleted gas fields and lined rock caverns, capital costs are likely to be greater than operating costs, although the proportional split between capex and opex will depend on technology and facility size. Larger facilities’ cost bases will tend to be even more dominated by capex.

Of the operating costs that geological storage facilities incur, fixed operating costs (i.e. costs that are incurred regardless of the level of usage, such as staff and maintenance) are generally expected to be greater than variable costs (such as the cost of using energy to compress gas). Table A.2 sets out some of the key components of a salt cavern’s cost base.

Table A.2: Typical costs of a salt cavern storage site

Cost	Key components
Capital costs	Construction of caverns, purchase of compressors and other above-ground plant equipment, cushion gas
Operating costs	Staff, maintenance, energy (for compression of gas), triethylene glycol (for dehydrating gas after it has been removed from storage)
Financing costs	Cost of equity and cost of debt

Chapter 4: Strategic planning

Introduction

Chapter 5 of the consultation set out a series of questions about how the build-out of hydrogen transport and storage (T&S) infrastructure might be strategically planned: whether such planning was necessary, what form it should take and by whom it should be conducted.

It suggested that strategic planning may be required to account for not only the geographical locations of hydrogen producers and end users, but the increasingly complex interlinkages within the wider decarbonised energy system and the need to enable an efficient transition to a deep, well-functioning hydrogen market.

Stakeholders were asked whether the build-out should evolve through either a solely market-led approach, a form of strategic planning or neither. The majority of respondents indicated their preference for a form of strategic planning or responded that a mixture of strategically planned and market-led development would be most appropriate for both transport and storage infrastructure, possibly with an evolution from more strategically planned in the early growth phase to more market-led in a steady state. The full summary of stakeholder responses to these questions is provided in chapter 4 of the Summary of Responses.

In this chapter, we set out our minded to position on strategic planning, following the analysis of stakeholder responses to the T&S consultation. Our position is that some form of strategic planning, potentially combined with elements of market-led development, is necessary to enable the efficient, cost-effective and timely roll-out of transport and storage infrastructure, and that in the future, the majority of that planning could be done by the Future System Operator (FSO). It is our view that the build-out of hydrogen transport and storage infrastructure, and in particular larger scale or systemically important assets, should be guided by centrally coordinated strategic planning that is integrated across energy and considers wider system interactions.

Our intention is for the FSO to undertake strategic network planning for hydrogen T&S. We expect the FSO to start building competence in hydrogen as part of its network planning roles in electricity and gas and its duty to consider whole system impacts. This puts it in a strong position to take on a central strategic planning role for hydrogen T&S infrastructure at an appropriate time following its establishment, within the statutory framework provided for by the Energy Bill.

We will work with Ofgem and ESO/FSO to fully develop the detail of the FSO's hydrogen planning role, and how it will interact with its other roles and relevant parties. This will be subject to further consultation. Some of the details of the role are closely tied to business model design, as discussed in chapters 2 and 3. Others will be dependent on the early development of the FSO itself, and ongoing work by Ofgem and government on wider energy planning policy.

In the interim, we envisage a central role for government in strategic planning, working closely with industry and the regulators. Our core objectives will be to assess early network requirements, identify priority projects and inform the business model allocation process. Our next step will be to develop a pathway for the early build-out of hydrogen transport and storage infrastructure to align with the Production Delivery Roadmap. As well as presenting early analysis of likely T&S system requirements in coming years, it will set out proposals for a central strategic planner role for the FSO and key considerations in identifying and supporting strategically significant projects.

Minded to position

The Need for Strategic Planning

Hydrogen transport and storage infrastructure will be essential to the development of the hydrogen economy, linking hydrogen production with demand to drive forward decarbonisation. Hydrogen networks infrastructure is both dependent on and essential to enable hydrogen production and demand. As a result, we consider there to be a high likelihood of purely market-led development resulting in sub-optimal outcomes for the wider hydrogen economy. A pipeline built to serve only a single confirmed offtaker could fail to enable further demand in the area or inhibit the expansion of connected production facilities. A storage facility may delay construction in the absence of confirmed demand for its services, while the lack of hydrogen storage options may inhibit potential production or demand projects from committing. A level of strategic planning can provide greater certainty on network requirements both in the short and longer term and give clarity and confidence to offtakers for whom hydrogen is a viable decarbonisation pathway.

The construction of larger scale infrastructure is expensive and comes with unavoidable disruption to the local area. The coordinated drive to net zero offers opportunities to align construction and identify efficiencies in infrastructure build out, assuming those opportunities can be readily identified. For example, strategic planning can help identify opportunities to convert existing natural gas infrastructure to hydrogen, which could be between 10 and 35% of the cost of new build pipelines, according to a summary review of estimated costs by ACER, the European Union Agency for the Cooperation of Energy Regulators.[39] Strategic planning that takes a wide, whole system view, provides a route to identify and make use of those opportunities where they exist.

More broadly, as noted in the Net Zero Strategy as the energy system goes through significant change and integration, our approach to system governance needs to evolve to help the whole energy system achieve our net zero ambitions.[40] Our energy system is becoming ever more integrated and a strategic, whole system approach provides the best opportunity to maximise

[39] ACER (2021): Transporting Pure Hydrogen by Repurposing Existing Gas Infrastructure: Overview of existing studies and reflections on the conditions for repurposing, (accessed June 2023).

[40] See https://www.gov.uk/government/publications/net-zero-strategy

decarbonisation, provide enduring system resilience and ensure value for money for energy consumers.

Strategic planning will lead to more efficient infrastructure build-out at the right pace, location and scale, resulting in greater investor confidence and ensuring that decarbonisation goals are met. We also see a potential role for market-led elements, and we want to ensure that the benefits of market-driven development are harnessed within a strategically planned system.

The Form and Design of Strategic Planning

In our consultation we set out several models of strategic planning the UK could adopt for hydrogen. Many of the features of these models were not mutually exclusive and none necessarily provided a precise template to follow. Responses to the consultation were broadly split across the different proposed forms of strategic planning. In their explanation of their choice, most respondents indicated that some combination of the suggested models would be preferrable. We are minded to agree with a significant proportion of respondents that there is a key role for a central strategic network planner, while recognising the role of the market and coordination across market participants in helping to drive optimal outcomes. To that end, we intend for strategic network planning to inform the allocation process of the transport and storage business models.

We are mindful that strategic planning should avoid being so prescriptive as to deter otherwise viable projects from coming forward when encouraged by market signals. Complex, optimised planning should not be pursued at the expense of rapid early development, while still guarding against the risks of undersized infrastructure, inefficiently independent development or assets at high risk of future stranding.

There may also be categories of infrastructure, based on criteria such as scale, flexibility, location or third-party access, whose development can be almost entirely market-driven, while strategic planning focuses on those assets whose scale, location, systemic role or other feature argues for a more planned approach.

Therefore, we are minded to focus near term strategic planning on areas where early clarity and direction can build investor confidence and accelerate growth, understanding that this will not be exhaustive. Assessments of strategic network requirements will continue to grow and evolve alongside hydrogen production and demand and as more projects begin to come online.

We also agree with those respondents that highlighted the need for a whole energy system approach. The way in which both the electricity and gas systems are strategically planned is also evolving, and hydrogen planning will need to be coordinated with and evolve alongside those developments, set out below.

For example, there are already a number of geological storage sites in the UK that are used to store natural gas. There is potential for existing natural gas storage sites to convert to hydrogen storage in the longer term, and due consideration will need to be given to how potential site conversions align with broader energy security objectives.

Future Strategic Planning for the Gas System

In 2021, Government's Net Zero Strategy indicated a 60% reduction in natural gas demand by 2037 versus 2020 levels in the key delivery pathway. Key dependencies of the way the gas system will look in the future include way in which hydrogen is utilised, the extent to which energy usage is electrified, and the development of carbon capture technologies. While the precise role the natural gas system will play in a decarbonised UK is uncertain, its importance in meeting energy demand – and so the need to plan effectively to ensure continued security and resilience – will remain into the future.

Gas transmission and distribution system planning is currently carried out independently by gas transporter licence holders. Gas storage facilities are owned and operated on a commercial basis by private entities, and planning is driven by a mixture of physical and economic factors. Government will continue to work with storage operators, as well as the regulatory community, to explore options around the role storage can play in supporting future gas system resilience. Following its designation, the Future System Operator will be responsible for gas strategic network planning, long-term forecasting and market strategy functions to enhance our ability to transition to a zero-carbon energy system and reduce the costs involved.

Future Strategic Planning for the Electricity System

For the electricity system, the Holistic Network Design (HND), published in July 2022 by the ESO, represents a step change in the planning of network infrastructure and will for the first time provide an upfront plan for both wider network reinforcements and the connections for offshore wind. In time, the ESO will build on the approach taken for the HND to deliver Centralised Strategic Network Planning (CSNP), which will take a whole system approach to designing the whole transmission network. Once established, we expect that the Future System Operator will take on responsibility for the CSNP.

The key message from responses to the consultation was that any approach to strategic planning for hydrogen should be flexible, enable coordination between market participants, be aligned across transport and storage, blend central strategic planning with more market-led elements where desirable and be able to evolve over time. Our position is that the next steps in strategic planning for the hydrogen network should be guided and informed by these principles, both as they apply to planning the immediate strategic needs of the hydrogen network and the enduring design of a central system planner role for the FSO.

The Role of the Future System Operator

Government has introduced legislation, as part of the Energy Bill, to establish a new, publicly owned Future System Operator (FSO). Depending on a number of factors, including timings of the Energy Bill and discussing timelines with key parties, the aim is for the FSO to be operational in 2024. We intend for the FSO to take on a role in central strategic planning for hydrogen T&S at an appropriate time following its establishment, within the statutory framework provided for by the Energy Bill.

Hydrogen presents a key decarbonisation pathway and is likely to play a significant role in the future evolution of natural gas networks. As we move towards net zero, efficient strategic planning for natural gas network infrastructure and hydrogen infrastructure will not be possible in isolation. Upcoming government decisions on blending and the use of hydrogen for domestic heating may also increase the need for holistic network planning between hydrogen and natural gas. The FSO could incorporate network planning for hydrogen transport and storage infrastructure into its system planning roles for natural gas and electricity. The FSO will undertake strategic network planning in gas, and while this role will be limited to natural gas in its early period of operation, together with Ofgem and the ESO/FSO, we will work towards the expansion of its role to include hydrogen.

The FSO is also intended to be the system operator and planner for electricity, and hydrogen has the potential to play a key role in the future of the electricity network. Hydrogen is likely to have a role in the decarbonisation of electricity generation as an alternative source of flexible dispatchable generation to natural gas. Electrolysers may also have a role in alleviating electricity network constraints and reducing the need to curtail renewable generation. Electricity system plans will be dependent on developments in hydrogen infrastructure, and the build-out of hydrogen T&S can be informed by electricity network development to provide whole system benefits. The FSO is therefore ideally placed to identify and balance network requirements across the energy system in the future.

Subject to the timings of the Energy Bill and other factors, the FSO is anticipated to become operational in 2024. We anticipate that the FSO's day one role for hydrogen would be limited to those considerations necessary to allow it to perform its other day one system planning roles for natural gas and electricity.

The FSO's statutory duties, including its duty to consider whole system impacts, will require it to take a broad view of the energy sector as it carries out its functions. From day one, it will need to take account of the impacts of what it does, such as network planning and forecasting, on the production, storage and transportation of hydrogen and their impacts on the electricity and natural gas sectors. It should therefore start building knowledge, skills and competence in hydrogen and soon become well equipped to take on functions that involve direct responsibility for hydrogen. While responsibility for strategic planning activities for hydrogen networks will continue to sit with government, the FSO should increasingly be able to offer some relevant and informed advice on early network requirements for hydrogen.

While we believe the FSO is the most appropriate body to take on strategic planning for hydrogen in the future, this will be subject to the details of that role being compatible with the

FSO's overall remit and statutory framework. Strategic planning for hydrogen will also need to be compatible with any future developments of the regulatory regime for hydrogen. See Chapter 5 of this document for more details. We will continue to work with Ofgem and the ESO/FSO, alongside continued industry engagement, on the detailed design and scope of the role, which will be subject to further public consultation.

Early Strategic Planning

The Role of Government in Interim Strategic Planning

We believe it is necessary for government, working closely with Ofgem and industry, to take a leading role in providing early strategic direction for the build-out of hydrogen T&S infrastructure. As discussed in earlier chapters, there will be complex trade-offs when considering the nature, scale and timing of projects to be supported through the business models, and we think government will be better placed to address these trade-offs in the early stages. We expect the strategic coherence of early projects to be intimately tied to government decisions on the hydrogen production business model allocation rounds, as well as wider decisions on CCUS cluster sequencing.

We see the primary objectives for government-led early strategic planning as:

- Assessing the evidence for T&S requirements in the hydrogen economy to identify early strategically significant needs,
- Identifying priority projects that could meet those needs, and
- Informing the allocation process for the transport and storage business models and its interaction with the nature and timing of support for early priority projects.

We intend to publish our approach to meeting these objectives alongside the Production Delivery Roadmap, as a pathway for the strategic planning of hydrogen networks. This document will aim to set out in more detail some of the early strategic priorities for transport and storage infrastructure and how they can be identified, as well as looking forward to future strategic planning objectives.

Clarity from government on the strategic approach to the development of hydrogen transport and storage infrastructure, especially in relation to uncertainty over location and right-sizing of assets, was identified as a critical requirement by stakeholders in their responses. To that end, we intend to set out a pathway for the development of hydrogen transport and storage infrastructure, to help ensure the network is built where and when it is needed, as well as at the right size, to support the wider hydrogen economy and whole energy system benefits. The development of this pathway will evolve alongside wider hydrogen and energy policy development and adapting as the hydrogen economy grows and as more evidence becomes available.

We envisage a coordinated allocation process between the hydrogen transport and storage business models, to ensure hydrogen networks develop in a coherent way. As set out in chapter 2, our initial view of allocation of the transport business model, especially in the short-term, is that it will likely be negotiated bilaterally between the department and prospective hydrogen transport providers – with a key role for the regulator and the counterparty. As set out in chapter 3, we anticipate hydrogen storage contracts will be negotiated bilaterally between the department and prospective storage providers. Strategic planning will ensure these levers can be used effectively to provide the infrastructure the nascent hydrogen economy and the wider energy system needs.

Eligibility for allocation will be informed by the strategic importance of an asset's contribution to the hydrogen economy and the wider energy system, as well as other criteria, such as deliverability and value for money. In the consultation, we set out a three-lens assessment to determine projects' strategic importance: does the asset meet a known immediate or future need, can it play a market building or capacity enabling role, and does it provide wider benefits to the energy system as a whole.

To assess the immediate need for an asset, considerations might include:

- Whether the asset is linked to confirmed current or future hydrogen production.
- Whether the asset is providing services to one or more credible hydrogen demand sources.

To assess the market building potential of an asset, considerations might include:

- Whether the asset is futureproofed, through either oversizing or scalability, to meet and/or act as an enabler for a range of future production/demand scenarios.
- The extent to which an asset opens up new growth avenues for the hydrogen economy, by connecting or servicing potential demand or production types.

To assess the wider systemic benefits of an asset, considerations might include:

- Decarbonisation potential of an asset that enables additional or timely fuel switching of carbon intensive demand.
- The contribution an asset is expected to make to energy security or system resilience, by balancing misalignment between entry and exit volumes, or providing redundancy.
- The extent to which an asset can alleviate or mitigate wider system constraints, both across energy and potentially beyond, especially those that are costly or otherwise damaging.
- The extent to which asset cost savings can be achieved through repurposing existing infrastructure, while ensuring wider energy system functionality is maintained as it decarbonises.

These considerations are illustrative and not exhaustive; we intend to consider further and develop a more detailed framework for assessing the strategic significance of assets. While there will be an initial focus on geological storage and pipelines transporting hydrogen as a gas - in recognition of the high upfront costs, long lead times and acknowledged strategic significance of these asset categories - the framework is expected to evolve and adapt as the hydrogen economy develops and more evidence of T&S requirements becomes available.

There may also be types of hydrogen T&S infrastructure that can grow more flexibly and in the absence of detailed network planning or government support. We do not intend strategic planning to act as an inhibitor where market signals can bring forward viable projects, where the risk of future asset stranding or capacity constraints is low.

We intend to provide a more detailed set of strategic considerations in our hydrogen networks pathway alongside updates on transport and storage business model design. Taken together, we expect these to provide a good indication of the strategic priorities for T&S within the early growth phase of the hydrogen economy.

Wider Government Work to Support Hydrogen Network Planning and Development

In addition to developing our approach to strategic planning for hydrogen infrastructure, we are also working across the sector to ensure strategic considerations for hydrogen are embedded in wider energy policy. Alongside this, we are working to resolve immediate barriers and ensure that support is available for key enabling transport and storage infrastructure.

We are currently consulting on a new Strategy and Policy Statement for Energy, with the aim of ensuring a fundamental role and responsibility for Ofgem, the FSO, government and industry partners in addressing barriers which prevent the near-term development of hydrogen infrastructure and helping ensure a suitable framework for hydrogen T&S expansion.[41]

In addition, we have recently consulted on new drafts of the energy National Policy Statements, in which references to hydrogen are now included in the relevant documents to provide additional guidance on hydrogen planning and development. For example, new draft text on planning consents for hydrogen pipelines sets out the expectation that applicants "consider foreseeable future demand when considering the size and route of their investments. Applicants may therefore propose pipelines with a greater capacity than demand might suggest at the time of consenting."[42] We are reviewing the responses to this consultation and assessing the suitability of the new suite of National Policy Statements for supporting hydrogen projects.

The earliest hydrogen transport and storage assets will be closely tied to production projects, and support for this initial build out is being provided through a number of mechanisms. For example, the Net Zero Hydrogen Fund and Low Carbon Hydrogen Agreement will provide the possibility of limited funding for costs of associated T&S infrastructure. We have also created measures to support the costs of developing stand-alone hydrogen T&S infrastructure as well as innovation funding for T&S, this includes but is not limited to:

- The Low Carbon Hydrogen Supply 2 which provided funding to further develop technologies in hydrogen production, transport and storage,

[41] https://www.gov.uk/government/consultations/strategy-and-policy-statement-for-energy-policy-in-great-britain

[42] https://www.gov.uk/government/consultations/planning-for-new-energy-infrastructure-revisions-to-national-policy-statements

- The Storage at Scale competition which provided capital grants to support the demonstration of large-scale energy storage, including hydrogen storage, using innovative technologies,
- The Long Duration Energy Storage Demonstration Competition which aims to accelerate the commercialisation of innovative long duration energy storage projects, at different technology readiness levels, including hydrogen, through first-of-a-kind full system prototypes or actual demonstrations,
- Ofgem's RIIO, which provided support for feasibility studies for early transport projects,
- UKRI's Industrial Decarbonisation Challenge, which supports the development of low - carbon technologies and infrastructure, including hydrogen pipeline projects in some industrial clusters, and research and innovation activities looking at the identification of systems infrastructure, assets and network design options.

The support provided through these mechanisms is helping to ensure that production projects have the infrastructure they need to serve their offtakers. As hydrogen production accelerates, larger scale infrastructure will be required to serve multiple offtakers and potentially multiple sources of production. We expect these projects will be supported by the transport and storage business models we have committed to designing by 2025. In May 2023 we introduced legislative amendments to the Energy Bill, which is a critical enabling step in designing these new business models by 2025. Early strategic planning activities will focus on informing the design of these business models to ensure that allocation is able to take relevant strategic factors into consideration.

Next steps

We recognise the critical importance to the early growth of the hydrogen economy of strategic planning for T&S infrastructure. Therefore, we will be building on progress to date to ensure that early projects that can provide strategically significant infrastructure are able to progress.

Following the recommendation in the Independent Review of Net Zero, led by former energy minister Chris Skidmore MP, we announced our intention to work with industry with a view to developing a hydrogen Production Delivery Roadmap by the end of 2023. Alongside that, we intend to publish a 'hydrogen networks pathway', to set out the next steps in our vision for the development of hydrogen T&S in the UK. One of the key objectives will be to address some of the barriers stakeholders have identified to the early growth of hydrogen T&S.

As noted above, some of the key barriers respondents saw to the early development of hydrogen transport and storage infrastructure were uncertain supply and demand and unclear locational and sizing requirements. While these uncertainties will remain a feature of the nascent hydrogen economy, we will work towards providing greater clarity on the early signals for transport and storage network requirements alongside the Production Delivery Roadmap.

We will also look to set out in more detail the considerations we will use to identify early priority projects. We expect these considerations to inform the strategic framework for hydrogen system planning and to inform the design of the business model allocation process for both transport and storage. The interaction of the business model allocation process with the nature and timing of support for early hydrogen transport projects will also be informed by this strategic framework. As discussed in chapters 2 and 3, our current timeline for the business models is ambitious but we believe it will provide revenue support at the right pace to bring projects forward.

By the end of 2023 we intend to set out the next steps in developing a future role for the FSO in strategic planning for hydrogen transport and storage infrastructure, including further consultation. We will work towards establishing the appropriate scope of the network planning the FSO would do for hydrogen infrastructure, ensuring the role can be compatible with the overall framework of the FSO, and establishing a timeline towards the FSO taking up this role. Additionally, the enduring role of the FSO in business model allocation will be the subject of the continued detailed design work of both the transport and storage business models.

Chapter 5: Regulatory framework

Part 1 - Market framework

Introduction

The first part of chapter 6 of our consultation on Hydrogen Transport and Storage infrastructure was concerned with the market framework and industry commercial arrangements for hydrogen. We noted that since hydrogen is a “gas” for the purposes of the Gas Act 1986, regulatory requirements and prohibitions that apply to the transportation, shipping, supply and storage of natural gas may also apply to hydrogen. We recognised that these existing arrangements might not be conducive to the emergence of hydrogen transport and/or storage infrastructure. Consequently, we sought the views of stakeholders on existing arrangements, and the extent to which they are optimal for supporting the development of hydrogen transportation and/or storage infrastructure. We asked stakeholders for their views on how any perceived shortcomings might be addressed.

33 out of the 40 responses we received to the questions posed in Part 1 thought that the existing market framework and industry commercial arrangements for hydrogen were sub-optimal for supporting the development of hydrogen transportation and/or storage infrastructure. Respondents offered views on a wide range of issues, and in some instances took opposing views. There were a few areas where there was a moderate degree of consensus, most notably on the need for hydrogen-specific industry commercial arrangements, i.e. something equivalent to the Uniform Network Code (UNC) but specifically for hydrogen. However, no single issue was raised by more than half of respondents, and most issues were raised by 4 (12%) respondents or fewer. This reflects the breadth and complexity of the subject matter, as well as the diverse nature of those individuals and organisations who provided responses. Nevertheless, it is clear that stakeholders are engaged with the subject matter and that many are concerned that the existing market framework and industry commercial arrangements could present barriers to the emergence of the hydrogen economy.

Minded to position and next steps

In light of the above, and in keeping with government’s ambitions to deliver a thriving low carbon hydrogen sector in the UK, it is government’s intention to keep the market framework and industry commercial arrangements under review with a view to introducing timely amendments where they are warranted. This review will include ongoing work taking place through the Hydrogen Advisory Council’s Transport and Storage working group in the first instance but is likely to encompass further engagement with stakeholders via a call for evidence and/or consultation on more specific proposals at a later date. In line with comments made by stakeholders, we will remain mindful of our long-term vision for hydrogen transport and storage infrastructure when thinking about which arrangements will best serve participants in the emerging hydrogen economy.

Part 2 - Non-economic regulation

Introduction

The second part of chapter 6 of the Hydrogen Transport and Storage Consultation outlined questions concerning the existing non-economic regulatory framework for hydrogen, focusing on its suitability in areas of planning, health and safety, environment, and broader onshore and offshore contexts.

The consultation suggested that the current non-economic framework for hydrogen is designed to accommodate a limited use of hydrogen that exists today and would require careful consideration of its current suitability in relation to the developing hydrogen economy. This may require updating regulation(s) in the future to facilitate larger volumes of production, anticipate increased demand, and accommodate for a variety of end uses to help meet the government's ambitions of 10 GW production ambition.

This chapter set out questions on different regulatory areas and their existing suitability for hydrogen projects across the value chain. Stakeholders were asked to comment on the optimality of the current arrangements of the existing onshore and offshore regulatory frameworks, the suitability of the existing planning regimes, non-pipeline transportation, and environmental regulations. For all of the questions, a majority of respondents indicated that the existing frameworks were not optimal for hydrogen projects and could be improved.

Minded to position

We thank respondents for sharing their views on existing regulatory frameworks throughout this chapter. This is very useful in our ongoing work to identify and address regulatory barriers for the efficient deployment of hydrogen infrastructure. We will continue to work closely with industry and regulatory bodies to consider the issues raised and the suggestions put forward on the suitability of existing regulatory frameworks for hydrogen, with a view to introducing timely amendments where they are needed.

On overall regulatory frameworks, we have considered the issues raised by respondents. The department will work closely with relevant industry and regulatory bodies to examine and develop the regulatory framework applicable for hydrogen projects and to address issues raised in this consultation. To this end, we will continue to use the Regulators Forum and ongoing industry engagement to map out and prioritise regulatory areas and barriers to address. This will enable us to coordinate an efficient approach to designing and delivering suitable regulatory frameworks for the UK hydrogen economy as it grows and evolves.

Building on this, we have identified some early priority areas to progress. For example, on environmental regulations, UK regulators have worked together, with industry and other stakeholders to produce guidance on Emerging Techniques for Hydrogen Production with Carbon Capture.[43] Further guidance is planned on emerging techniques of hydrogen

[43] https://www.gov.uk/government/publications/emerging-techniques-for-hydrogen-production-with-carbon-capture

production via electrolysis. These documents will help industry navigate these complex areas to bring new projects to fruition.

Alongside this and in line with stakeholder comments received, government considers the issue of leakage and potential fugitive hydrogen to be important. Now that a Global Warming Potential for hydrogen has been identified, the department will continue to collaborate with other government departments, UK specialists and the National Physical Laboratory (NPL) to develop more reliable estimates of GB fugitive emissions, identify their impacts and increase our capability to detect, measure and quantify hydrogen emissions in a more systematic way, and ensure this is suitably reflected in applicable standards and regulations.

More broadly, the department will continue to work with relevant regulators to prioritise considering and assessing the environmental regulatory regime for hydrogen and will take the views raised in this consultation into account when future policy/regulation is being designed.

On planning regulations, the government recognises the need for clear and robust processes and guidance. The government has committed to improving the process for Nationally Significant Infrastructure Projects (NSIPs) to make it better, faster, and greener. The NSIP Action Plan[44] sets out 18 actions to achieve this, working to make the system more optimal, as raised here as an issue, while keeping communities and the environment at the heart of decision-making. One of the reform areas in the NSIP Action Plan is to improve system-wide capacity and capability, which includes developing skills and training, and extending proportionate cost recovery by the Planning Inspectorate and key statutory consultees to support effective preparation and examination of NSIPs and build resilience into the system.

Alongside this, new drafts of the Energy National Policy Statements (NPS) documents[45] were published for consultation on 30 March 2023. References to hydrogen are now included in the relevant NPS documents to provide additional guidance on hydrogen planning and development. The government invited responses to revisions to the NPS from 30 March 2023 to 23 June 2023 and will then examine the reviews provided by relevant stakeholders on these latest changes.

As this work progresses, the department will continue to monitor and assess whether a bespoke NPS for hydrogen is needed. We will also continue to work with relevant regulators, stakeholders and local authorities to understand their views on planning and hydrogen projects, including discussions within the Hydrogen Regulators Forum.

We will consider responses from this consultation that suggest potential changes to national planning policy on energy. Wider planning reforms are currently underway, being led by the Department for Levelling Up, Housing and Communities. Planning reforms are being partly delivered through the Levelling Up and Regeneration Bill and partly through reviews of national

[44] https://www.gov.uk/government/publications/nationally-significant-infrastructure-projects-nsip-reforms-action-plan/nationally-significant-infrastructure-action-plan-for-reforms-to-the-planning-process#annex-a-nsip-reform-actions
[45] https://www.gov.uk/government/consultations/planning-for-new-energy-infrastructure-revisions-to-national-policy-statements .

planning policy. This consultation does not pre-empt the outcomes of wider planning reform or the outcome of any supporting government consultations.

More broadly, we continue to work with industry and regulators to consider reviewing existing guidance, including how effective it is at signposting relevant planning and licensing requirements to industry.

We will continue to work with relevant regulatory bodies and stakeholders on the issues raised in the consultation, and we welcome continued engagement on any regulatory issues experienced by UK hydrogen projects. This will help inform our ongoing work on future regulatory design, and how it can best serve hydrogen projects in the emerging hydrogen economy.

Next steps

On offshore regulation, the department consulted on certain aspects of offshore hydrogen regulation[46] in April and May 2023. The consultation sets out initial proposals for offshore hydrogen pipelines and storage facilities. The proposals, which would require secondary legislation to implement, seek to ensure that certain offshore activities are conducted with proper regulatory oversight, whilst ensuring the environmental impacts of early hydrogen projects are duly considered.

We aim to publish our response to this consultation alongside a summary of the responses received in Q3 2023. We will be reviewing evidence in the consultation prior to making a final decision on a future legislative pathway.

We regard the proposals in the Offshore Hydrogen Regulation Consultation as an initial approach to regulatory design which is operable for early offshore hydrogen projects and will help to support innovation in this sector. As early projects develop through this framework, we will be able to gain a better understanding of whether and how it might be improved further. We will therefore continue to review the future offshore regulatory regime for offshore hydrogen projects and will work with relevant regulators and industry to identify what further changes to the regime may be necessary.

[46] https://www.gov.uk/government/consultations/proposals-for-offshore-hydrogen-regulation

Chapter 6: Hydrogen blending

Introduction

Government is aiming to reach a policy decision in 2023 on whether to support the blending of up to 20% hydrogen by volume into the GB gas distribution networks. Blending hydrogen into the existing gas network may help provide market-building benefits for the hydrogen economy and could generate carbon-savings of up to 6-7% on current GB grid gas consumption.

For blending to be enabled, it must demonstrate economic and strategic value as well as being safe. Industry is undertaking trials and demonstrations to provide safety evidence for blending to inform the safety case. The economic case will be based on technical models, considering where hydrogen should be injected into the networks, what market and trading arrangements should be in place and whether billing processes might need to be amended. The economic case will also assess commercial models, including the question of whether and, if so, how blending should receive government commercial support. Work is on-going to assess the costs and potential mechanisms to implement blending, if enabled, which was not the focus of this consultation chapter. We aim to further explore these topics via a hydrogen blending consultation ahead of our intended policy decision.

This chapter sought to better understand the hydrogen market-building potential of allowing hydrogen blending into the existing gas grid, and how this might affect the economic and strategic case for blending. The chapter provided the rationale for the strategic role of blending as a reserve offtaker, to support hydrogen economy growth whilst managing the impact of blending on the supply of hydrogen to alternative end users who require it to decarbonise. It was noted that blending could manage the risk of producers being unable to sell enough volumes of hydrogen to cover their costs (i.e. volume risk) by providing a route to market for hydrogen whilst hydrogen transport and storage infrastructure and end user markets are developing. Within the chapter, we identified and reviewed three categories of volume risk:

Early years of hydrogen economy

- **Hydrogen transport and storage infrastructure risk:** There is a risk that producers will likely sell their volumes to offtakers within a localised area, with limited ability to grow new offtake markets due to an initial lack of larger scale transport infrastructure. Prospective electrolytic hydrogen producers using renewable electricity with intermittent production profiles may also struggle to find suitable flexible offtakers, especially ahead of larger scale storage capacity becoming available.
- **Delays to at scale adoption of hydrogen:** There is uncertainty around the scale and pace of hydrogen adoption across sectors. This may be affected by the need for regulatory changes, the availability of alternatives (e.g. electrification), the need for industrial changes (e.g. permanent changes in industry structure), the lack of technology readiness, concerns about security of supply for end-use sectors, and the pace and effectiveness of hydrogen research and innovation.

Ongoing

- **Demand volatility:** Even where hydrogen offtakers have been secured, natural and commercial demand cycles or financial and technical issues can lead to offtaker outages or closures. These may be temporary, e.g. if an offtaker shuts down for maintenance, or long-term, e.g. if an offtaker goes insolvent.

In the consultation questions, we sought to further understand the value that a reserve offtaker, such as blending, may have in managing these categories of volume risk.

Minded to position

We thank respondents for sharing their views on hydrogen blending throughout this chapter. This is highly useful in forming our assessment of the hydrogen market-building potential of allowing hydrogen blending into the existing gas networks. Alongside the potential benefits and risks explored in this chapter, we are considering the potential means to deliver blending, if blending is enabled by government. This includes assessment of technical delivery models for blending, market and trading arrangements, impacts on gas billing and potential commercial support mechanisms.

Next steps

Our aim is to publish a consultation on hydrogen blending that sets out our lead options for these policy considerations ahead of the intended 2023 policy decision. In the consultation, we also plan to set out the nature of our intended 2023 decision on blending into gas distribution networks given broader strategic, economic and safety considerations. We aim to bring together our assessment of the potential strategic and economic value of blending with the potential technical and commercial means to deliver it. This will also consider the potential costs that may be associated with that delivery mechanism, which may be published as part of the wider consultation. We invite readers to engage with this next consultation, once published.

Acronyms

Acronym	Definition
CAPEX	Capital expenditure
CCUS	Carbon capture, usage and storage
CfD	Contract for difference
COMAH	Control of Major Accident Hazards
DEVEX	Development expenditure
ESO	Energy System Operator
FOAK	First of a kind
FSO	Future Systems Operator
GB	Great Britain
GGSS	Green Gas Support Scheme
HAR	Hydrogen Allocation Round
HPBM	Hydrogen Production Business Model
LCCC	Low Carbon Contracts Company
NSIP	Nationally Significant Infrastructure Projects
NOAK	Nth of a kind
NPL	National Physical Laboratory
NPS	Energy National Policy Statement
NZHF	Net Zero Hydrogen Fund
Ofgem	Office of Gas and Electricity Markets
OPEX	Operational Expenditure
R&D	Research and development

RAB	Regulated Asset Base
RTFO	Renewable Transport Fuel Obligation
SoS	Secretary of State
T&S	Transport and storage
TRL	Technology readiness level
UNC	Uniform Network Code
UK	United Kingdom

Glossary

Term	Definition
Allocation	The process of allocating revenue support through the hydrogen transport and storage business models
Balance sheet	The national balance sheet shows the market value of the financial and non-financial assets for the UK
Carbon Budget 6	Limits the volume of greenhouse gases emitted over a 5-year period from 2033 to 2037, taking the UK more than three-quarters of the way to reaching net zero by 2050
Carbon Capture Utilisation and Storage	The process of capturing carbon dioxide from industrial processes, power generation, certain hydrogen production methods. The captured carbon dioxide is then either used or stored permanently
CCUS cluster sequencing	The process by which CCUS industrial clusters are chosen, with two anticipated by the mid-2020s, and a further two clusters by 2030 as outlined in the 10 Point Plan
CCUS-enabled hydrogen production	A process for producing low carbon hydrogen, and capturing, monitoring, metering and exporting CO2 generated in the production process
Contract for difference	A Contract for Difference, as set out in the Energy Act 2013, is a contract between a generator and a counterparty to encourage the generation of low carbon electricity whereby the counterparty will pay an electricity generator the difference between the CfD reference price and the CfD strike price
Electrolysis	A hydrogen production process which involves using electricity to generate hydrogen from water. Low carbon hydrogen is created when low carbon electricity is used as the input fuel
Electrolytic hydrogen production	Hydrogen produced from electrolysis

Energy Bill	A Bill to make provision about energy production and security and the regulation of the energy market.
First of a kind	The first low carbon hydrogen projects accessing revenue support through the business model, who take on first mover risk by entering an undeveloped low carbon hydrogen market
Hydrogen production business model	The objective of the hydrogen business model is to incentivise the production and use of low carbon hydrogen, and help us achieve our ambition of up to 10 GW by 2030, subject to affordability and value for money. It is designed to provide hydrogen producers with revenue support to overcome the operating cost gap between low carbon hydrogen and fossil fuels in order to unlock private investment in hydrogen projects.
Hydrogen transport provider	Hydrogen transport provider could relate to an investor, owner, operator or developer of hydrogen transport infrastructure, including any combination of these.
Low carbon hydrogen	Hydrogen that is produced with significantly lower greenhouse gas emissions compared to current methods of production – methods include methane reformation with CCUS and electrolysis using renewable electricity. The hydrogen produced will be subject to meeting the 20gCO2e/MJ LHV of hydrogen threshold set out in the proposed UK LCHS to be considered low carbon for the purpose of this scheme
Net Zero	Legislation passed by the government to reduce greenhouse gas emissions to net zero by 2050
Net Zero Hydrogen Fund	A £240m fund to support low carbon hydrogen production
Nth of a kind	Low carbon hydrogen projects entering into a more developed hydrogen market using mature technologies and processes with less risk
Ofgem RIIO mechanism	RIIO is a mechanism established by Ofgem that involves setting Revenue using Incentives to deliver Innovation and Outputs designed to encourage energy network companies to: play a full role in delivery of a sustainable energy sector and deliver value for money network services for existing and future consumers.
Reference price	Reflects the price that the producer would receive for hydrogen in the market under a variable premium model
Renewable Transport Fuel Obligation	Mechanism to support the production and use of renewable fuels based on obligation on suppliers of transport and non-road mobile machinery fuel in the

	UK to show that a percentage of the fuel they supply comes from renewable and sustainable sources
Revenue support	The funding provided on an ongoing basis, for an agreed term, which would cover a proportion of operating costs and an appropriate rate of return on private sector capital invested
Volume risk	The risk that a hydrogen production facility is unable to sell enough volumes of hydrogen to cover costs with reasonable confidence

This publication is available from: www.gov.uk/government/consultations/proposals-for-hydrogen-transport-and-storage-business-models

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