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Models for Transport and Storage of Captured CO_2

An overview of options

June 2021

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Summary

- Carbon capture projects require guaranteed, reliable access to safe and cost-effective CO_2 transport and storage. Without this it will not be possible for capture projects to secure investment, or for CCS to play the role it needs to play in reaching emissions reductions goals.

- Pipeline transport of CO_2 has large economies of scale, and so a tendency towards natural monopoly, with typically no alternative networks available to a capture project. In this CO_2 transport resembles other networks, including, for example, those for natural gas, electricity and water. Storage sites and transport by ship are also likely to be subject to only limited competition, especially in the early years of CCS deployment.

- This dependence of capture projects on one or two transport and storage providers means that some form or regulatory oversight is necessary to prevent the abuse of monopoly power.

- Regulation may be in the form of direct government control, or an independent regulator acting to fulfil objectives specified by government.

- Ownership arrangements may also contribute to regulation. Full or partial state or local authority ownership may allow direct influence over decisions on transport and storage, and enable management of risks. However private ownership with regulation can also secure policy objectives. The choice will depend on project circumstances, established practice for other sorts of network, and political culture.

- Economies of scale in pipelines means that it will usually be preferable to build pipelines with greater capacity than required by initial projects. Again, CO_2 networks resemble many types of networks in this respect. This creates financial opportunities and challenges which need to be addressed by design of access pricing and financing arrangements.

- There are volume risks for the transport and storage provider, for example due to delays in capture projects. These are reduced if there are clusters of capture projects.

- Cross chain risks also need to be allocated, with some form of government participation likely necessary to address risks unmanageable and uninsurable by the private sector.

1 Introduction

Substantial deployment of Carbon Capture and Storage (CCS) is widely acknowledged to be a necessary part of reaching net zero greenhouse gas emissions. It is especially important for industrial sectors, such as cement, where there are few if any alternatives for reducing emissions. Creating Transport and Storage (T&S) infrastructure that can safely and efficiently transport captured CO_2 and permanently store it underground is a central part of CCS deployment.

There are significant opportunities and challenges in establishing this new infrastructure, and ensuring that capture projects can gain access to it on appropriate terms.

Network access regimes face issues especially around **volumes transported** and **pricing**. The required size of infrastructure will be uncertain, and so will be the pricing of T&S services. These issues need to be addressed in a way that enables **cost effective access to T&S for capture projects**, while still **making T&S viable**.

The issue of pricing for capture projects is complicated by the **natural monopoly characteristics of CO_2 networks** that arise from the large economies of scale in pipeline capacity. In the early years of CCS deployment there are likely to be few if any alternatives for transport, either by ship or pipeline, and few storage sites. Even in a mature industry, the natural monopolies are likely to persist in transport by pipeline, and to a lesser extent in provision of storage sites. Transport by ships may be more competitive at locations with unfavourable conditions for installing pipelines on land, or far from the nearest CO_2 storage site, but with good access to a port.

There will also be **cross chain risks**. Events in the T&S network will affect the capture project. These risks need to be allocated and managed. The pipeline will also be exposed to such risks, and although these will be mitigated to some extent by the presence of multiple capture projects in **clusters**.

Consequently, business and regulatory models are needed that can both:

- incentivise the provision of infrastructure; and
- give appropriate long term access by capture projects that will allow them to invest and operate their capture facilities.

A regulatory framework needs to be established that enables CCS at sufficient volume to achieve the necessary emissions reductions, and in a way that avoids excessive costs. This includes choices about ownership of T&S infrastructure.

This briefing note looks at models for doing this and some issues raised. It does not provide complete solutions, which will require substantial work to develop in the relevant contexts. Furthermore, there is no single design which will fit all circumstances. Approaches will depend on physical circumstances, market maturity, differences in regulatory approaches, and differences in political culture. Instead this note seeks to show the range of issues raised and some routes to addressing these.

This briefing paper addresses CCS rather than carbon capture and use (CCU). The vast majority of captured CO_2 volumes will require transport and geological storage. There may be a role for CCU if the form of use permanently prevents the carbon from entering the atmosphere. However, this is currently expected to account for only a small minority of captured volumes.

Industrial CCS is in the very early stages of its deployment globally, so there are few examples of practice to date. Some of the analysis must be based on parallel with other activities, for example from existing network regulation. However, there are now some emerging models and we consider the lessons that can be learnt from these.

2 Regulation of pipelines

Capture projects depend on T&S for the long term, because assets are long-lived. Once the investment in capture is made there will be a need for continuing access to T&S, usually with no alternative options, so assets are dependent on each other.

One solution is **vertical integration** where a single entity (private or state owned) provides an "end-to-end" service, owning and operating the entire CCS chain. Companies or consortiums may emerge to provide such an offering. However, in practice capture projects are often closely integrated with the emitting facility, for example a cement plant, and it will be difficult to separate the two. This may make this option impractical. In any case some kind of regulatory framework is likely to be required for T&S infrastructure access and pricing.

Another possibility is to put in place **long term contracts** between capture projects and transport and storage. The capture project may be owned by the industrial facility from which emissions are captured, or by a specialist capture service provider. This approach separates capture from T&S, reflecting the likely reality of operation.

However, in the absence of regulation, negotiating such deals will inevitably put the capture project at a disadvantage, because the T&S provider will have an effective monopoly. Indeed, both the vertical integration route and long-term contract options are limited by the **natural monopoly characteristics of the pipeline system** and the consequent risk of monopolistic pricing.

For this reason, some kind of **regulatory oversight** is likely to be necessary. This can take various forms, including the following.

- Explicit regulation, either by an independent regulator or by the relevant government department. This may include, for example, setting target rates of return for infrastructure investment.
- Government ownership and provision of T&S services. This allows direct control of infrastructure to meet government objectives.
- Direct government participation in contract negotiations.

Ownership of transport and storage networks currently covers the complete range from 100% state or municipal ownership to 100% private ownership, as summarised in the table.

Table 1: Examples of ownership structure for T&S

Jurisdiction and Project	Ownership model
Netherlands (Porthos)	Entirely government and municipally owned
Norway (Northern Lights)	Some state ownership by the participation of the state-owned Equinor
USA	Privately owned
UK	Likely that in the UK the transport and storage company will be entirely privately owned (this is not yet confirmed)

A possible partial exception to this need for regulation could arise if in the long term there is a liquid market for shipping from coastal locations to storage in a variety of sinks. A trend like this was observed in Liquefied Natural Gas (LNG) where there was a trend from dedicated equipment and contracts to a greater degree of spot trading. However, this took several decades and very large growth in volumes to be realised. It does not seem a likely prospect for most CCS for at least a decade.

The **network asset owner** and **system operator** can in principle be separate functions carried out by separate organisations. However, in practice they are likely to be merged, especially in the early years of CCS deployment.

Regulatory models

Regulatory models can take a range of forms, most of which have been applied in some form to other types of network. Most will involve seeking adequate but not excessive returns for transport and storage services provided. Examples include the following. Hybrids or combinations of these are possible.

Regulated Asset Base (RAB) The T&S company receives a licence from an economic regulator, which grants it the right to charge a regulated price to users in exchange for delivering and operating the T&S network. The charge is set by an independent regulator which considers allowable expenses, over a set period of time, to ensure costs are necessary and reasonable. Prices are typically reviewed every few years, although revision may be more frequent during early years of operation. The regulator will need to review major expenditure such as network expansion to confirm consistency with specified objectives, and the network owner will need to submit long-term plans.

RAB with financial support. The RAB model could be adapted to include the provision of financial support to decrease the upfront capital expenditure. This approach looks likely to be adopted in the UK.

"Cost Plus" Open Book Direct operational payments are made by government to cover properly incurred costs annually, on an open book basis, with an addition of agreed profit margins and return on investment. This model is widely used in transport and infrastructure projects in other sectors, and has traditionally formed an important part of network pricing in the USA.

Government-owned model. The government sets up a regulated, publicly owned CO_2 T&S network, which is responsible for delivering and operating the T&S infrastructure and implementing goals set by the government. In the UK this would likely include eventual **privatisation** of the network as the CCS market matures, with a transition to a RAB model. However other jurisdictions, for example the Netherlands, may pursue continued state ownership.

Government oversight of or involvement in contracts. The government directly participates in contract negotiations.

Each of these models will likely be accompanied by rights of access to the infrastructure to ensure that capture projects can secure services.

Example: Northern Lights

The Norwegian Northern Lights T&S project will ship CO_2 to a storage facility on Norway's west coast from where it will be injected into a deep saline aquifer. It is envisaged that it will take CO_2 volumes from elsewhere in North Western Europe and is understood to have had a very large number of expressions of interest for such services.

The initial capture project has access to Northern Lights via contracts. These were negotiated with direct government involvement, made easier because the government provides a subsidy accounting for 75-80% of total project costs (including capture). Financial contracts are via the government rather than directly between Northern Lights and the capture project.

In future Northern Lights could also compete with pipelines to other storage facilities, and with other projects based on shipping. At current there do not appear to be any plans to regulate the prices it charges for such services. It is not clear to what extent the prices charged will be limited by competition.

Northern Lights has mixed state and private ownership. It is jointly owned by Equinor (which is owned by the Norwegian State) and Total and Shell which are private companies.

Example: CO_2 pipelines in North America

North America has by far the world's largest CO_2 transport infrastructure with around 8000km of pipeline. The Department of Transport's Pipeline and Hazardous Materials Administration (PHMSA) regulates safety of CO_2 transportation including pipelines.

At present, the network is mainly used to transport CO_2, including both captured and naturally occurring CO_2, for use in Enhanced Oil Recovery (EOR). As such it has a very different rationale from networks planned in Europe. It nevertheless offers insights into how networks can be provided. Furthermore, the situation is likely to change as there is greater federal funding and more CCS projects are built that do not include EOR.

CO_2 pipelines are privately owned. There are currently no third party access rights. Instead, any access is by commercial negotiation. However this appears likely to change in future as Federal Government funding will contribute to infrastructure development (see separate box).

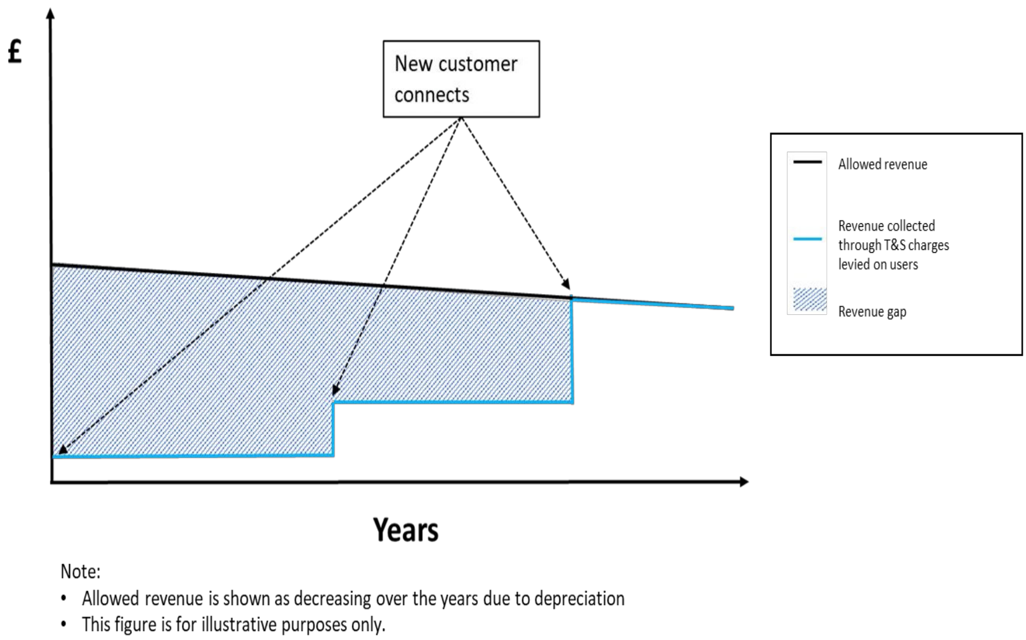
3 Infrastructure scaling

The **large economies of scale in pipeline construction** – building a pipeline with twice the capacity costs much less than twice as much - mean that there are significant cost advantages per tonne of CO_2 in building a larger pipeline. However, a decision on pipeline size will usually need to be taken before the volume from capture projects is known. For example, there will usually be a need to be able to accommodate uncertain future projects. There will therefore be **spare pipeline capacity** in the early years. This issue is especially prominent because the immaturity of CCS deployment means that volume uncertainty is much greater than in more established networks, such as current networks for electricity and gas, although similar issues would have arisen in the early stages of their growth.

Similar considerations can apply to storage. For example the pipe used for injection at the Northern Lights storage facility is larger than required by early volumes.

This raises financing challenges because initial volumes are relatively small (see Figure). Either early users must pay a high price, or the T&S will earn little revenue. There is also the risk that future projects will not happen, and the pipeline will be bigger than needed, and will need to recover its costs from smaller volumes. Conversely, there are risks that building pipelines smaller than eventually required will lead to increased costs because economies of scale are foregone.

Figure 1: illustration of the impact of planned underutilisation during early operational phase



Source: UK Department for Business, Energy and Industrial Strategy.

This issue is common to much network infrastructure across a range of sectors. There is the need to capture the opportunity of much lower unit costs from larger capacity while recognising the short term challenges in recovering capital costs.

There are various possible solutions to this issue. These include the following (as is often the case, hybrids of these options are also possible):

- **Subsidy**. The government may provide capital cost subsidy, or operational subsidy for the early years. This may extend to long-term government investment and ownership.
- **Profiling of revenue**. The allowed revenue profile over time could be shaped to match the expected utilisation profile of the T&S network. For example, the depreciation of the regulated asset value (RAV) could be profiled as opposed to using straight-line depreciation.
- **A fixed price**. A price may be set with a pre-determined course, for example fixed or indexed to inflation, or with a fixed annual decrease. This would be set in a way that would lead to the required rate return over time with expected volumes, but with lower returns in the early years. The rate of return would reflect the possibility of actual revenues being higher and lower than expected.

These approaches could be accompanied by explicit **Incentives on the T&S operator** to increase utilisation by connecting additional projects.

Example: Netherlands & the Port of Rotterdam 'Porthos' project

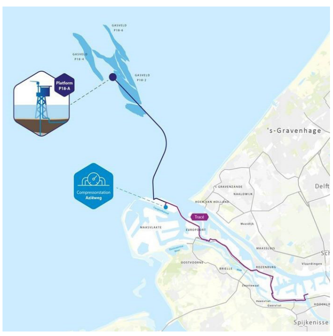
Porthos is a joint venture between the Port of Rotterdam Authority, Gasunie and EBN. EBN and Gasuine are owned by the Dutch state. The shares in the Port of Rotterdam Authority are held by the Municipality of Rotterdam (approximately 70%) and the Dutch government (approximately 30%). Ownership in the Dutch CCS chain will be retained by the operating companies/consortiums.

Financial support is provided under the SDE++ subsidy scheme, which provides a Contract for Difference on the carbon price, covering the uncommercial cost of the CCS chain above the EUETS price. Each capture project bids in a tender process for a 15-year subsidy contract. The bid includes both capture and T&S costs.

To ensure sufficient T&S capacity is available at the time that the capture plant is operational, each application needs to provide a declaration with the T&S operating parties to this effect. As such, multiple parties can apply with the same T&S partners, as for example the case for the Porthos project in the Port of Rotterdam.

The Port emits an annual 25 million tonnes of CO_2, or 20% of total Dutch emissions. A large part of this is from maritime transport. There are also several large point sources in the port area. During the first round of the SDE++, four companies from the port area totalling some 2.5Mt CO_2 applied for funding. All will be connected to the shared T&S infrastructure.

There are plans to build a pipeline able to accommodate 10 $MtCO_2$ per annum. This is in the expectation that additional volumes will be captured in future, both from the Netherlands (particularly the chemical cluster at Chemelot) and neighbouring countries (Belgium & Germany).



Source: [Porthos. 2021. Project - Porthos]

Example: The proposed US SCALE Act provides fund to support investment in T&S infrastructure

The proposed Storing CO_2 And Limiting Emissions (SCALE) Act in the USA would provide flexible, low-interest grants and loans to cover a portion of the cost of CO_2 transport infrastructure development. This would be common carrier capacity, with third party access to the infrastructure. The Act would also establish a Secure Geologic Storage Infrastructure Development Program to cover part of the costs of developing of saline geologic storage projects, with an emphasis on large-scale commercial projects serving as regional storage hubs for multiple capture facilities across industries.

Source: Clean Air Task Force

Price structure

Price risks can be managed to some extent through the structure of pricing. Different elements reflect different costs. Prices may consist of:

- Commodity charge per tonne of CO_2 transported
- Capacity charge for a certain maximum flow rate paid irrespective of the volumes transported
- A connection fee.

For example, a capacity charge can reduce the risks to the network of variations in capture volumes from a project, because this charge is not dependent on volume transported. Similarly, a connection fee can recover costs specific to an individual capture project, for example a smaller branch pipeline serving only that project.

If financial support is put in place for capture projects that includes transport and storage costs it will need to reflect the structure of T&S prices.

Risk sharing and refinancing

A contingent or risk sharing mechanism could be included, with consumers or taxpayers paying for any remaining under recovery of allowed revenue, and sharing any excess returns. This may reduce the risks to investors in the inevitable presence of large uncertainties.

This may be especially relevant in the case of refinancing of privately owned networks. Following successful commissioning of the T&S network, a T&S company may look to refinance the project. The regulator would undertake careful consideration of the refinancing opportunity in setting regulated Weighted Average Cost of Capital (WACC) to balance between potential excessive profit and financeability, and it may be desirable to claw back at least some proportion of excess returns.

Example: The UK model of independent regulation to set prices

The UK has a 30 year tradition of independent regulation of networks. It is envisaged that the regulatory regime for CCS will follow this type of model. The regulator may be the existing regulator for electrcity and gas networks (Ofgem) or some new institution. The regulator will operate and exercise its functions within a regulatory framework defined by law, including a duty to ensure that an efficient transport and storage company (T&SCo) can finance its operation and to support delivery of the Government's objectives for CCS deployment.

Under this model T&S investors will receive a long-term revenue stream, providing investors with revenue and cash flow predictability (subject to volume uncertainties). Revenue will be paid by T&S users (capture projects). These will each have a support contract from government, likely a Contract for Difference or similar, providing further confidence in the reliability of the revenue stream, because it has an element of government backing.

Allowed revenues will be determined based on efficient and economic costs incurred and consideration of events within T&SCo reasonable control. T&SCo investors will earn returns that are commensurate with the risks that they bear, with an opportunity to earn additional returns when outperforming targets. T&SCo investors will be incentivised to maintain the availability of the T&S network and attract new users to connect to the T&S network, including imports from elsewhere in Europe.

Price controls will be set every few years. These will specify the framework of rules that determine T&SCo's activities, the level of service expected and the allowed efficient and economic costs.

4 Cross chain risks

There will also be cross-chain risks where the actions of one party can affect the other. These will need to be allocated by contract. These will be the most material for a capture project, as it is exposed to the network for the entirety of its capture, whereas a network will typically serve multiple capture projects so will be less exposed to any individual project. Risks include:

- Either the network, storage facility or capture project is delayed
- Either the network, storage facility or capture project experiences downtime
- Industrial production is reduced, leading to lower capture volumes, and thus lower volumes transported.
- Composition of captured CO_2, including impurities, falls outside the range permitted by the network.

In some cases, risks may need to be absorbed by the state. For example, it may be necessary for states to absorb risks around the long term integrity of storage and potential for leaks.

For early projects there will be a need to co-ordinate development, probably through co-ordinated stage-gate decision points. This is likely to be led by the T&S company.

5 Closing Remarks

This brief review of options for ownership and regulation makes it clear that there is no single model that will be universally adopted. Instead there is a range of approaches that can be selected and adapted to the needs of each jurisdiction. This range of possibilities can enable CCS to paly the role it needs to in decarbonising economies.