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ARUP

Pinsent Masons

CO2 Transportation and Storage Business Models

Summary Report

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Contents

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1.0 Executive Summary

This study focused on developing CO_2 transport and storage infrastructure business model options as a part-CCS chain activity

The CO_2 T&S infrastructure business is not yet commercial

CO_2 T&S infrastructure differs from other infrastructure in that; it includes subsurface risk and an extended project duration

Key challenges to the development of T&S infrastructure include: CO_2 supply certainty, cross-chain performance, leakage liability and allocation of risk

Whilst there are a wide range of potential business models for T&S infrastructure development, a sub-set of 11 has been developed which includes viable options of; full public ownership, mainly public ownership, a public private entity and a fully private venture.

Further development and analysis of the short-listed business models is required in the next phase

Scope of activity

This study explored potential business models for the Transport and Storage of CO_2 (T&S) as part of a full chain Carbon Capture and Storage (CCS) project. T&S infrastructure is defined to include onshore pipeline, coastal terminals, offshore pipelines, shipping facilities, offshore facilities, wells and storage reservoirs.

The objective was to identify a small number of potentially viable business models which could be assessed in more detail in a subsequent phase of work.

Previous work in related areas was reviewed, whilst recognising that much of that work in CCS related to full chain business models or was not reflective of current UK CCS circumstances. Recognising learning from other projects and studies. this work focuses on the T&S as a part chain business model, separating T&S from Capture. Business model case studies from non-CCS infrastructure projects were developed and summarised on a Business Model Canvas developed for the project, along with case studies from other global CCS projects. Challenges which constrain the development of T&S were summarised from this material and other input.

A Business Model Options Framework has been developed, to reflect the key components of a T&S business model (ownership, capital funding, revenue model, risk appetite and investor driver) and the choices available within each. This provided the basis for developing a Long List of business model options and subsequently a sub-set list of those most viable for this stage of the sector.

T&S Infrastructure Business Model Canvasses have been developed for 4 of the models on the sub-set list, to better detail each.

Finally, a methodology and scope is proposed to progress this material by developing further detail of the model options identified, in a phase 2 study.

Transport & Storage Challenges

The study identifies that T&S infrastructure investment is materially different to infrastructure investments in other sectors. Key differences include having subsurface risk, an extended project duration (appraisal to post closure monitoring), alignment with CO_2 supply and being in a new market. Moreover, infrastructure business models are distinct from other businesses in several important ways, some of which have not previously been considered within the context of CO_2 activities.

Developing T&S infrastructure is not yet a commercial activity, due to the lack of business model and functioning market. Key challenges to the development of T&S infrastructure include:

1. CO_2 supply/stranded asset;
2. Cross-chain performance;
3. Uncapped leakage liability;
4. Allocation of risk;
5. Change of law; and
6. Policy uncertainty

Items 1-4 are factors that can be addressed within the T&S business model as part of this study. Factors 5 & 6 are considered broader policy matters, which are beyond the scope of the T&S business model. Items 1-4 were further expanded in specific challenges (below), which impact the 5 areas of Cost, Revenue, Financing, Schedule and Liabilities;

- Current absence of a functioning revenue model or commercial incentive for CO_2 transportation and storage business
- Private sector inability to accept long term, unknown and uncapped liabilities for leakage of CO_2
- CO_2 supply volume uncertainty due to potentially unknown timing and performance of CO_2 capture project
- Cross-chain performance risk – how can the CO_2 storage operator guarantee performance of the storage system to the CO_2 emitter and how can the operator manage uncertainty of CO_2 supply volumes
- Aligning timing of project investment to synchronise with CO_2 capture project progress and start of commercial operations
- Imbalance between the size of investment and the Balance Sheet strength of the T&S contractor
- Current absence of customers for a CO_2 transportation and storage service
- Need for Government to balance public/consumer needs with those of private sector when entering into risk sharing arrangements for long term, uncapped liabilities of unknown magnitude for leakage of CO_2
- Uncertainty surrounding acceptance criteria (and their achievability) of the Regulator for handover of a closed store

- Lack of appreciation regarding the complexities of providing sufficient assurance of a sufficient quantity of CO_2 storage capacity for emissions from multiple large-scale sources
- Uncertainty & ambiguity around what is required for Financial Security under the Storage Permit
- Defining & meeting CO_2 specification, impact of multiple suppliers of CO_2, need for an allocation and attribution type agreement

<u>Business Model options</u>

The case studies of other infrastructure projects in the UK and elsewhere, including 3 international CCS projects, were contributed to the development of T&S infrastructure models. Whilst many of the case studies have elements which are relevant to the T&S business model, there is no one model which is directly analogous. The 3 CCS case studies are very much oil and gas sector projects, driven by commercial aspects of oil and gas production. This makes them very different from the 'waste' disposal model required for CCS.

A business model options framework was developed, with expert input. This identifies five key components of the business model; ownership, capital funding, revenue model, risk appetite and investor driver. For each component, there are a range of choices. This framework is shown in Figure 1-1

By using the business model options framework, it is possible to create a Long List by combining the choices for each of the components in multiple permutations. This resulted in a long list of 324 potential business model varieties. By screening out the options which are considered not feasible, either due to incompatibility or being judged to be implausible, a partially qualified long list of options was developed

Grouping the partially qualified long list models based on suitability to market maturity, enabled identification of those business models which were suited to the current early stage of CCS market maturity and had potential to evolve with the market.

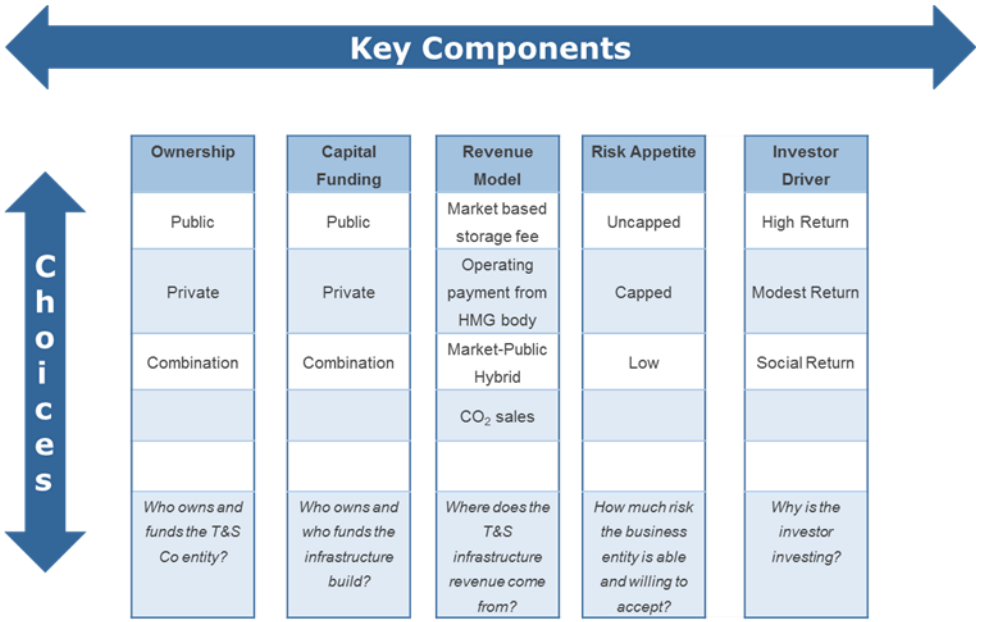

Figure 1-1 Business model options framework

Using this analysis, a short list of 11 potential business models for T&S infrastructure development has been developed. From these a representative four have been more fully articulated on Business Model Canvases. The 4 are: full public ownership, mainly public ownership, a public private entity and a fully private venture.

<u>Interventions</u>

A number of more general market interventions are proposed to support the emergence and development of CCS projects and specifically to enable development of T&S infrastructure in the four areas of;

- Adjusting T&S legislation
- Making progress on T&S
- Building momentum
- Future funding

Looking Ahead

The next phase of activity in developing the T&S business models needs to address: further details of the four models outlined and the wider sub-set list; quantification of the magnitude, type and likelihood of key risks, further detail on risk allocation including management; the cost and attractiveness of funding, using a range of T&S infrastructure case scenarios. This will enable an effective analysis of the value proposition for each of the models and the way in which the T&S business model interacts with other policy objectives and activities.

2.0 Introduction

2.1 Background to the Study

Evidence and experience from previous UK projects (e.g. the Demo1 and CCS Commercialisation Programme) has shown that the commercial risks which arise from T&S infrastructure make a significant contribution to the overall risk of a CCS project. The expected financial impact of these commercial risks occurring is additional to the project cost and thus act to increase cost and compound the challenges faced by a full-chain CCS project in reaching a financial investment decision (FID). Examples of these risks include: funding and revenue risks, risks from variable offshore operating costs, CO_{2}- supply risks, CO_2 storage liability risks and the unknown (and unknowable) magnitude of these liabilities. Evidence suggests that separate funding and delivery of CO_2 capture and CO_2 transport and storage infrastructure, CCS could be mode more cost effective (PAG CCS, 2016), (Gross, 2016).

The Department of Business, Energy & Industrial Strategy ("BEIS") engaged Pale Blue Dot Energy (PBD) to take a step back from previous approaches and to document the range of business models which could potentially be used to finance, deliver and operate CO_2 T&S infrastructure in the UK. PBD was also asked to identify a subset of the models and outline a methodology with which a follow-on study could test their suitability and likely performance in greater depth.

The objectives of the study were to:

- Document the challenges that can increase the risk and cost of delivering and operating CO_2 T&S infrastructure;
- Define the range of potential delivery and operating business models for CO_2 T&S infrastructure;
- Consider how those models can differently address the challenges identified;
- Present case studies to illustrate different models on other CCS projects and other infrastructure projects;
- Identify which business models should be subject to further, more detailed analyses to test their suitability for UK use, and to propose an appropriate methodology to deliver a Phase 2 study

The range of possible business models were characterised and assessed on their potential to address existing barriers to CCS deployment. Recommendations on the scope of further work to assess the potential of the proposed business models to enable more cost-effective CO_2 T&S infrastructure are provided.

2.2 CO_2 Transportation and Storage Infrastructure

CO_2 T&S infrastructure is illustrated in Figure 2-1 and is likely to include one or more of the following 7 main elements. All of these elements of infrastructure are tried and tested in multiple locations around the world.

a) **Onshore pipeline:** The purpose of onshore CO_2 transport is to move CO_2 to a coastal terminal for compression and transport offshore to geological storage. There are 50 individual CO_2 pipelines with a combined length of 7200km in the USA and many of these have been operating for decades (US Department of Energy, 2015)

b) **Coastal terminal** at which CO_2 is received from onshore transport infrastructure and compressed and treated for transport and geological storage offshore. There is a coastal terminal for handling the import and export of CO_2 at Teesport, UK operated by Praxair Inc.

c) **Offshore pipeline** to transport dense phase CO_2 from the coastal terminal to the offshore injection site. The Snohvit CO_2 storage project includes a 153km offshore pipeline running from Melkoya in Northern Norway to the Snohvit field in the Barents Sea. The pipeline has been operating since 2008.

d) **Offshore facilities** at the injection location which could be provided by a platform (with facilities above water) or a subsea template (with equipment below water). CO_2 has been injected offshore at the Sleipner platform since 1996 and at the Snovit subsea site since 2008.

e) **Injection wells** will be drilled from the injection site (either platform or subsea) into the storage reservoir to inject the CO_2 into the optimum location for long term storage. Multiple wells will usually be required at each injection site. Examples include those mentioned above and the very many CO_2 injection wells used in enhanced oil operations in North America.

f) **Subsurface CO_2** storage reservoir which is either a saline aquifer or a depleted gas field. It is also possible to permanently store CO_2 in an oil field as part of an enhanced oil recovery (EOR) project. Unlike other parts of the CO_2 T&S infrastructure, the reservoir is a natural feature and cannot be 'constructed' to suit requirements. Consequently, the effective selection, appraisal and design of a CO_2 storage site is critical to the delivery of a successful CCS project. There are several examples of CO_2 being sequestered at scale in subsurface formations including: the Sleipner field, the Snohvit field and the Radway aquifer (Quest project).

g) **CO_2 shipping** and associated loading and unloading facilities to move CO_2 between sources and sinks, especially internationally, when they are not connected by a CO_2 pipeline. The transport of CO_2 by ship is analogous to transporting LNG and has been operating at commercial scale for many years by a number of companies including Anthony Veder, Maersk, Praxair, Yara.

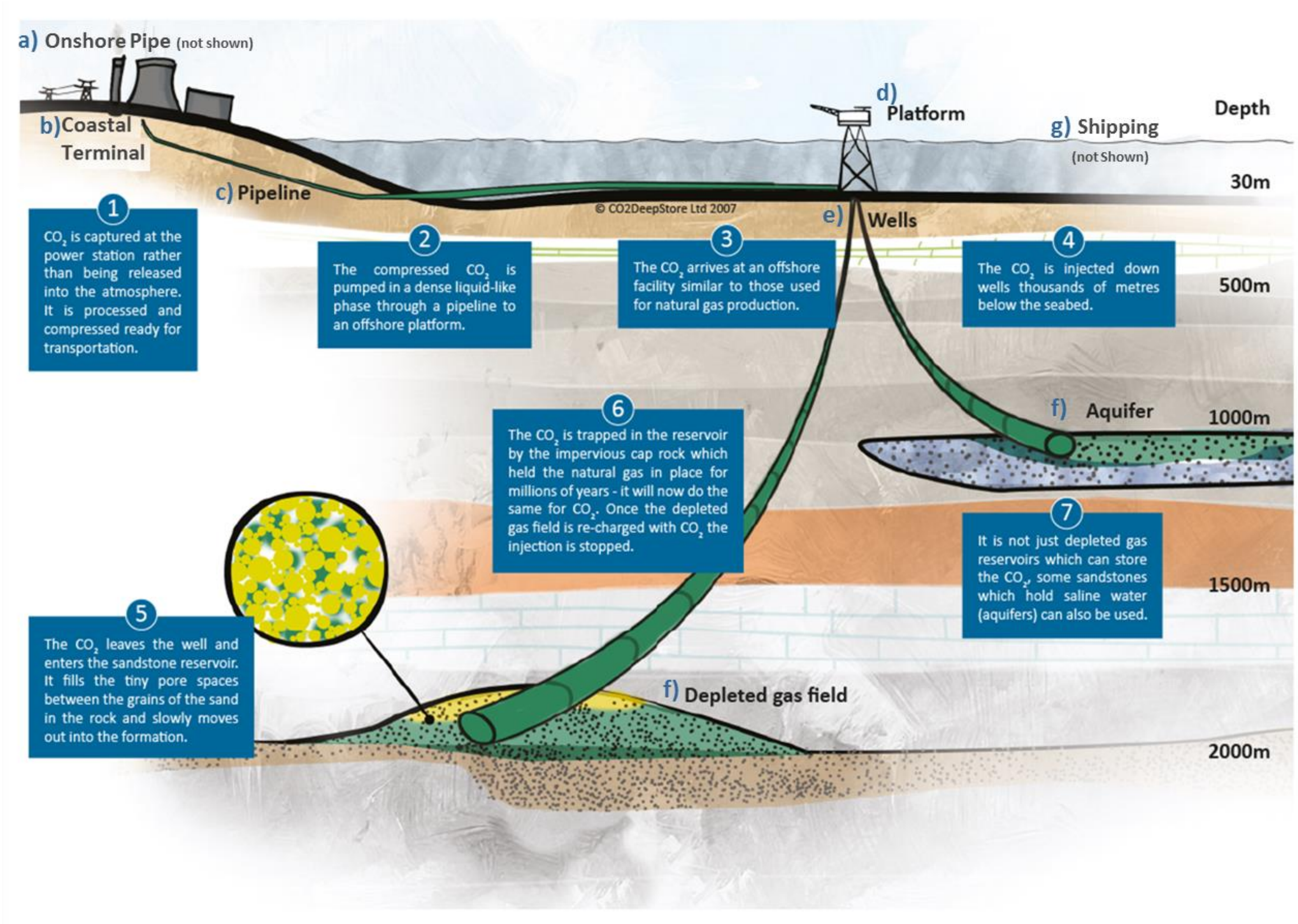

Figure 2-1Transportation and Storage infrastructure business model limits

2.3 Business Models

The term “Business Model” was defined within the ITT as:

> *“the structures used to develop, operate and finance CO_2 infrastructure, including ownership, financing and risk/revenue flow arrangements*.”

Expanding the initial definition, a business model is defined more generally as:

> *“the organisation’s chosen system of inputs, business activities, outputs and outcomes that aims to create value over the short, medium and long term*.” (Bryson, et al., 2014).

However, infrastructure businesses differ from other sorts of businesses models in that they are more akin to systems involving multiple interacting business models. This important fact leads to the following definition of business model for infrastructure businesses:

> *“The system of physical artefacts, agents, inputs, activities and outcomes that aim to create, deliver and capture economic, social and environmental values over the whole infrastructure life cycle.”* (Bryson, et al., 2014).

For many infrastructure systems, profit is not always the main driver for an organisation and these models differ from other businesses in several important ways such as:

a) Complex value metrics, often including indirect components that are difficult to quantify in monetary terms – such as CO_2 sequestration;
b) Longer life-cycles;
c) Long term legacy (and lock in);
d) Necessity of the service being provided;
e) Public sector involvement (financing, regulation, underwriting risks etc.);
f) They often create natural monopolies and exclusivity;
g) Capital intensive financial profile;
h) Involve multiple stakeholders & agents - different agents will seek to maximise different values at various phases in lifecycle; and
i) They are often run for the broader societal benefit.

3.0 Commercial Challenges of CCS

3.1 Key risks

CO_2 storage infrastructure has unique project lifetime attributes when compared with capture and transport. This includes the need for potentially lengthy and costly appraisal activity prior to final investment decision (FID) for the scheme, and the need for post-injection monitoring of the store after CO_2 injection (and therefore income) has ceased. Figure 3-1 is adapted from earlier work (Zero Emissions Platform, 2014), and shows the relative timeline and expenditure for CO_2 capture, transport and storage, highlighting the far greater duration of the storage project lifetime.

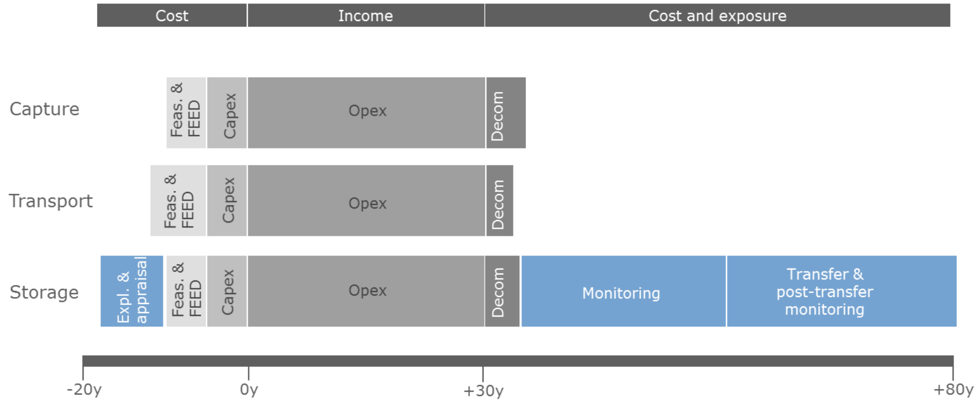

Figure 3-1 Cash flow timelines for CO_2 capture, transport and storage

Transport and storage activities have very different technical and economic characteristics to capture activities. The likely operators of capture plant may also have markedly different, risk appetite and balance sheet capabilities to likely CO_2 transport and storage operators.

These factors give rise to specific issues which must be addressed in the development of CO_2 T&S business models, including consideration of the commercial model to support early and long-term costs and revenue flow, that achieves best value for money (VfM). In a report to the Committee on Climate Change (CCC) Poyry (2016) suggest that to reduce costs, the Government could adopt a part-chain approach, separating the business models for capture activity from T&S activity, with Government absorbing certain risks via a "part-chain" approach; such an approach would require a part-chain T&S infrastructure business model.

Review of previous studies has identified six common areas of risk which hinder development of CO_2 T&S infrastructure[1].

1. Uncertainty of CO_2 supply;
2. Uncapped CO_2 leakage liability;
3. Cross-chain performance;
4. Risk appetite incompatibility;
5. Change of law; and

For the purposes of this report, items 1-4 are considered to be risks that could be addressed by the choice of T&S business model, whilst items 5 & 6 are assumed to be addressed outside the T&S business model and as such are outside the scope of this report.

6. Policy uncertainty

Uncertainty of CO_2 supply This can also be referred to as "volume risk" or "stranded asset risk". The current absence of a CO_2 supply for storage in the UK means there is no clear service revenue for initial T&S operators. The risk that T&S infrastructure would be built, with only some of the capacity being used and resulting in a stranded asset, deters speculative investment and development. This becomes more pronounced for larger capacity infrastructure schemes (which offer greater potential economies of scale). This area of risk can become a circular problem in that the investment decisions regarding T&S infrastructure assets and the generation and capture assets are concurrent and interdependent. It is an aspect of cross-chain risk.

Uncapped CO_2 leakage liabilities. This risk occurs because currently there is no cap on leakage liabilities under the CCS Directive. Any leakage from the store at any future point in time would require repayment of EUAs[2], the future price of which is not known. Despite the licencing process and permit conditions meaning leakage can be expected to be very unlikely, the associated liability is potentially large. The risk is characterised as low likelihood but large impact and is consequently difficult to manage. The lifetime of the store and duration of the post-closure monitoring required before this liability transfers to Government are unfixed. Being uncapped and of unfixed duration, this risk is currently uninsurable and creates difficulties in making projects financeable.

Cross-chain performance. Sometimes referred to as "cross-chain funding risk" or "revenue flow risk", this is the risk that during operation, the revenue for a CO_2 T&S infrastructure provider could be reduced by interruptions to the CO_2 supply and that the T&S operator would be obliged to guarantee levels of performance to the capture project(s) since capture project revenue is also dependent upon the availability of T&S services. Given the high level of interaction between the CO_2 supplier and the CO_2 storer (during planning, development, construction and operation) cross-chain risk is clearly a multi-faceted issue.

Risk allocation. Early CCS developers may have the opportunity to agree risk sharing arrangements with Government. The ability to allocate risk will be affected by risk appetite and risk management capability of the developer, which in turn will be driven by the risk appetite, risk management capability and rates of return required by individual consortium members. This presents a risk that risk-share terms sought by the developer and government are incompatible.

Change in law. Whilst not unique to CCS, a change in law would potentially expose CCS projects to greater cost or reduced revenue. Whilst different business models may address potential change in law in different ways, this risk is not considered likely to initially drive the choice of business model, and as such change in law risk is not addressed further in this study.

Policy uncertainty. Whilst not unique to CCS, the industry considers policy uncertainty in connection with CCS is a key risk. This was exacerbated by Government's November 2015 decision to withdraw capital support to the CCS Commercialisation Competition, which was interpreted by industry as evidence that Government no longer viewed CCS as core to the UKs decarbonisation

European Union Allowance certificates are a traded commodity for offsetting CO_2 emissions in the European Emissions Trading Scheme.

programme (Capture Power Ltd., 2016). However, whilst a clear and consistent CCS policy is required to enable CCS, this risk is not considered to be affected by the nature of the business model and is therefore not addressed further in this study.

3.2 Key lessons learned

Full Chain vs Part Chain approach

A full-chain project compounds the risks of each element in the chain and thus increases likelihood and consequence of cross-chain default (Dixon & Mitchell, 2016)The UK CCS competition illustrated that financing schemes on the basis of full chain funding can be difficult (National Audit Office, 2017; Capture Power Ltd., 2016), with the technical complexity of the project, risk allocation and the developers' choice of business model also relevant in this regard. It can be challenging to raise equity and debt finance for a full chain project (Capture Power Ltd., 2016, (Dixon & Mitchell, 2016) (Gross, 2016), whilst the immaturity of the CCS industry also means it can be challenging for significant shareholder capital to be placed at risk.

This study assumes that CO_2 transport and storage infrastructure would be delivered and operated independently from CO_2 capture. However, whilst this assumption is helpful in focusing on the transport and storage issues it doe not mean that the cross chain risks have been eliminated. The study examines alternative business models for delivering and operating transport and storage infrastructure.

Risk allocation approach

The primary challenge of allocating risk between private sector developers and Government is identifying who is best placed to accept the risk and thereby provide improved value for money. Being best placed to accept risk includes both the capacity to take on risk and the capacity to manage it. Achieving a common view of all elements of a specific risk, (i.e. the trigger, the likelihood of it occurring, the impact on financial, environmental and reputational issues) as well as potential mitigation options is a precursor to being able to agree how to allocate the elements of risk between the various parties.

The CCS Competition made use of a Baseline Risk Allocation Matrix (BRAM) which differentiated between "business-as-usual" risks and CCS specific risks. In line with wider energy policy, the developers were expected to accept business-as-usual construction and operation risks; government proposed to share certain CCS specific risks which might otherwise be detrimental to a scheme's economic viability. Little material regarding the discussions about risk allocation during the competition process has been published and this acts to compound uncertainty for project developers.

Evidence suggests that the costs of early CCS may be reduced (and value for money increased) if developers' exposure to certain CCS specific risks is reduced or removed (PAG CCS, 2016) and (National Audit Office, 2017). Lessons learned through the CCS Competition showed that a developer's choice of business model affected its capacity to accept and manage risk (National Audit Office, 2017). The choice of business model is therefore material when examining alternative risk allocation arrangements, and which risks may need to be shared, pursuant of cost reductions.

3.3 CO_2 T&S Business Model Challenges

Challenges relating to the transportation and storage of CO_2 have been identified, informed by a review of literature and discussion at an expert workshop attended by representatives from a range of sectors, including from the petroleum and financial sectors. This study focusses on those considered by the workshop to be most relevant to the choice of CO_2 T&S business model.

Table 3-1 identifies the challenges facing the business model and provides a qualitative assessment of the likely impact on;

- **Cost**. The likely increase in capital investment or operating expense that the challenge could cause.
- **Revenue**. The likely reduction in revenue that the challenge could cause.
- **Financing**. The degree to which the challenge makes financing the CO_2 T&S infrastructure more difficult.
- **Schedule**. The potential delay that the challenge could cause to an investment or T&S operation.
- **Liabilities**. The degree to which the challenge increases the liabilities that the T&S developer must manage.

A traffic light system is used in Table 3-1 to illustrate the degree of impact.

- High
- Medium
- Low

Challenges inhibiting T&S Business Models specifically		Cost	Revenue	Financing	Schedule	Liabilities
1	Absence of a revenue model or commercial incentive for CO_2 transportation and storage business	●	●	●	●	
2	Private sector difficulty accepting long term, uncapped liabilities of unknown magnitude for leakage of CO_2 whether as an individual company or a consortium, the sector is immature, and no insurance market yet exists.	●		●		●
3	CO_2 supply volume uncertainty due to potentially unknown timing and performance of CO_2 capture project		●	●		●
4	Cross-chain performance risk – how can the CO_2 storage operator guarantee performance of the storage system to the CO_2 emitter and how can the operator manage uncertainty of CO_2 supply volumes			●		●
5	Aligning timing of project investment in T&S development activity, to synchronise with CO_2 capture project progress and start of commercial operations		●	●		●
6	Potential imbalance between the size of investment required and the Balance Sheet strength of the T&S developer			●		●
7	Current absence of customers for a CO_2 transportation and storage service		●	●		
8	Need for Government to balance public/consumer needs with those of private sector when entering into risk sharing arrangements for long term, uncapped liabilities of unknown magnitude for leakage of CO_2	●				
9	Uncertainty of level and duration of monitoring (and achievability acceptance criteria) required to allow handover of a closed store to the Competent Authority.	●		●	●	
10	Commercial complexities of multiple large-scale capture schemes sharing T&S facilities with sufficient assurance on availability of capacity	●		●		●
11	Uncertainty & ambiguity around what is required for Financial Security under the Storage Permit application	●				
12	Defining & meeting CO_2 specification and need for an allocation and attribution type agreement when servicing multiple suppliers of CO_2.	●				

Table 3-1 Challenges and Impacts

4.0 Case Studies

13 infrastructure case studies were assessed, with input from Pinsent Masons and Arup. These were selected to represent a range of infrastructure projects from across a range of sectors, locations and regulatory environments. Each is summarised on a one-page business model canvas template, designed to effectively communicate key aspects of each. Three further case studies of CCS schemes were also assessed and summarised on the same business model canvas. A summary of all 16 case studies and their relevance to the current study is provided in Table 4-1, with the canvases included in Appendix 10.1.

The infrastructure case studies assessed and summarised provide a view of the wide range of infrastructure business model options available and their applications. The CCS case studies provide additional context for CCS specific infrastructure projects. Each infrastructure, by its nature, is unique. The projects take place in different countries, with different regulatory arrangements and in different sectors. Whilst there is no direct analogy for the UK CCS T&S infrastructure business model, there are themes which can be drawn from these case studies for use in this project.

The key themes emerging from this review that are of relevance to business models for CO_2 transportation and storage infrastructure are;

- A wide variety of revenue models are available, ranging from RAB-style arrangements to fully commercial performance related fees.
- Evidence of progression from public to private ownership.
- Increasing levels of performance assurance are associated with higher fees
- All examples have arrangements which last for at least 20 years and in one case, 125 years.
- Aspects of geological risk are included within the revenue and obligations aspects of natural gas storage.
- Successful CCS projects have utilised a government grant and operating fee (or credit) arrangement.
- In some instances, government provides significant underwriting of the investment to provide a contingent support package which seeks to mitigate some risks, transferring liability to the taxpayer if those risks materialise (e.g. Thames Tideway and risks such as cost overruns above a certain cap or the impact of certain political events make it unable to access debt or capital markets (National Audit Office, 2017))

Whilst none of the models provide a direct analogy for the business model for CO_2 T&S, there are aspects from some of the models which influence thinking in this study. These aspects are noted in the case study summary provided in Table 4-1.

No.	Case study	Country	Sector	Public Private involvement	Revenue & Commercial aspects	Notable similarities to T&S business model	Key differences from T&S bus model	Relevance to this study
1	Bergermeer Gas Storage	Netherlands	Oil & Gas	Public private equity joint venture	Storage fee structure	Subsurface storage with wells Multiple customers	Commercial market	Project of strategic national significance that required or benefitted from public sector involvement
2	London Array Offshore Transmission Owners (OFTO)	UK	Electrical Grid	Private equity	Regulated return	Not applicable	Competitive market	Regulated asset model
3	Thames Tideway	UK	Waste water	Private JV with government support package	Regulated return from Thames Water consumers	Novel model required Societal benefit	A recognised need for the service exists	Novel model with government support to enable private finance Regulated asset model
4	Rehden Gas Storage	Germany	Oil & Gas	Private equity	Storage fee structure	Subsurface storage with wells Multiple customers	Commercial market	Illustrative of the commercial options that might become available as the CO_2 T&S sector matures
5	NEMO Interconnector	UK/Belgium	Electrical Grid	Two countries Public private	Capacity contracts with regulated cap and floor	Multiple customers	Commercial market	Variation on regulated asset model
6	Swedegas gas transmission pipelines	Sweden	Electrical Grid	Private (privatised)	Regulated return	Multiple customers	Commercial market	Regulated asset model

7	OFTO Regime	UK	Electrical Grid	Private equity	Regulated return	Not applicable	Competitive market	Regulated asset model
8	Military Flight Training System	UK	Defence	Public Private partnership	Fee structure for services	Not applicable	Competitive market	Partnership arrangements
9	Greater Manchester Waste	UK	Waste	Public Private partnership	Fee structure for services	Waste management activity	Commercial market	Fee structure and partnership arrangements
10	Gas Peaking Plant (name confidential)	UK	Electrical power	Private	Fees bid to National Grid in the Capacity market	Not applicable	Competitive market	Limited direct relevance. Example of another commercial model
11	Nuclear Decommissioning Authority	UK	Nuclear	Public body (executive non-departmental)	Publicly funded	Waste management activity Societal benefit	Agency does not itself own infrastructure	Potential model for government agency to oversee CCS
12	Varmevarden District Heating	Sweden	Heat	Private	Service/heating fees	Not applicable	Commercial market	Limited direct relevance. Example of another commercial model
13	Nippon Vopak oil storage	Japan	Oil & Gas	Private	Service/storage fees	Not applicable	Commercial market	Limited direct relevance. Example of another commercial model
14	Weyburn CCS CO_2 T&S	Canada	Oil & Gas (CCS)	Private	EOR	CO_2 T&S	EOR is a commercial market which is different to CO_2 storage	Highlights the commercial aspects which are addressed at Weyburn by EOR need to be addressed in the T&S business model
15	Quest CCS	Canada	Oil & Gas (CCS)	Private with grant contribution	T&S obligation to develop heavy oil Returns capped to achieve a zero	CCS	Full chain CCS No 3rd party customers	Saline aquifer storage JV carries performance and some leakage risk Gov takes over store after closure

					net present value using a carbon credit arrangement Possible future sale of CO_2 to 3rd parties for EOR			
16	Sleipner CCS	Norway	Oil & Gas (CCS)	Private JV (Statoil part state owned)	Agreed as part of the petroleum licence CO_2 tax in Norway incentivises storage	Not applicable	No 3rd party customers	Saline aquifer storage Long track record JV carries performance and some leakage risk (details unclear)

Table 4-1 Case Study summary table

5.0 Business Models Options Analysis

5.1 Government Involvement

The scale of government intervention for CCS will depend upon the model ultimately preferred by government. It may also be expected that the scale and nature of Government involvement will change over time, as the CCS market matures.

Some funding for both pre-FID (e.g. FEED costs) and post-FID activity will probably be required to encourage investment by the private sector in CCS infrastructure (Deloitte, 2016; Dixon & Mitchell, 2016). Pre-FID funding could be either public sector investment to a company in the private sector for storage site characterisation, or a public-sector entity completing the characterisation work. Post-FID, funding options could include a public-sector CO_2 storage operator or a private sector CO_2 storage operator, with capped liability and back-stop insurance provided by the public sector.

In September 2016 a business model outline was proposed (PAG CCS, 2016) whereby Government would be involved through a UK CCS Development Company (CCSDC). The proposed CCSDC would take the long-term CO_2 storage liability that the private sector has not been able to take to date, and specifically this would reside in the Transport and Storage Company (T&SCo), a subsidiary of CCSDC. This model represents one way in which the "part chain" approach previously advocated by the CCC could be implemented in the UK. Further business model development, would usefully be cognisant of the current difficulty for private sector to accept certain types and levels of CCS specific risks, the likelihood that private sector full-chain sponsors will be atypical, and the potential benefit of maximising the competition between private sector players in the elements of the CCS chain in which they excel. The case studies in this report illustrate that targeted government interventions can enable suitable business models to successfully develop and operate challenging infrastructure projects. Further consideration of the potential interface(s) between Government and a chosen T&S business model entity is required to more fully define understand potential performance.

5.2 Financing models

Deloitte (2016) considered financing models for full chain projects and suggested the following options (for more information about each of these, see the Deloitte report):

- **Regulated Asset Base (RAB).** Investment levels and return are controlled by a Regulator;
- **PFI/PPP**. Potentially a combined ownership model, typically with revenue via an operating payment contingent upon performance;
- **CfD.** Emitter is paid a premium for clean electricity via a CfD, enabling costs of T&S to be afforded;
- **Cost Plus**. Open book, with an agreed return on investment and profit margin;
- **Waste Sector**. Payment of a fee per unit of CO_2 injected and stored; and
- **Hybrid**. A combination or evolution of one or more of the above models.

For the CCS Competition, financing models were different for the two projects. For the Peterhead CCS Project, the financing was part grant and part equity funding from Shell, with the likelihood of other investors in the Joint Venture noted as an important consideration (Shell UK Ltd., 2016). The White Rose CCS Project had a project finance structure involving 3 elements: base and contingent (i.e. in the event that certain risks materialised) equity from the White Rose Consortium (Capture Power Ltd., 2016), a grant from the UK government and debt (both medium and long term).

5.3 CO_2 T&S Business Model Concepts

The review of issues relating to CO_2 T&S infrastructure outlined in Sections 3.0 and 4.0 identified a significant number of detailed attributes that are relevant to the design of business models. Table 5-1 groups these attributes into four theme areas that are subsequently combined with insights from the discussion on revenue models to form the five main options used in the framework analysis discussed later in this Section (see Section 11.0 for list of references). Previous work which only considered the full chain CCS has not been included.

Theme	Example options for business model component
Risk arrangements	• T&S leakage risks shared by Government • Government owns storage • Fully integrated Joint Venture company
Revenue Models	• Grant • RAB -style • PPP/PFI-style • CO2 sales for EOR • CO2 capacity booking fee and throughput fee as part of a CCS project
Private Sector Involvement	• Market led disaggregated CCS chain • Liberalised market
Public Sector Involvement	• Contractor to the State* • Market Maker* • Government owned

Table 5-1 Summary of T&S business models from previous studies

* (Zero Emissions Platform, 2014) and (PAG CCS, 2016) discuss how different business models could be effective for different phases for CCS development. For example, in the ZEP models, the Contractor to the State is suggested for when market failure means that CCS needs state support. The Market Maker model is a public funded T&S entity that purchases CO_2 from power and/or industrial facilities & is considered helpful for growing storage volumes in the pre-commercial stage, and Liberalised Market for a more mature market, without state direction.

Much of the published previous work is around the numerous sorts of revenue models that could potentially be applied to a T&S infrastructure business. Consequently, this report draws out the highlights from that work in the following section and recommends future studies to explore the potential risk arrangements, and various types of involvement for public and private sector organisations.

5.4 Revenue models

Revenue models range from a storage fee paid to the T&S operator, through to the T&S operator paying for the CO_2 to use for CO_2 enhanced oil recovery (CO_2-EOR), where the revenue stream comes from selling the produced oil. To date, only very few CCS projects without CO_2-EOR have been commercially viable without government intervention (Global CCS Institute, 2015).

In the White Rose Project, the T&S revenue model was a fixed capacity fee, with CPL paying NGC under a Transport and Services Agreement (Capture Power Ltd., 2016).

Societe Generale (2015) suggested a hybrid model (which Poyry (2017) developed further), with a two-part payment based on both a capacity fee for building and maintaining the transportation and storage infrastructure, and also a usage fee, per tonne of CO_2 transported and stored. Penalties would be sought for unavailability of the infrastructure. The hybrid model considered CO_2 from both power and industry. The report drew the important distinction that for industry the nature of globally traded products precludes the additional costs of CCS being passed on to the customer, whereas for power the costs can be passed on to the consumer via a CfD or similar.

To reflect the immaturity of the CCS industry, ZEP (2014) suggests that the rate of return for early CO_2 T&S projects will likely be 15-20% post tax, which may reduce to 6-10% in a mature industry.

T&S infrastructure costs are best considered in terms of cost per tonne of CO_2 stored (rather than cost per MWh), to ensure that non-power sources of carbon dioxide can be included (Gross, 2016).

A wide range of potential revenue models could be applied to CO_2 T&S infrastructure, the main ones are summarised in Table 5-2 which also identifies their respective benefits and drawbacks.

Revenue model	Benefits	Drawbacks
PPP/ PFI *Potentially a combined ownership model, typically with revenue via an operating payment contingent upon performance*	• Well-known and understood by government, contractors and lenders. • Track record of having been modified to deal with specific risks • Model set up for construction and operations phases • Flexibility in funding arrangements (departmental vs local authority)	• May be challenging to include range of circumstances associated with CO_2 storage in the contract as model developed for relatively low risk sectors using well-known technologies • Expansion of contract to include additional CO_2 sources is challenging • Change of law provisions designed for industries where law unlikely to change. Challenges with CO_2 storage, with some regulations not yet fully tested in practise (for consideration in future work) • No funding for pre-FID activity in the structure
Waste sector type contract *Payment of a fee per unit of CO_2 injected and stored*	• Well-known and understood model • Accommodates greater construction and technology risk than PFI • An arrangement is established where funding from local authority budgets can be supported by PFI credits	CO_2 storage less similar to waste sector due to: • Immaturity of regulatory structure means lower certainty of CO_2 throughput (vs waste sector and with long term understanding of waste flows) • Current lack of third party revenue potential for CO_2 storage • Difficulty in financing commercial and industrial waste projects due to dependence on short term contracts. This may have implications for financing CO_2 T&S activity. • No funding for pre-FID activity in the structure
Cost-plus *Open book, with an agreed return on investment and profit*	• Simple with payment to T&S entity • Structure works for early stage of CO_2 storage, where industry unlikely to have price competition due to there only being a few players. As the market matures more entities will be involved and act to increase the economic rent	• May not fit with CO_2 storage as government has indicated that it sees as an industry for the private sector • Cost-plus structures do not generally fit for private sector customers • No funding for pre-FID activity in the structure
Regulated asset base (RAB) *Investment levels and return are controlled by a Regulator*	• Lower cost of finance compared to some other structures • Normally used in more mature industries, with existing operating business and less construction but has been adapted for the Thames Tideway Tunnel • Mechanism to review and account for any changes in costs, investments etc. Can also have exceptional review if events have large impact on economics.	• Compared to network utility businesses which this model was designed for, CO_2 storage has greater construction and geological risk • As an immature industry, CO_2 T&S will have far fewer customers than most network utilities for which this model was designed for • Would likely need additional support mechanisms in addition to usual RAB arrangements due to greater uncertainty and risk of CO_2 storage • No funding for pre-FID activity in the structure
Contract for difference (CfD) *Emitter is funded by a CfD*	• Since its introduction in 2015 this structure is known in the power market • An existing mechanism exists for recovery of the subsidy cost from consumers (the supplier obligation)	• No existing market basis for T&S Entity to use CfD structure due to lacking market for CO_2 based CfD • The power CfD is a relatively new mechanism and so still to be established in closed project finance transaction for CCS i.e. that

and pays the storer a fee		includes a power provider and CO_2 T&S entity. • Currently only applicable to the power sector • No funding for pre-FID activity in the structure
Hybrid	• A combination or evolution of one or more of the above models that would seek to enhance the positive traits of other models and minimise the negative aspects to suit different circumstances.	

Table 5-2 CO_2 T&S Revenue Models

5.5 Options Framework

The study has used an Options Framework approach to identify the main options for T&S business models. This approach is in line with Green Book guidance on public sector business cases (HM Treasury, 2013). The method is to systematically analyse each of the categories of choice that combine to form a whole business model option.

The Business Model Options Framework summarised in Figure 5-1 was used to generate the long list of options for further evaluation and appraisal. The model was developed considering the Case Studies assessed (Section 4) and the previous work (above). The model was refined and developed with input from a panel of experts and with representatives from BEIS. The framework identifies the five key components which make up the business model for a T&S infrastructure business. For each of the key components, a range of choices was developed. By considering the choices available for each component, a wide range of business model options was created.

5.5.1 Ownership of T&S Infrastructure Company

Three choices are available, fully publicly owned, fully privately owned or a hybrid combination.

5.5.2 Capital Funding of Infrastructure

There are three main choices for the funding of the infrastructure itself: public, private or a hybrid combination such as PFI.

5.5.3 Revenue Model

Four broad choices of revenue models were identified:

- Market based storage fee from the emitter for the provision of a T&S service;
- Public sector operating fee, possibly in conjunction with a capital grant;
- Market-Public hybrid;
- CO_2 Sales to an EOR customer.

Each of these four models has a wide range of permutations and can be adapted to arrange of different circumstances. The specific model to be used is very much dependent upon the allocation of risk and the maturity of the sector. In a mature sector, revenue could flow from the emitter rather than the government. It is conceivable that, in time, uses of CO_2 other than EOR may become economically attractive. However, at the current time the UK market for CO_2 is 2 million tonnes per annum (of food grade quality) (IBIS World, 2016) and this is fully met from existing sources.

5.5.4 Investor CCS Risk Appetite

This component of the model attempts to distinguish business models according to the degree of CCS-specific risk that the entity might be able to accept. It is intrinsically linked to the level of reward being sought. Section 3.1 identified six key areas of risk. Two of these; change of law and policy uncertainty are outside the scope of this current study. The risk associated with risk allocation is that there will be an asymmetry between the risk and reward for the various parties and consequently no way of proceeding. A fourth area of risk relates to the uncertainty about initial CO_2 supply resulting in a stranded asset. This current study aims to explore potential business models for a CO_2 T&S entity and an implicit assumption is that a suitable supply of CO_2 exists.

The two remaining areas of CCS risk are long-term CO_2 leakage liability and CO_2 supply. CO_2 supply is one aspect of cross-chain risk. In terms of an organisations capacity to accept risk, the three choices identified are: ability to accept uncapped liabilities, capped liability and low appetite.

5.5.5 Investor Driver

Three choices of return are considered to be available, High, Modest or Social (to reflect the unique nature of infrastructure businesses).

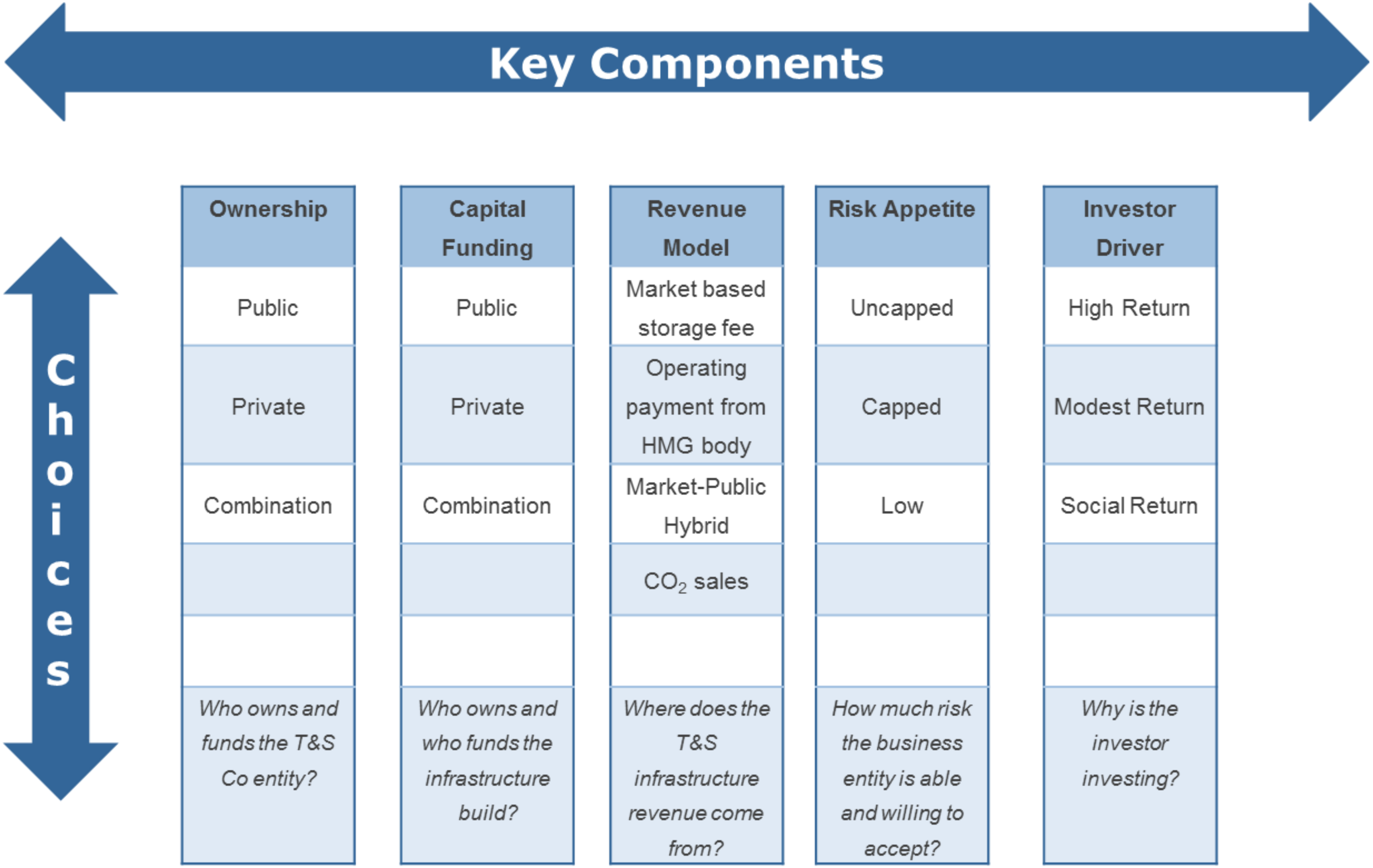

Figure 5-1 Business Model Options Framework

5.6 Long List

The Business Model Options Framework was used to develop a long list of potential business model options, by combining different choices for each component. This resulted in a list of 324 permutations. Some permutations are considered not feasible, either due to incompatibility or being judged by the authors to be implausible and were removed to create a partially qualified long list. Examples of reasons permutations were considered not feasible include:

- Risk – reward asymmetry
- Public sector funding in a mature sector
- Private sector funding for only social benefit.

The full long list was provided under separate cover.

6.0 Model Selection

6.1 Categorising models

An approach of categorising the models was adopted to help with the analytical process. This stage does not distinguish between the way in which the models address the challenges outlined in Section 3.3 but groups the models by considering a specific attribute.

The partially qualified long list was examined for groups of models with some similar attributes. Whilst the business models could be categorized in many ways, an approach to support the subsequent development of a short list for early stage CCS projects was adopted. Five categories have been identified by the authors. Four are described according to the stage of the CCS sector that they are most likely to be appropriate and the fifth relates to a group of business model options that are contingent upon the development of CO_2 EOR in the North Sea. The five categories are:

- Early: relevant to the early phase of CCS development
- Developing: applicable to the phase before the market is mature
- Mature; valid for a mature CCS market
- All: applicable to any phase of market maturity
- EOR; valid only in conjunction with CO_2 EOR

6.2 Sub-Set

A sub-set of potential business models has been developed for further analysis. This involved selecting the models in the ‘Early’ and ‘All’ market maturity stage categories, as being of most relevance. Generally, the sub-set involve an operating payment from the public sector (which could form part of one of the revenue models described in Section 5.4), rather than a market driven revenue stream, in line with the early phase nature of the market, i.e. non-commercial. Furthermore, the risk to the CO_2 T&S business model is generally (but not exclusively) on a capped basis. These models are considered to be able to evolve over time, to suit a more mature CCS sector in which private sector or market based revenues could work either in a hybrid model or potentially on a standalone basis.

This approach provides a sub-set of 11 potential business models. The eleven models vary principally based on ownership and source of capital funding. These models can evolve with the market over time.

Business model canvasses have been developed for four of these models (highlighted in blue), which are considered on first inspection to be the most interesting. Further analysis is recommended of all 11 models on the sub-set list, in a subsequent phase of this work. Within the canvases, values/requirements in square brackets are indicative only.

Option	Ownership	Capital Funding	Revenue Model	Risk Appetite	Driver	Feasibility	Family
12	Public	Public	Operating Payment from Public sector	Uncapped	Social Benefit	Yes	Early
14	Public	Public	Operating Payment from Public sector	Capped	Modest Return	Yes	All
18	Public	Public	Operating Payment from Public sector	Low	Social Benefit	Yes	All
86	Public	Combination	Operating Payment from Public sector	Capped	Modest Return	Yes	All
122	Private	Public	Operating Payment from Public sector	Capped	Modest Return	Yes	All
126	Private	Public	Operating Payment from Public sector	Low	Social Benefit	Yes	Early
158	Private	Private	Operating Payment from Public sector	Capped	Modest Return	Yes	All
162	Private	Private	Operating Payment from Public sector	Low	Social Benefit	Yes	Early
230	Combination	Public	Operating Payment from Public sector	Capped	Modest Return	Yes	Early
233	Combination	Public	Operating Payment from Public sector	Low	Modest Return	Yes	Early
302	Combination	Combination	Operating Payment from Public sector	Capped	Modest Return	Yes	Early

Figure 6-1 Sub-set list of business models

CO_2 T&S business model 14;	’Public entity’

Summary

Publicly owned and funded company, set up as a regulated asset business to enable future privatisation. Directs investment in T&S infrastructure, retains expertise to enable effective design, build, operation, maintenance, monitoring and closure of the transport and storage assets, potentially in multiple UK regions. Business could also specify infrastructure and prioritise regions. Business could be privatised in whole or on a regional basis.

Value Proposition

- Public body to initiate CO_2 T&S
- Regulated asset business providing an agreed return on investment over a fixed (long) period
- Potential for future privatisation

Ownership

- 100% government owned
- Set up as a standalone commercial RAB business
- Structured to enable full/part privatisation at some point if appropriate

Funding

- Funding for the business and infrastructure capital and operating costs (capacity payments) would be from public funds
- Low cost of capital based on government project/business. On balance sheet.

Revenue

- A regulated long-term revenue stream would be provided in return for designing/appraising and delivering T&S services
- Payments are fixed, subject to agreed adjustment mechanisms and regular reviews (annually initially)
- Potential risk/reward based on availability, with a floor at [10%] deduction in any one year
- Potential revenue stream based on CO_2 volumes transported & stored, paid by the emitter (depending on wider CCS business model)
- Potential exists to leverage carbon price (as EU ETS, CPF, Carbon tax etc) to act as a revenue stream for T&S

Obligation to customers

- To transport and permanently store CO_2 on a contracted basis from multiple sources
- To agree a transfer specification (pressure, temp, quality, location)
- To agree take/send or pay provisions and liabilities for T&S unavailability, all of which depend on the nature and ownership of the CO_2 emitter

Government

- Government establishes new organisation and regulatory framework to govern operations, and the RAB model under which T&S entity would operate.
- Multiple agencies involved with permitting and consents
- Potentially to provide the leadership to select regions, specify requirements for regional infrastructure projects

Risk

- Risk for storage liabilities are likely to need to be carried within this corporate entity and backed by government
- Cross chain performance risk on T&S availability is likely to be carried within this corporate entity and backed by government
- Some construction (cost/time) risk could be passed to contractors
- Other risks carried by this corporate entity and backed, if required, by government
- Structures should provide for an evolution which could lead to privatisation
- Options for managing leakage liability (and handover obligations) include building a single or cross project set aside fund

Table 6-1 Public Entity business model canvas

<table>
<tr><th>CO_2 T&S business model 86</th><th colspan="2">‘Mainly Public entity’</th></tr>
<tr><td colspan="2">Summary
A majority publicly owned and led company, with some investment and ownership from the private sector, probably set up as a regulated asset business to enable future full privatisation. Focus is on design, build, operation, maintenance, monitoring and closure of the transport and storage assets, potentially in multiple UK regions. Business could also specify infrastructure and prioritise regions. Business could be privatised in whole or on a regional basis.</td><td>Value Proposition
• Publicly led body to initiate CO_2 T&S
• Regulated asset business providing an agreed return on investment over a fixed (long) period
• Potential for future privatisation</td></tr>
<tr><td>Ownership
• >50% government owned
• <50% privately owned
• Set up as a standalone commercial RAB business
• Structured to enable full privatisation at some point if appropriate
• Private equity brings; strong commercial drive, access to expertise, ability to deliver etc
• Private equity gets; option on additional equity, involved in driving T&S, return on capital with major risks capped</td><td>Funding
• Funding for the business would initially be from public funds (set up, appraisal, regional selection etc)
• Infrastructure capital is part private funded
• Capacity payments publicly funded
• Low cost of capital based on government project/business</td><td>Revenue
• A regulated long-term revenue stream would be provided in return for [designing/appraising and] delivering T&S services
• Payments are fixed, subject to agreed adjustment mechanisms and regular reviews (annually initially)
• Potential risk/reward based on availability, with a floor at [10%] deduction in any one year
• Potential revenue stream based on CO_2 volumes transported & stored, paid by the emitter (depending on wider CCS business model)
• Potential exists to leverage carbon price (as EUETS, CPF, Carbon tax etc) to act as a revenue stream for T&S</td></tr>
<tr><td>Obligation to customers
• To transport and permanently store CO_2 on a contracted basis from multiple sources
• To agree a transfer specification (pressure, temp, quality, location)
• To agree take/send or pay provisions and liabilities for T&S unavailability, all of which depend on the nature and ownership of the CO_2 emitter</td><td>Government
• Provide the leadership to select regions, specify requirements for regional infrastructure projects could be within or outside remit of this entity
• Government establishes new organisation and regulatory framework to govern operations, and the RAB model under which T&S entity would operate.
• Multiple agencies involved with permitting and consents</td><td>Risk
• Risk for storage liabilities probably need to be capped with risks below a cap carried within this corporate entity and risks above a cap carried by government
• Cross chain performance risk on T&S availability is likely to be capped with risks below a cap carried by corporate entity and risks above a cap carried by government
• Some construction (cost/time) risk could be passed to contractors
• Other risks carried by this corporate entity and backed, above a cap, by government
• Structures should provide for privatisation
• Options for managing leakage liability (and handover obligations) include building a single or cross project set aside fund</td></tr>
</table>

Table 6-2 Mainly Public Entity Business Model Canvas

CO_2 T&S business model 158; 'Private entity'

Summary

A Private company, fully funded by private equity and debt, set up as a regulated asset business. Focus is on design, build, operation, maintenance, monitoring and closure of the transport and storage assets, potentially in one (or more) UK regions. Different regions are may use different T&S entities, in a similar manner to the way in which regional water, gas and electricity companies operate at the current time. A different entity specifies the regional infrastructure and location/outline.

Value Proposition

- Private entity to deliver specified regional infrastructure
- Regulated asset business providing an agreed return on investment over a fixed (long) period
- Government carry key risks above a [low] cap
- Some incentivisation on key performance metrics e.g. availability

Ownership

- 100% privately owned
- Government carry certain risks above a cap to make the venture viable, with scope for the cap to reduce as market matures.
- Set up as a standalone commercial RAB business

Funding

- Equity and debt funding
- Infrastructure capital is privately funded
- Cost of capital likely to be higher than with public involvement

Revenue

- A regulated lon- term revenue stream would be provided in return for delivering T&S services
- Payments are fixed, subject to agreed adjustment mechanisms and regular reviews (annually initially)
- Potential risk/reward based on availability, with a floor at [10%] deduction in any one year
- Potential revenue stream based on CO_2 volumes transported & stored, paid by the emitter (depending on wider CCS business model)
- Potential exists to leverage carbon price (as EUETS, CPF, Carbon tax etc) to act as a revenue stream for T&S

Obligation to customers

- To transport and permanently store CO_2 on a contracted basis from multiple sources
- To agree a transfer specification (pressure, temp, quality, location)
- To agree take/send or pay provisions and liabilities for T&S unavailability, all of which depend on the nature and ownership of the CO_2 emitter

Government

- Separate government leadership is required to select regions, specify requirements and 'procure' regional infrastructure projects.
- Government establishes new organisation and regulatory framework to govern operations, and the RAB model under which T&S entity would operate.
- Multiple agencies involved with permitting and consents

Risk

- Risk for storage liabilities are likely to be capped quite low with risks below a cap carried within this corporate entity and risks above a cap carried by government. Potentially the risk of storage liabilities could be covered within the RAB model and could be a recoverable cost
- Cross chain performance risk on T&S availability is likely to be capped quite low with risks below a cap carried within this corporate entity and risks above a cap carried by government

		• Financing risk • Construction risk, operational risks carried by entity. Some construction (cost/time) risk could be passed to contractors • Other risks carried by this corporate entity and backed, above a cap, by government • Options for managing leakage liability (and handover obligations) include building a single or cross project set aside fund • No utilisations risk. Some availability linked incentive.

Table 6-3 Private Entity business model canvas

CO_2 T&S business model 302; 'Combined Public Private entity''

Summary

A PPP/PFI company, with joint investment and ownership from the public and private sectors, set up as a regulated asset business. Focus is on design, build, operation, maintenance, monitoring and closure of the transport and storage assets in one (or more) UK regions. Different regions are may use different T&S entities, in a similar manner to the way in which regional water, gas and electricity companies operate at the current time. Other entities would specify the regional infrastructure and location/outline.

Value Proposition

- To deliver specified regional infrastructure
- Regulated asset business providing an agreed return on investment over a fixed (long) period
- Government carry key risks above a cap

Ownership

- >50% privately owned
- Government ownership/funding/involvement leveraged to enable creation of an attractive commercial entity
- Set up as a standalone commercial business
- Public involvement brings; low cost of capital, carries key risks above a cap, provides market commitment, potential grant funding, wide variety of model options etc
- Public involvement gets; T&S infrastructure moving, clear visibility of activity/learning, off balance sheet option, ability to direct/step in etc

Funding

- Funding for the business could initially be via a PPP/PFI model developed specifically to suit a regional T&S infrastructure project
- Infrastructure capital is principally privately funded
- Cost of capital dependant on level and nature of public involvement

Revenue

- A regulated long-term revenue stream would be provided in return for delivering T&S services
- Payments are fixed, subject to agreed adjustment mechanisms and regular reviews (annually initially)
- Potential risk/reward based on availability, with a floor at [10%] deduction in any one year
- Potential revenue stream based on CO_2 volumes transported & stored, paid by the emitter (depending on wider CCS business model)
- Potential exists to leverage carbon price (as EUETS, CPF, Carbon tax etc) to act as a revenue stream for T&S

Obligation to customers

- To transport and permanently store CO_2 on a contracted basis from multiple sources
- To agree a transfer specification (pressure, temp, quality, location)
- To agree take/send or pay provisions and liabilities for T&S unavailability, all of which depend on the nature and ownership of the CO_2 emitter

Government

- Separate government leadership is required to select regions, specify requirements and 'procure' regional infrastructure projects.
- Government establishes new organisation and regulatory framework to govern operations, and the RAB model under which T&S entity would operate.
- Multiple agencies involved with permitting and consents

Risk

- Risk for storage liabilities are likely to need to be capped with risks below a cap carried within this corporate entity and risks above a cap carried by government
- Cross chain performance risk on T&S availability is likely to be capped with risks below a cap carried within this corporate entity and risks above a cap carried by government

		• Some construction (cost/time) risk could be passed to contractors • Other risks carried by this corporate entity and backed, above a cap, by government • Options for managing leakage liability (and handover obligations) include building a single or cross project set aside fund

Table 6-4 Combined Public Private Entity business model canvas

An initial assessment is provided below of how well the sub-set of four business models summarised above can address the T&S Challenges identified in Section 3.3. By developing a suitable commercial structure, carrying certain risks and obligations the government could create a market which is of interest to private ventures. Such business model interventions are outlined in the right-hand column of the table below. The early stage T&S infrastructure would, however be best served by one of the models with public involvement. In essence, it becomes a trade-off between Government accepting key risks and degree of private sector funding.

Challenges inhibiting T&S Business Models		14 Public entity	86 Mainly Public entity	158 Private entity	302 Combined Public Private entity	Potential Business model intervention
1	Current absence of a functioning revenue model or commercial incentive for CO_2 transportation and storage business	In the absence of a defined commercial model a public entity would be better able to initiate and progress CO_2 T&S	Private entity investors would not be able to develop T&S infrastructure without a defined commercial model	Private entities would not be able to develop T&S infrastructure without a defined commercial model	Private entities would not be able to develop T&S infrastructure without a defined commercial model	Development of a functioning revenue model would create private investment interest
2	Private sector difficulty accepting long term, uncapped liabilities of unknown magnitude for leakage of CO_2 whether as an individual company or a consortium, the sector is immature and no insurance market yet exists.	Public sector may need to take such liabilities	Might be feasible for the venture to be structured such that the public-sector element could take such liabilities	Private entities unlikely to be willing to take such liabilities	Private entities unlikely to be willing to take such liabilities	Establishing a means by which government or a gov agency can carry such liabilities would enable private investment
3	CO_2 supply volume uncertainty due to potentially unknown timing and performance of CO_2 capture project	Public sector may need to take supply risk	Might be feasible for the venture to be structured such that the public-sector element could take the supply risk	Private entities unlikely to be willing to take supply risk	Private entities unlikely to be willing to take supply risk	Establishing a means by which government or a gov agency can carry supply risk would enable private investment
4	Cross-chain performance risk – how can the CO_2 storage operator guarantee performance of the storage system to the CO_2 emitter and how can the operator manage uncertainty of CO_2 supply volumes	Public sector may need to take cross chain risk	Might be feasible for the venture to be structured such that the public-sector element could take the cross-chain risk	Private entities unlikely to be willing to take cross chain risk	Private entities unlikely to be willing to take cross chain risk	Establishing a means by which government or a gov agency can carry cross chain risk would enable private investment

5	Aligning timing of project investment to synchronise with CO_2 capture project progress and start of commercial operations	Public sector may need to take timing risk for first project	Private entities unlikely to be willing to take timing risk on first project	Private entities unlikely to be willing to take timing risk on first project	Private entities unlikely to be willing to take timing risk on first project	Establishing a means by which government or a gov agency can carry timing risk would enable private investment
6	Potential imbalance between the size of investment required and the Balance Sheet strength of the T&S developer	Public sector would not have an issue	Public sector backing would address this issue	Private entities may not have balance sheet strength	Public sector backing would address this issue	Establishing a means by which government or a gov agency can stand behind private developers would address this issue
7	Current absence of customers for a CO_2 transportation and storage service	Public sector could manage this risk by being involved in CO_2 capture market	Private partner would need insulating from this risk	Private entities are unlikely to carry this risk	Private entities are unlikely to carry this risk	Establishing a means by which government or a gov agency can carry this risk would address this issue
8	Need for Government to balance public/consumer needs with those of private sector when entering into risk sharing arrangements for long term, uncapped liabilities of unknown magnitude for leakage of CO_2	Public sector may need to take such liabilities, since private sector is also unwilling	Private entities unlikely to be willing to take such liabilities	Private entities unlikely to be willing to take such liabilities	Private entities unlikely to be willing to take such liabilities	Establishing a means by which government or a gov agency can carry this risk is required
9	Uncertainty of level and duration of monitoring (and achievability acceptance criteria) required to allow handover of a closed store to the Competent Authority.	Public sector may need to carry this risk	Risk likely to be an issue	Risk likely to be an issue	Risk likely to be an issue	Government or regulator could improve clarity or protocol regarding handover
10	Commercial complexities of multiple large-scale capture schemes sharing T&S	Expertise would be required within a development agency	Expertise would be required within a development	Expertise would be required within a development company	Expertise would be required within a development company	

	facilities with sufficient assurance on availability of capacity		company			
11	Uncertainty & ambiguity around what is required for Financial Security under the Storage Permit application process	Public body may be less concerned about this risk	Public body may be less concerned about this risk	Risk likely to be an issue	Risk likely to be an issue	Government or agency could underwrite certain risks
12	Defining & meeting CO_2 specification and need for an allocation and attribution type agreement when servicing multiple suppliers of CO_2.	Public body likely to be able to manage this risk	Public body likely to be able to manage this risk	Risk likely to be manageable	Risk likely to be manageable	Government or agency could underwrite certain risks

Table 6-5 Addressing the challenges

7.0 Market Interventions

7.1 Other Potential Interventions

As noted in section 3.2 the UK's previous CCS Competition made use of a BRAM as the basis of risk sharing discussion between Government and the developer. Other infrastructure projects have benefitted from Government support packages tailored to meet their respective needs and risk profiles (such as the Thames Tideway) or from support through the UK Guarantees scheme for infrastructure (allows eligible projects to enter into agreements to transfer risk to Government in return for a fee). Further consideration of support mechanisms additional to those outlined in BRAM could be also considered in the future. A number of CCS specific potential interventions have also been proposed in other studies (e.g. saleable Carbon Credits or tax relief benefits).

Table 7-1 contains examples of possible interventions which could potentially compliment or improve the performance of any given CO_2 T&S business model by helping avoid or mitigate key challenges identified in Table 3-1. The examples in Table 7-1 have been collated from previous studies and discussions during the Expert Workshop, as well as being informed by the current work. The list is non-exhaustive and examples are not specific to particular T&S Business Models. Appraisal of the suitability of each for UK use was outside the scope of this study.

With regard the case studies in Section 4, the following observations are made about the role of specific interventions that affected business model performance:

- Most of the UK case studies presented in Section 4, benefited from some Governmental intervention at some point.
- The OFTO case studies have benefited from the creation of a viable structured market, within which developers can see the commercial opportunity to build offshore transmission assets to support offshore wind generation. This regulatory intervention to enable Offshore Wind is analogous to interventions proposed below.
- The Nuclear Decommissioning Authority was created to deliver a societal need in terms of effectively managing the issues around decommissioning of nuclear installations. As a Public body, it was created by a specific governmental intervention.
- The Thames Tideway Case Study required a project specific intervention in order to develop a project structure which was sufficiently commercially attractive for private investors to commit funds.

Topic	Intervention	Benefit
T&S legislation	Possible revision of regulatory requirements if no longer bound by CCS Directive requirements post-EU exit	Arrangements around storage liabilities potentially more favourable to industry
	Complete an assessment and review of the licensing arrangements for the offshore storage of CO_2 to ensure that they are fit for purpose and not likely to cause any unintended impediment to the development of the UKs storage resource.	Increase awareness of challenges and options to address them
	Complete a National Infrastructure Assessment of CO_2 T&S infrastructure through the National Infrastructure Commission and establish what specific actions might be possible	Promote infrastructure and ease planning issues
	Mandate independent re-use assessments ahead of oil and gas decommissioning	Increase awareness of challenges, identify opportunities for CCS
Make progress on T&S		
	Build on Strategic UK Storage Appraisal study to develop a UK T&S infrastructure plan	Establish an initial infrastructure plan for use alongside business model refinement and application
	Outline T&S strategy as part of UK CCS strategy	Clarity of direction and engagement with funders, emitters and developers
Build momentum	Develop a cross government recognition of the value of CCS to the economy and climate targets	CCS champions across government to deliver action and build investor confidence
	Develop engagement at regional level on options/opportunities for CCS	Regional buy in for any public investment or policy changes
	Promote O&G supply chain involvement in CCS	Leverage existing skills, encourage investment, support UK plc
	Educate public on need for CCS	Get buy in for any public investment or policy changes
	Market UK storage potential	Encourage investment in UK and position the UK CCS industry for growth
Future funding	Develop outline model for CO_2 credits (PAG CCS, 2016)	Progress future funding options and build investor confidence

Table 7-1 Potential intervention options

8.0 Further Work

8.1 Methodology

The analysis conducted in this study was intended to bring together input from other infrastructure projects, other CCS projects, other CCS studies and by considering the challenges, develop a realistic list of potential business models which could be used to develop a CO_2 T&S in the UK. A short list of 11 models has been proposed, which can sit within a variety of CCS structures. The methodology for a future phase of work to progress the analyses of these business models is outlined here.

Considering the material in this study, especially the 11 recommended business models, develop them further considering;

- Value proposition of the models
- Risk allocation
- Funding and cost aspects
- Government interface requirements of the different models.

Assess the models against these factors and the drivers for public and private investment to prioritise the model options and develop recommendations for preferred models(s)

Develop the timeline and implementation aspects of the recommended option(s).

8.2 Value Proposition

Based upon the 5 categories of models, the sub-set of 11 business models, the outline business model canvasses and the wider CCS structure, further assessment of the models is required to develop the necessary detail, identify variants within each and to check that there are no other enhanced variants excluded through the process. Key elements of the work required are

- Develop further detail of the short-listed models
- Identify key variants of each
- Describe and quantify the costs and benefits
- Iterate with other model options not on the sub-set list to check for validity
- Highlight any options that have particularly pronounced benefits

8.3 CO_2 T&S Risk

Key to the business model will be, the risk allocation, risk understanding and clarity over risk management options. Further definition of these is required for the business models outlined. This involves;

- Breaking out the risk aspects further
- Assess fit and variations with and between models
- Develop a sensible risk allocation and quantified risk levels
- Test risk allocation with experts and potential funders
- Quantifying the magnitude of the primary CO_2 T&S risks and identifying potential risk sharing mechanisms

8.4 Funding

In order to assess the attractiveness of funding each of the models proposed additional work is required to detail and better understand the cost of funding and the project/regional economics.

- Assess cost of capital for various families of models and options
- Develop a cost model for a regional T&S infrastructure project(s) (e.g. based on the ETI/DECC Strategic UK CO_2 Storage Appraisal Project)
- Outline the funding plan for each model for the infrastructure project(s)
- Outline project economics for each model for the infrastructure project(s)
- Compare funding aspects between models

8.5 Government interface

The CO_2 T&S business models which this study has outlined could interface with Government in a number of ways. To further characterise and assess the potential business models, it will be necessary to further develop and characterise the potential structures and options for Government interface. This will enable the benefits and drawbacks of the various structural options.

- Identify and characterise realistic options through which the sub-set of CO_2 T&S business models could interface with Government, setting out potential structures (and likely cost/resource implications associated to each).
- Appraise the potential pros/cons for each option,
- Risk sharing
- Licensing
- Identification and assessment of support mechanisms additional to those outlined in the BRAM and with potential application to CO_2 T&S infrastructure

8.6 Timeline

In order to ensure the T&S business model thinking is integrated into a holistic strategic planning for CCS, the study and implementation schedule needs aligning with wider activity.

- Develop an implementation schedule
- Integrate T&S thinking with emissions/capture thinking
- Assess any implications of business model on timing

8.7 Model assessment

Assess the short-listed models using these criteria and considering the drivers for achieving successful public and private investment and delivery of a successful outcome. Prioritise the model options and develop recommendations for implementing preferred models(s).

A recommendation should be brought through for further work to explore the process to design these interventions e.g. how various support models were developed for specific projects such as Thames Tideway, Quest CCS or more generic options that might be possible though the taxation system.

8.8 Input & Reporting

Engage with experts in T&S to ensure business model development incorporates the technical, risk, regulatory and commercial aspects of appraising, designing developing, operating, monitoring and decommissioning a CO_2 storage facility.

Develop report to summarise the activity and outcome and present material to BEIS.

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10.0 Appendices

All Appendices are provided in a separate document.

10.1 Case Study Canvases

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