Zero emissions platform

Business models for commercial CO_2 transport and storage

Delivering large-scale CCS in Europe by 2030

June 2014

European Technology Platform for Zero Emission Fossil Fuel Power Plants

Key conclusions

- **A policy framework for CO_2 transport and storage is critical to deliver EU climate targets**
For CO_2 Capture and Storage (CCS) to be widely deployed in Europe by 2030, CO_2 transport and storage infrastructure must be in place – at the right time, in the right place, at the right capacity. In the current policy environment, however, this is unlikely to happen. Innovative business models are therefore needed which align commercial interests across the *entire* CCS chain; and given the long lead times – 6 to 10 years for both pipelines and storage sites – development must start *now*, ahead of wide-scale deployment. A staged roll-out of key hubs is envisaged: initially focused on the North Sea, followed by the Baltic Sea and ultimately moving onshore and to other EU regions.

- **Transport and storage operators need market certainty + manageable risk**
Business models need to create the market certainty and long-term secured cash flows required for private capital and industry investment. In the currently immature CCS market, this means being able to fund business development costs, capital, operating costs, plus the closure and post-closure phases of projects. Funding also needs to be flexible and in large enough 'chunks' to accelerate the development of large-scale infrastructure. Finally, as capture, transport and storage are usually independent businesses, minimising counterparty risk for the duration of a storage project (~60 years from beginning to end) is essential. This means decoupling capture businesses from transport and storage.

- **A risk-reward mechanism is vital to realise storage potential – in the timeframe needed**
Pre-investment capex for storage exploration and appraisal is incurred 10 years *before* a capture operator takes final investment decision (FID) – yet can be in the order of €100 million+ (up to a quarter of total storage capex). It must also cover 20 years of post-closure monitoring when it will be exposed to risk and uncertainty, but without recourse to any balancing income stream. Given the risk of investing in the exploration of storage sites that are ultimately found to be unsuitable – and the fact that time to pay back the investment will be long – a risk-reward mechanism is vital.

- **Different business models are effective for different phases of CCS development**
Three distinct business models have been identified for the three stages of market development: demonstration, pre-commercial and mature industry:

    1. 'Contractor to the State' is effective before an established incentive mechanism exists and when market failure requires state support. Here, state funding is divided into smaller, project-size pieces, determined on a case-by-case basis. *This model has already proved successful for the North Sea region and will be key to incentivising early movers in other regions.*

    2. An 'Enabled Market' comprises state support in some parts of the market, managed competition in others. It consists of a regulated entity (the 'Market Maker') which removes counterparty risk by a) Managing the development of primary infrastructure on behalf of the state (trunk pipeline + back-up storage site) and b) Having a duty to take all captured CO_2 and ensure corresponding storage is available. *This model is ideal for growing storage volumes during the pre-commercial phase.*

    3. In a 'Liberalised Market', private companies develop and manage pipelines, hubs and storage sites without specific state direction. *The CCS market is not yet sufficiently mature to move to this model*.

This development path is similar to that of other network industries, such as gas and water.

ZEP'S RECOMMENDATIONS

- Establish a Market Maker to accelerate the development of key hubs and deliver economies of scale
- Create a flexible funding mechanism to develop storage and transport infrastructure.
- Establish a liability management mechanism to remove the heavy cost burden from storage operators.
- Support a well-defined and predictable growth trajectory for CO_2 capture in national plans.

ZEP recommends a phased approach: **in 2014**, ZEP to build on these recommendations via an implementation taskforce; **in 2015**, work to begin on an implementation plan for the North Sea basin hub, in conjunction with Member State governments; **from 2016 onwards**, the North Sea implementation phase to commence, while work on other regional plans is also underway.

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Executive summary

The critical role of CCS in meeting Europe's energy, climate and societal goals[1] is now indisputable: the European Commission's Communication on CCS confirms that it is "*vital for meeting greenhouse gas reduction targets*", while the Communication on the 2030 energy and climate framework highlights that CCS *"may be the only option available to reduce direct emission from industrial processes at the large scale needed."* As importantly, it will ensure Europe has access to a diverse, reliable and secure energy supply.

While attention to date has focused on the emitting part of the CCS chain (CO_2 capture), large-scale CCS requires CO_2 transport and storage infrastructure – at the right time, in the right place, at the right capacity. In the current policy environment, there is no indication this will happen. There is a dearth of companies developing storage sites.

Innovative business models are therefore needed which align commercial interests across the *entire* CCS chain; and given the long lead times – 6 to 10 years for both pipelines *and* storage sites – development needs to start now, ahead of wide-scale deployment. **Indeed, having a framework in place which enables storage projects to be established with the confidence that then *also* enables investment in CO_2 capture is critical to the timely deployment of CCS in Europe.**

The question is: "What is needed to make CO_2 transport and storage a viable business?" In order to answer it, ZEP created a dedicated taskforce of experts representing a broad cross-section of the CCS value chain, including industry, academia and NGOs. Their conclusions – and solutions – are outlined in this ground-breaking report.

A policy framework for CO_2 transport and storage is critical to deliver EU climate targets

Large-scale CCS requires an infrastructure capable of transporting hundreds of millions of tonnes of CO_2 every year – from power plants and energy-intensive industries to geological storage sites, EU-wide. The economies of scale are potentially enormous – especially if different CO_2 sources are located in close proximity so they can share infrastructure. CCS will therefore develop as a staged roll-out of key hubs and connecting infrastructure, initially focused on the North Sea (Figure 1).

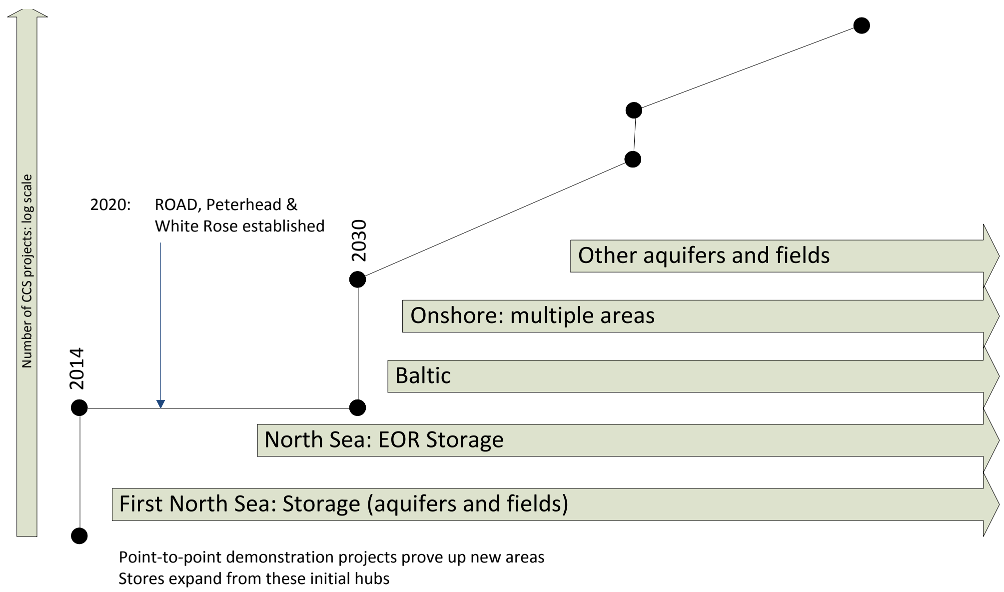

Figure 1: CO_2 transport and storage will focus on key hubs in a staged roll-out

[1] For more information, see "*The case for urgent action on CCS in Europe: Getting ready for deployment – pace and scale of CCS demonstration pre-2030*": www.zeroemissionsplatform.eu/library/publication/241-roadmapeu2030.html

However, the CCS industry is too immature to move straight to a free market. While it has a ‘mature market’ level of regulation via the ‘CCS Directive’,[2] it has no large-scale operation, with the associated ability to spread risks and liabilities across multiple projects. It is also unique in that the commodity (CO_2) generally has no value other than that assigned to it by regulation – yet the disposing company retains liability for the commodity for decades.

A policy framework for CO_2 transport and storage is therefore critical to create the market certainty and long-term secured cash flows required for private capital and industry investment. Without it, a network will simply not materialise in time to deliver EU climate targets.

There are many precedents for the state supporting infrastructure development which is clearly in the public interest (see Chapter 4), together with a growing recognition that critical energy and climate challenges can only be met by pooling resources at national and EU level.[3] To this end, ZEP has identified the key enablers (and barriers) for any potential operator to transport and store captured CO_2 from third parties on a commercial basis.

Transport and storage operators need market certainty + manageable risk

An effective business model for CO_2 transport and storage must apply to one of the three key stages in the development of the CCS market: demonstration, pre-commercial and mature industry. This includes the ability to fund business development costs (especially exploration and appraisal of storage sites), capital, operating costs, closure and post-closure phases.

It therefore means addressing the following challenges:

Causality

- Capture operators need to have a guaranteed CO_2 storage solution, at a known price, before they can gain finance.
- Storage operators need a guarantee of income before they can invest in (costly) exploration, appraisal and feasibility work.
- Transport operators need to have confidence in income in order to perform feasibility and routing studies, including public engagement.
- All operators need to know that other parts of the chain are technically, politically and commercially feasible before investing.

Longevity

- All parties need confidence that other parties (or substitutes) will be present for the duration of the projects (at least 30 years) and that policy underpinning business models is stable.

Exposure

- Storage operators not only have significant exposure at the feasibility stage, but also an overhang of ~20 years for the closure and post-closure stewardship periods.

Value for money

- CCS will benefit significantly from economies of scale, which implies a level of pre-investment in infrastructure – while reduction in risk exposure will reduce the cost of individual storage projects.

Funding must be flexible and in large enough ‘chunks’ to accelerate infrastructure development

Assuming that capture, transport and storage are independent businesses, each part of the CCS chain requires that the other be present long enough for the investment (including the cost of statutory obligations such as decommissioning) to be recovered. Minimising counterparty risk is therefore essential.

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[2] 2009/31/EC

[3] For exanple, the winner of the Energy Realities competition, managed by the Economist Intelligence Unit and sponsored by Statoil, advocates a “Central Bank for Energy Innovation”: www.statoil.com/en/newsandmedia/pressroom/pages/innovationglobalcompetitionmarch2014.aspx

Recognising the unique nature of this emergent business, funding should also be flexible and in large enough ‘chunks’ to accelerate the development of large-scale infrastructure. This should include enabling Enhanced Oil Recovery (EOR) with CO_2 storage as EOR provides an additional source of income, reducing the need for finance for pure storage. As storage is an inherent part of an EOR project, the cost of storage to the network is also reduced. However, as capital requirements are high, a long-term source of CO_2 is a prerequisite.

A risk-reward mechanism is vital to realise storage potential – in the timeframe needed

Figure 2 shows that the timeline for expenditure differs widely for CO_2 capture, transport and storage: while total storage capex is less than the capex for a capture plant, *pre-investment capex* for the exploration and appraisal of a storage site can be in the order of €100 million – as much as a quarter of total storage capex.

A storage operator must therefore be confident of making a return on its expenditure ~10 years *before* a capture operator takes final investment decision (FID) – as well as covering 20 years of post-closure monitoring when it will be exposed to risk and uncertainty, but without recourse to any balancing income stream.

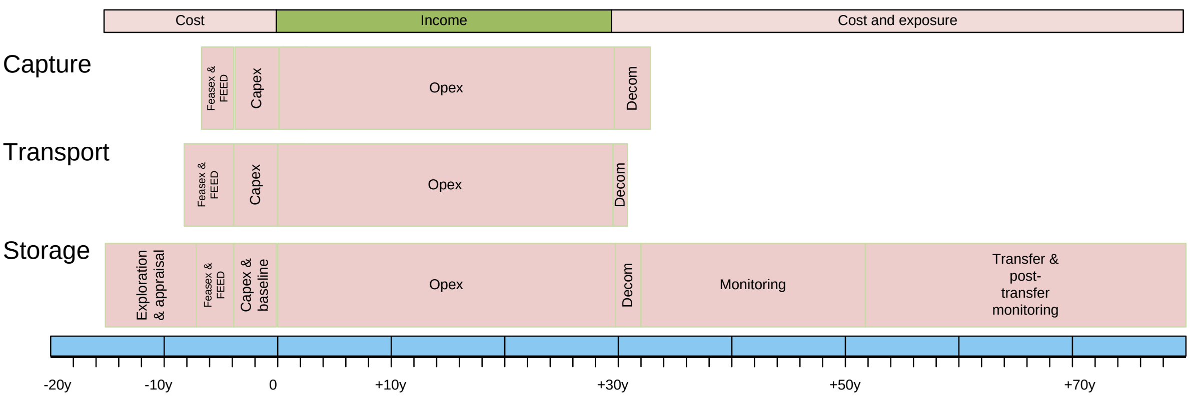

Figure 2: Timeline for income and expenditure for CO_2 capture, transport and storage

In short, an investor in CO_2 storage needs to look at least 60[4] years ahead: the full storage chain includes exploration and appraisal of storage sites (5-7 years), development (3-5 years), operation (20-30 years), post-closure stewardship (~20 years) and post-handover monitoring (~30 years).

This means that potential storage sites require urgent appraisal, with the design and financing of transport networks starting from 2015 in order to ensure wide deployment by 2030. Given the risk of investing in the exploration of storage sites that are ultimately found to be unsuitable – and the fact that time to pay back this investment will be long – a risk-reward mechanism is vital.

Different business models are effective for different stages of CCS development

Three business models have been identified for the three key stages in the development of CCS: demonstration, pre-commercial and mature industry:

1. ‘**Contractor to the State’** is effective before an established policy incentive mechanism exists and when market failure requires tailored state support. Here, state funding is divided into relatively smaller, project-size pieces with each investment assessed on its individual merits. This approach gives the flexibility to adapt policy in response to events. This business model is highly effective for kick-starting infrastructure development (e.g. maximising gas sales from the Norwegian Continental Shelf, see section 4.2) and is being applied in the UK for the CCS commercialisation programme.

[4] Depending on Member State legislation, this can be any period from 60-80 years

The EEPR and NER 300 schemes have also successfully provided partial funding for some projects.[5]

This model has already proved successful for the North Sea region and will be key to incentivising early movers in other regions.

2. An '**Enabled Market'** is a hybrid business model comprising state support in some parts of the market and managed competition in other parts. The Enabled Market consists of a regulated entity (the 'Market Maker') which has two key roles:

   - To manage the development of primary CCS infrastructure on behalf of the state (trunk pipeline + back-up storage site). This ensures optimal design, construction and operation in order to achieve system efficiencies, including economies of scale.
   - To have a duty to take all captured CO_2 and ensure corresponding storage is available (including for low-cost EOR storage projects): thereby decoupling capture, transport and storage, and removing counterparty risk.

   A Market Maker is a proven method of developing emerging markets (e.g. Gasunie in the Netherlands, see section 4.3). In most cases, these entities start with significant state underwriting, but are later partially or completely privatised, or even disbanded. Provision of storage to the Market Maker may be through a secondary, competitive market.

   This model is ideal for growing storage volumes in the pre-commercial phase.

3. In the '**Liberalised Market'**, private companies involved in the CCS chain develop and manage pipelines, hubs and storage sites without specific government direction. The government's role is limited to creating the mechanism that enables CCS to be a viable business opportunity (whether via a high, robust carbon price, a premium price for low-carbon power, or an incentive to store) and providing an appropriate regulatory framework.

   The CCS market is not yet sufficiently mature to move to a liberalised market.

KEY RECOMMENDATIONS

ZEP recommends that the following actions be taken as a matter of urgency:

1. **Establish a Market Maker to accelerate development of key hubs**
   - Establish an initial Market Maker for the North Sea, with initial capital provided and underwritten by governments who intend to use it for geological storage. Subsequent Market Makers for other 'storage' regions can then follow (once the 'Contractor to the State' model has been successfully applied).
   - The Market Maker can be as large (with wide-ranging responsibilities) or as small as required to suit national/regional circumstances.

2. **Create a flexible funding mechanism to develop storage and transport infrastructure**
   - In conjunction with Member States, establish a storage evaluation and development funding programme, focusing on key areas to be developed in the 2015-2035 timeframe.
   - Undertake spatial planning (both capture and storage locations) to enable transport operators to build cost-effective capacity for a 30(+)-year period.
   - Underwrite finance or income streams to underpin the business case for investment in large-scale CO_2 transport infrastructure and storage sites *ahead of need* in order to realise economies of scale.

[5] The GETICA project in Romania is similar to the Contractor to the State as it is state-owned, providing CO_2 capture, transport and storage services. This level of state control is well suited to delivering new infrastructure, however, the business model is not favoured in most of the countries bordering the North Sea where the initial large-scale demonstration projects are being developed.

3. **Establish a liability management mechanism for storage operators**
   - Create a mechanism for underwriting the cash flow for a storage operator.
   - Establish a liability sharing/underwriting mechanism to reduce individual project risk premia.
   - Examine the possibility of reducing the magnitude and duration of the liability.

4. **Support a well-defined and predictable growth trajectory for CO_2 capture in national plans**
   - As CCS is not yet a mature business, it requires political commitment to ensure continuous growth and co-financing by private capital and industry investment.

N.B. The majority of the above recommendations can be delivered via the current European political and regulatory framework. While this report refers mainly to CCS in the power sector, recommendations are also applicable to energy-intensive industries.

NEXT STEPS

In order to build on this work, a phased approach is recommended:

(i) **During 2014**: transform ZEP's Temporary Taskforce on CO_2 Transport and Storage into an implementation taskforce, with refocused membership in the policy and commercial arenas, and the mandate to put greater detail onto the recommendations.

(ii) **During 2015**: work with North Sea governments (along the lines of the North Sea Basin Taskforce) to localise the recommendations and develop an implementation plan for the North Sea basin hub.

(iii) **2016 onwards**: North Sea implementation phase starts; work on other regional plans is underway.

The Zero Emissions Platform (ZEP)

Founded in 2005, the Zero Emissions Platform (ZEP) is focused on CCS as a critical technology for achieving Europe's energy, climate and societal goals. A coalition of over 200 members from 19 countries – representing academics, scientists, European utilities, petroleum companies, equipment suppliers and environmental NGOs – ZEP serves as an advisor to the European Commission on the research, demonstration and deployment of CCS.

www.zeroemissionsplatform.eu

1 Background

1.1 What makes a viable business?

This report relies on a careful examination of the various elements that make for a viable transport and geological storage business in Europe. It is therefore useful first to consider the needs of a generic business, before introducing the elements specific to CO_2 transport and storage.

Businesses invest capital (capex) and incur operating expenses (opex) in anticipation of receiving income. For a business to be viable, the cumulative income must exceed the cumulative opex and capex. If there not a high expectation that this simple fact will hold then capital investment will not take place. Capex also generates additional costs as the suppliers of capital – be they shareholders, bond holders or lenders – require a return on their capital. Regulatory requirements may mandate that companies make provision for decommissioning (abandonment) expenditure: termed abex. This can also generate costs, in terms of capital that must be held on the balance sheet, or the costs of buying a form of financial security from a third party.

1.2 The costs of CO_2 transport and storage

CO_2 transport has the following cost elements:

- Market feasibility studies and route selection
- Business development
- Front end engineering design (FEED)
- Consenting and wayleaves
- Capital + financing costs
- Detailed design and construction
- Operating costs
- Decommissioning costs.

Transport of CO_2 is very similar to that of hydrocarbons: it requires that investors have **confidence of income** (e.g. a transport tariff) of sufficient **size and duration** to cover opex and repay capex and financing costs, while giving a return on the capex commensurate with the risk.

CO_2 storage has the following cost elements:

- Prospect access (licensing of acreage for exploration)
- Exploration and appraisal expenditure: to appraise the storage site and assess its feasibility for geological storage, including site characterisation
- FEED
- Storage permit development and application
- Capital + financing costs
- Detailed design, construction and monitoring baseline acquisition
- Operating costs, including monitoring
- Financial security for operating period: as per the CCS Directive and covering corrective actions and decommissioning costs
- Site decommissioning costs
- Monitoring and financial security during the post-closure period
- Payment of financial mechanism upon site transfer
- Specific risk and liability provisions and insurance as per the CCS Directive.

Assessment of CO_2 storage potential and performance is complicated by its reliance on geology with all its attendant and deeply buried geological variability. When dealing with the sub surface, there is always the possibility that the location will be found to be geologically unsuitable and not in line with assumptions made before the investment decision. The challenge is that getting to an investment level of maturity in the assessment of storage potential requires exploration and appraisal expenditure that must take place *before* any income is received. The cost of the two phases can be in the tens to hundreds of millions of euros.

Any storage business must be compensated for the high financial risk of exploration and appraisal – and the fact that time to pay back this investment can be long. A risk-reward mechanism for exploring deep saline aquifers is therefore vital, as highlighted in ZEP's CCS cost reports.[6]

In the minerals extraction business, companies run a portfolio of exploration and appraisal activities. If exploration and appraisal are successful, companies are then confident of receiving a significant return on the individual *successful* investment. This diversification of opportunities means that the high returns on successful projects compensate for the losses of failed projects. The returns during the extraction/ production phases of successful projects also allow well-run companies to pay for the decommissioning expenditures.

Another unusual element of CO_2 storage is the requirement that an operator continues to monitor the site for ~20 years after injection has ceased. Assuming monitoring is successful, the company is expected to pay the *competent authority* a transfer payment and the site is then transferred. The duration of monitoring and the size of the transfer payment is not certain until the time the transfer takes place.

All activities that rely on geological systems are subject to performance challenges related to geological variability. Projects will expect to experience challenges, be it during construction or operation, e.g. a new injection well may need to be drilled; or additional water extraction facilities constructed; or, in extremely rare cases, corrective actions may be required such as drilling an intersection well to re-plug an old well bore in the subsurface. Projects must be able to generate income to cover these eventualities; if they cannot, then the project will be abandoned. This is seen in minerals extraction (e.g. mine flooding) or hydrocarbon developments (e.g. smaller than expected reserves).

1.3 Forms of income

Income can take a number of forms. If a liberalised market is assumed (such as in the European hydrocarbon business), then all the risk is taken by the provider of capital/finance. The portfolio is sometimes managed within the companies (e.g. oil and gas), or by the stock market or venture capitalists. In all cases for hydrocarbon extraction, if the project is successful, then it can generate income by selling gas and oil on an open market. If the company or project runs into difficulties, or the price of oil falls, the project can be placed on hold, but the oil/gas asset still exists.

For CO_2 storage, the parallel would be that if a project develops (e.g.) 100 Mt of storage, it will need to have a high degree of certainty that it will be able to sell **sufficient** of the storage space at a price that will cover all the costs above (see section 1.2). If this is not the case, then other sources of income are required for the business to be viable. These could take the form of capital grants to cover the cost of exploration and appraisal; mechanisms that hedge against the uncertain post-closure and transfer costs; or income guarantees.

As in CO_2 transport, the above complexity reduces to the requirement that investors have **confidence of income** of sufficient **size and duration** to cover all costs, while giving investors a return on their capex commensurate with the risk.

1.4 Counterparty risk and flows in the CCS chain

Flows of CO_2 and income

With a few exceptions discussed below, the only funding mechanism for CO_2 capture, transport and storage is the avoidance of purchasing Emission Unit Allowances (EUAs). In Norway, CO_2 emitted is subject to a tax, while in the UK emissions are subject to a carbon floor price. In addition, the UK's Contracts for Difference funding mechanism for clean power developed under the EMR provides the vehicle for putting low-carbon power generation on a similar footing to renewables.

[6] www.zeroemissionsplatform.eu/library/publication/165-zep-cost-report-summary.html

What all CO_2 reduction incentivisation schemes have in common is that they pay or incentivise the emitter: payments then have to flow with the CO_2 through the transport system to finally reach the storage site.

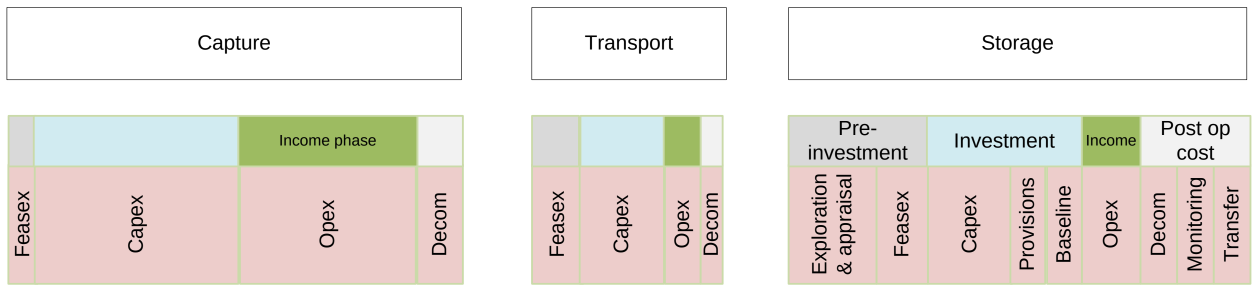

Figure 2: Schematic of cost breakdown between phases in CO_2 capture, transport and storage

Figure 2 shows the timing differences in pre-investment costs between CO_2 capture, transport and storage, and post-operational costs. Any business model must be able to fund all pre-investment costs, including any uncertainty. Another useful depiction is to align spend for all elements of the CCS chain according to the date of FID (Figure 3).

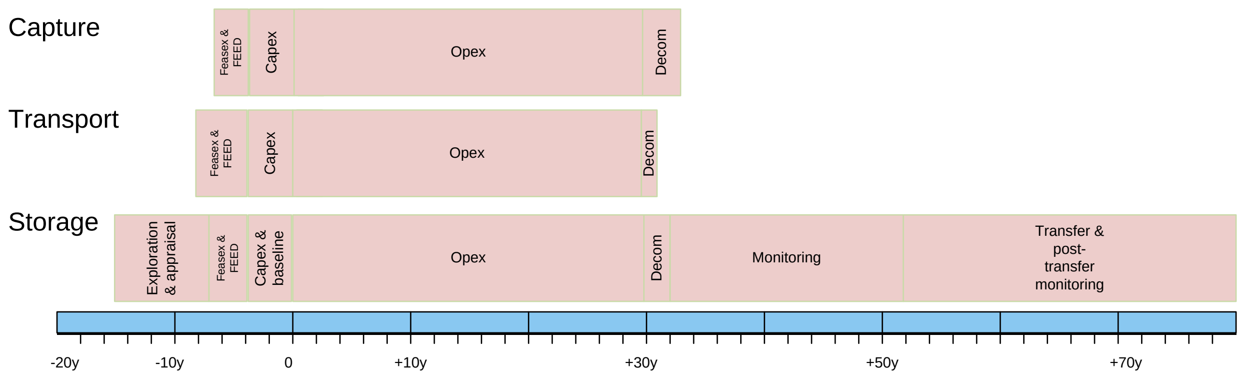

Figure 3: Timeline for expenditure for CO_2 capture, transport and storage

For power and energy-intensive industries (e.g. cement, steel, refining), the unusual components of storage are a) the magnitude and risk of expenditure in the 5-10 years covering the exploration, appraisal and feasibility phases and b) the 20 years of post-closure monitoring. Pre-investment capex can be as much as one quarter of the storage capex and while total storage capex is less than capex for a capture plant, this can still be in the order of €100 million+ that must be spent more than 10 years prior to receiving the first income.

Counterparty risk

Assuming that capture, transport and storage are independent businesses, each requires that the other be present long enough for the investment (including the cost of statutory obligations such as decommissioning) to be recovered. This confidence must exist *before* significant outgoings take place: so the storage business must be confident that it will make a return on its exploration and appraisal expenditure ~10 years *before* FID for capture.

Counterparty risk can be mitigated in several ways:

- There is confidence that all the businesses will continue during the entire operational period.
- The returns are sufficiently high, or are front end loaded, so that capital can be rapidly recovered, reducing the exposure.

- Substitute providers exist with a low-cost/effort to switch. This is a characteristic of a mature market with a fungible commodity.

It is evident that the CCS market is not mature; in fact it currently does not exist. Counterparty risk is therefore a real challenge. There needs to be certainty that investors will be able to generate returns on capital commensurate with risk; assuming that the return will not be large, the risk element then needs to be reduced.

1.5 Required rates of return

In any commercial business, participants need to make an acceptable rate of return on their investment. What, then, is acceptable?

The industry closest to the transport and storage industry, in terms of capital and capability/technology requirements and the geological risks borne, is the oil and gas industry. Oil and gas companies have a diverse range of investment metrics and benchmark returns, and individual company rates are generally confidential. For a commercial storage project, the appropriate hurdle rate is even harder to estimate, as the inherent operational risks, CO_2 supply risk, price and regulatory environment (i.e. liabilities, socio-political support) are much less well defined than for oil and gas – these will evolve over the lifetime of the project. Regulatory changes will probably apply retrospectively to projects already consented and will result in complete dependence on government policy and the rest of the value chain for monetisation.

To estimate an average required rate of return, it is useful to consider two key studies that have already partly covered this ground. In 2011, ZEP published "The Costs of CO_2 Transport and Storage" based on confidential data provided by ZEP member organisations on existing pilot and planned demonstration projects. This suggests 8% post tax as an appropriate cost of capital for a storage-only project in a mature industry. This aligns with McKinsey's 2008 report, "Carbon Capture and Storage: Assessing the Economics", which concludes that 6%-10% would be appropriate in a mature industry. (It is likely that in the earlier stages of the storage industry the cost of capital would need to be higher to cover the additional risks.) This aligns with external studies on the cost of capital for integrated oil companies (e.g. NYU Stern suggests 7.71%); is slightly higher than that for utilities (e.g. 5.6% for E.On in 2012); and similar to that for companies in the Environmental and Waste sectors (8.1%, according to NYU Stern).

The challenge is to define the capital at risk upon which the return is made. In general, only capital specifically associated with project construction and FEED is quoted; Exploration & Appraisal (E&A) costs are taken as sunk costs, but these still have to be covered by the business. This will tend to inflate the apparent rate of return on an individual project basis. As a result, the required rate of return for a storage project will inevitably be higher than the cost of capital – particularly at the early stages of the industry given the high risks involved. (The risks may be broadly compared to those of oil and gas exploration and production.) As the ZEP-estimated cost of capital is similar to that of the oil and gas industry, the required rate of return may also be similar. Several recently published economic studies on North Sea CO_2-EOR have provided estimates of required returns for oil and gas projects.[7]

An illustrative North Sea investor requirement is a ratio of 0.3 for the Net Present Value: Discounted Capex for mature technology investments. This correlates with ~15-20% post tax rate of return, which may therefore be an appropriate range for early stage storage projects. As the industry matures, required rates of return may reduce towards the industry's cost of capital. There are regulated gas storage companies that are willing to take lower returns (e.g. the levels quoted here) in return for lower risk achieved through higher upfront exploration and appraisal cost (including acquiring depleted hydrocarbon fields) to reduce uncertainty, with the E&A cost contributing to their regulated rate base.

A follow-on question would be required rates of return for storage projects that include EOR. Given the added supply and policy risks for CO_2-EOR compared with normal oil production, operators may apply higher benchmarks (the North Sea CO_2-EOR studies quoted above suggest this may be as high as 0.5 in

[7] E.g. Element Energy et al, 2012, Kemp et al; 2012, and Element Energy et al 2013

certain cases). However, as the CO_2 supply industry matures and EOR projects in the North Sea are de-risked, this risk premium will reduce.

1.6 Liability for CO_2 stored: during operation and post closure

Every storage project needs to set aside a significant sum of money to cover liaiblity during both the operational and post-closure periods (part of the financial security requirement under the CCS Directive).

There are a number of potential solutions:

- Create a mechanism for underwriting the cash flow for a storage operator.
- Establish a liability sharing/underwriting mechanism to reduce individual project risk premia.
- Examine the possibility of reducing the magnitude and duration of the liability.

The CCS 'ROAD'[8] project has proposed a solution for the demonstration phase. This involves reducing the number of EUAs auctioned in any year by the equivalent amount of CO_2 reported as leaked in the previous year from all storage sites (country by country and year by year). The unquantifiable exposure faced by individual operators is therefore absorbed by the market with negligible impact – and the insurance issue evaporates. There is no impact on the level of care taken by operators, but the element of financial security relating to the purchase of EUAs in the event of leakage is removed from the calculation. The result: artificial barriers that currently obstruct storage operators from coming forward then disappear. N.B. This solution could be adopted in 2014 with no need to amend either the EU ETS or CCS Directives.

[8] http://road2020.nl

2 The CCS market in Europe

2.1 The unique characteristics of CCS

The CCS industry has a number of distinctive features:

- It has been regulated *before* the first demonstration projects have reached FID.
- The commodity (CO_2) generally has no value in itself – it is a by-product of combustion.
- The commodity requires the development of networks and hubs; gathering the commodity from multiple sources; linking via hubs for aggregation, connected to an offshore system with complex ownership along the entire chain.
- Utilisation of some elements of existing infrastructure may be possible. To optimise this, mothballing platforms, pipelines and wells for decades may be required until integrated networks and supply sources develop.
- Some limited volumes of the commodity may be used as a raw material to increase production levels of a valuable product (EOR, greenhouses).

2.2 The CCS industry will develop in three key stages

Most parties recognise three key stages in the development of the CCS industry:

At this point in time, Europe is trying to enter the demonstration stage with potentially three large-scale projects: the ROAD project in the Netherlands, the White Rose project in England in the UK and the Peterhead project in Scotland in the UK.

The end point is a mature industry. This would be characterised by a policy incentive for the majority of large stationary point sources of CO_2 to be captured and stored. Comparisons with analogous infrastructure-based industries suggest that this will lead to networks of pipelines and a supply and demand balance for sources and stores. Depending on the development trajectory, this could take the form of a liberalised market or a regulated monopoly.

The pre-commercial stage is sandwiched in the middle: there will only be a few sources and stores, yet it is during this period that major investments in transport infrastructure and storage exploration will be needed to ensure wide deployment by 2030 – and the delivery of EU climate targets.

When examining any business model it is therefore key to bear in mind how it would suit each stage in the development of the CCS industry.

2.3 Current status of CCS and future requirements

Examination of business models identified in isolation may give the impression that there are no issues. Mineral extraction businesses function effectively, as do other businesses that supply basic needs to consumers such as water and electricity. Table 1 below presents the conditions as seen today in 2014, along with the requirements for both an emergent and a liberalised market.

Table 1: Conditions relevant to CCS: a view of the present and possible futures

Demonstration stage

Current day

- ✓ CCS Directive transposed
- ✓ Limited funding in some Member States (MS)
- ✓ Storage demonstrated by Statoil[9]
- ✓ Three CCS power projects are moderately mature: one stalled, two in FEED. Public/private partnerships.
- ✓ UK: Contract for Difference (CfD) fund and Carbon Price floor[10]

- × Current funding so complicated by rules that it cannot be spent
- × EUA price €6;energy market in turmoil (billions written off in shares)
- × Not all countries allow CCS
- × Significant concentrated CO_2 emitted, only in Norway is it stored
- × Zero commercial power capture or dedicated storage projects
- × Lack of potential storage providers
- × No security of demand for storage service (supply from power)
- × Power plant has no security that the store will be there long term
- × Except in UK, only income stream for CCS is avoided cost of EUAs – this comes to the power plant.
- × Storage provider is at the end of the value chain and bears residual liability for decades
- × No functioning business model

Demonstration stage

Emergent: transition steps
To deliver current three or more demonstration projects

- ✓ Funding for capex, opex and downside/overspend
- ✓ Projects do not need to make significant profits, but risks are covered
- ✓ Assured revenue stream to cover cost of (e.g.) power generation (capex, opex) and capture, transport and storage, and cost of capex (temporary measure)

Pre-commercial stage

Emergent market
For market to develop

- ✓ Signal EUA rise, in law create ‘growing market’
- ✓ Flexible funding source: for storage appraisal, capture plant and transport – in large enough ‘chunks’
- ✓ ‘First mover’ incentives to oil and gas operators to unlock storage
- ✓ Ability to provide CO_2 to EOR storage projects
- ✓ Funding mechanism created for oversized ‘common infrastructure’ and third party access
- ✓ Fund a portfolio – do not try to pick winners
- ✓ Flexible funding source for opex (and capacity charge) – long-term cash flow guarantee
- ✓ Stable business and political environment and outlook – avoid white elephants. Path to ‘more and bigger’. Political commitment and roadmap.
- ✓ Concentration on MS that are willing to proceed rather than all; others opt in later. Mature offshore storage.
- ✓ Develop liability limiting/sharing mechanism
- ✓ Decoupled CCS chains

Mature industry

Liberalised market

- ✓ EUA price high and robust: 80-90% emission reduction on track
- ✓ Confidence that policies work and will be in place for some time
- ✓ Lots of captured CO_2 looking for a home, multiple sources
- ✓ Extensive transport network
- ✓ Storage offshore mature
- ✓ Onshore storage becoming possible
- ✓ CO_2 production will swing (excess capacity relative to average rate)
- ✓ CCS regulation mature and well tested
- ✓ Liabilities and risks of storage well understood and predictable
- ✓ Capital providers well used to funding, cost of capital reducing
- ✓ Storage technology proven, business-as-usual
- ✓ North Sea ring established, other countries adopting
- ✓ Widespread public acceptance
- ✓ Portfolio of projects: risks are spreadable/sharable/insurable
- ✓ Conditions for competition and TPA will exist
- ✓ Technology will be improving, competition and technology will drive down prices
- ✓ CCS supply chain will be mature

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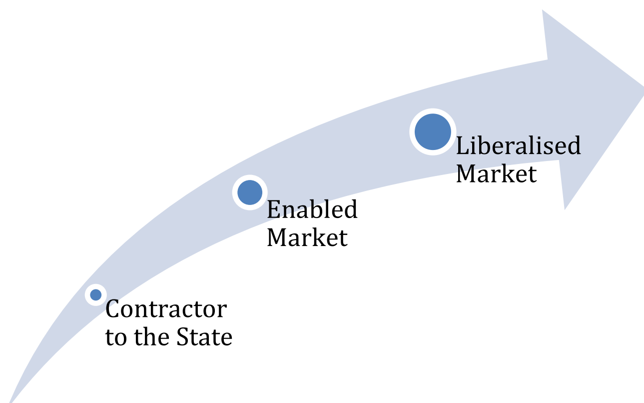
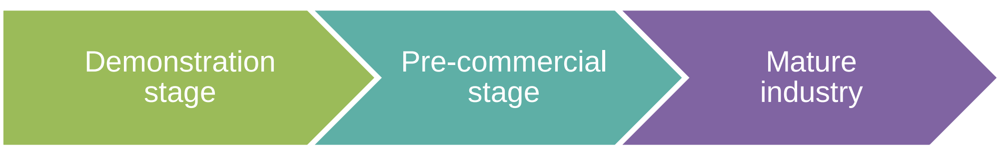
[9] Part of gas project, driven by Norway carbon tax
[10] Political indications that this may not last

3 Key business models for CO_2 transport and storage

Government intervention in CCS is a given as it relies upon the creation of an artificial market though regulation and incentivisation. The level and degree of intervention, however, is up for debate. The evolution of potential business models may be divided into three periods depending on the level of state control:



The level of state intervention is highest on the left-hand side and reduces naturally as the industry matures.



3.1 Contractor to the State

A '*Contractor to the State'* model is suitable before an established policy incentive mechanism exists and when market failure requires tailored state intervention. It has the following characteristics:

- The state can take full control of the planning, development and operation of CCS transport and storage.
- Investments and operating costs are predominantly financed (or guaranteed) by the state (with the contractor holding some 'skin in the game').
- The state may pre-invest in infrastructure, in which case future users pay compensation to the state for utilisation of the infrastructure.

The contractor to the state acts as a technical service provider for the state, providing central overview – in all phases of the project.

Several options and hybrids exist: the contractor to the state may be a national industry/body or a private industry; it may also own the infrastructure. Cash-flows, risks and liabilities are also issues which may be tailored to respective projects in order to establish a risk-reward balance acceptable to the contractor. This model may require exceptions from mature market rules that are prevalent, and indeed enshrined in law, in mature economies such as the EU: while suited to extremely rapid action, it has the potential to be slow and expensive if mature market rules are rigidly applied.

It has been suggested that CCS should follow a fully nationalised route: the ‘state storage board’. ZEP does not consider that all elements are well suited to this; however, transport could be suited to a natural monopoly, be it state or private owned.

Role of the state

The state makes each investment decision on a case-by-case basis, which requires it to have a view of future infrastructure scenarios and gain assurance of the delivery of proposed solutions. It underwrites project revenue and sets the direction/dictates the pace. It can supply capital directly and bear risk/liabilities to facilitate progress, bearing in mind the need to ensure appropriate contractor incentives and satisfy State Aid guidelines. With respect to the handover of a storage site to the state at the end of a project, the state has several distinct roles – recipient of the store, client for the contractor and regulator. For early projects, the state should identify and intervene as appropriate to remove barriers to the project. It also needs to ensure that learnings are disclosed and shared across other European CCS projects.

Non-CCS examples include Member State infrastructure (e.g. Ministry of Transport in the UK) and Member State owned or controlled industry (e.g. CEGB historically or Scottish Water currently in the UK). The work conducted (up to FID so far) on the first demonstration project under the UK CCS Commercialisation Programme (providing FEED funding, capital grants and a payment for the cost of clean electricity), and on EEPR funded projects, is also effectively under this model.

3.2 The Enabled Market

An *‘Enabled Market’* is a hybrid model comprising state intervention in some parts of the market and managed competition in other parts. The Enabled Market consists of a regulated entity (the ‘Market Maker’) which has two key roles:

- To manage the development of primary CCS infrastructure on behalf of the state (trunk pipeline + back-up storage site). This ensures optimal design, construction and operation in order to achieve system efficiencies, including economies of scale.
- To have a duty to take all captured CO_2 and ensure corresponding storage is available (including for low-cost EOR storage projects): thereby decoupling capture, transport and storage.

Geographical constraints mean that there is likely to be a number of storage hubs. There may be multiple Market Makers – one per hub – or potentially one per nation or region, e.g. the North Sea.

A Market Maker does not need to own infrastructure and could be limited to a guaranteeing function, but it is more natural for there to be some link with infrastructure. However, a key point is that the Market Maker can be a company independent of the state, although it will be strongly regulated. It will have the obligation to act as an aggregator to manage intra-chain FID timing issues for private market operators emitting CO_2 from individual sources, transporting CO_2 or storing CO_2 at individual storage facilities.

The Market Maker may also be an efficient mechanism for separating post-closure monitoring and stewardship activities from development and injection by allowing the development of specialist service companies optimised for development or optimised for stewardship. Using a Market Maker to accelerate the development of primary infrastructure for CCS will create economies of scale and subsequent cost reduction; it will also send out a clear message to capital providers that there is an industry in which to invest.

What is crucial for private operators is that the balance sheet and credit-worthiness of the Market Maker is sufficiently robust to underpin the financing of their capital expenditure. If the Market Maker is a financially weak counterparty, private sector operators will struggle to raise their required finance. Much consideration also needs to be given to the extent of primary infrastructure provided by the state and the basis for charging for that infrastructure. In particular, private sector operators will be looking for primary infrastructure to come close to their boundaries, while any desire to 'oversize' will run the risk that subsequent customers do not materialise.

Role of the state

The Market Maker can either be a state-owned entity or a regulated private company; the two roles can be undertaken by different bodies. The state's key role is to agree the location/scale of key infrastructure investments and set the access and charging methodologies of the Market Maker (both for CO_2 offtake from emitters and CO_2 supply for EOR). It allows the Market Maker to operate independently with a regulated framework that provides the vehicle for state direction and the reward mechanism (e.g. CfDs in the UK).

The state can provide capital directly or indirectly (e.g. by granting the Market Maker a levy income) and can also underwrite risk (including storage exploration/appraisal risk and leakage liabilities). A mature storage industry should ultimately generate sufficient revenue to cover such risk. Independently funded extensions to infrastructure (storage and transport) are encouraged. The state requires comprehensive market knowledge to inform long-term plans, provide direction and identify the need for interventions to accelerate deals. Regarding the transfer of a storage site to the state at the end of a project, the state is both the recipient of the store and the regulator. Where the Market Maker is independent, the state will also be its principal customer.

3.3 The Liberalised Market

The *'Liberalised Market'* model describes a market in which private companies involved in the CCS chain develop and manage pipelines, hubs and storage sites without specific state direction. Individual participants are free to decide how their business will be structured – whether to pre-invest in over-sized transport and storage capacity, and how to allocate risk and return. A comparable example is the development and operation of the oil and gas industry in the UK North Sea.

A free market model may suit a mature market best, as the high costs and risks for the first projects in the CCS industry, and for isolated projects distant from aggregated hubs, may require substantial additional state intervention.

Role of the state

Here, the role of the state is reduced to that of light touch regulator to ensure unplanned monopolies are avoided and creating the mechanism that enables CCS to be a viable business opportunity (whether through a high, robust ETS, a premium power price for low-carbon power, or an incentive to store). Government has no ownership and no central planning role. The offshore oil and gas industry in the North Sea is a clear analogue for delivery of infrastructure via a liberalised market. With respect to transfer of a storage site to the state at the end of a project, the state is again both the recipient of the store and the regulator.

3.4 Key differences between the models

A key difference between models is the role played by state intervention:

- In Contractor to the State, the state decides on each investment on its merits. This means that state funding is broken up into relatively smaller project-size pieces with the flexibility to adapt policy in response to events (e.g. technology developments in CCS or alternative technologies such as renewables or energy storage, changes in fuel or market prices, international agreements on climate change, scientific understanding, political and public sentiment etc.).
- The Market Maker ('Enabled Market') can be an arm of the state, in which case the nature of state intervention could be similar to the Contractor to the State model. It could also be independent, funded through levy mechanisms and functioning under a regulated legal framework that makes it appear

much more like free market approach. However, even in this case, the state would still find it much easier to adjust support levels and policy objective in light of events.

- In a Liberalised Market, the state establishes a general market mechanism covering the entire energy market (ideally Europe-wide, but more likely the national energy market). Details depend on the mechanism, but either the costs or the scale of CCS will necessarily be uncertain. The mechanism must be stable to give investor confidence and address the fact that local monopolies will naturally develop. In order to deliver a free market solution for CCS, the state therefore needs to commit to a firm long-term policy of uncertain (but undoubtedly large) cost and uncertain results.

4 Analogues to the early stages of the CCS industry

4.1 Network-dependent industries

Several network dependent industries have elements that suggest analogues, but no industry represents a perfect parallel to CCS:

- *Early rail networks* – their financing and development offer some parallels. The networks were built to accelerate the economic development of distant regions, connect commercial and industrial centres, and speed up and increase the scale of transport. Different specifications for the trains as a result of non-standardisation of gauge (distance between rails) led to separate networks that could not be amalgamated. Governments facilitated the compulsory purchase of land to ensure wayleave along new routes. Financing by visionary investors was supported by loans from banks or by governments, again enabled by banks. Ownership was usually fully incorporated, including track and trains.
- *New rail networks* – renovated connections or high speed connections have relied heavily on subsidy, with capital costs frequently exceeding estimates. Governments are key to facilitating development, but the process of government is often a major hurdle to such projects because investments become politicised. Ownership of track and trains is often unified, but there are some examples of other train operators renting track capacity. Permitting new routes becomes very difficult and often needs government intervention and compensation. Utilisation does not always match the original vision.
- *Canal networks* have parallels similar to rail networks.
- *Household waste and landfill do not use a network* other than public roads and occasionally rail.
- *Sewage networks* – financed and built by local communities or regional governments to improve living standards and health, these are managed by local councils, with standards set by central government. Their operation is publicly funded via rates charged to households and subsidised by government. Networks transport a waste product away from communities to a location for disposal or treatment. Originally waste was released down river to flow into the sea, but technology was developed to treat sewage, separate harmful elements, collect methane and generate dried sludge for use as fertiliser, or otherwise disposed of in landfill. Such networks are perceived as necessary by the public and government alike – it is generally accepted that the public pays. This is perhaps the closest analogue.
- *Power transmission networks* carry a commodity of value and were developed for commercial reasons. Their development is not based on subsidy and their function is not related to disposal.
- *Natural gas, oil and product pipeline networks* each carry a commodity of value and were developed for commercial reasons. These networks often involve complex ownership and their permitting and operating standards are the precursor for CO_2 transport and storage. Their development is not based on subsidy and their function is not related to disposal.
- An example of government action against air pollution is the UK Clean Air Act of 1956 which led to the obligation to burn smokeless fuels in residential areas and the relocation of power stations away from population centres and the introduction of taller chimneys at power stations and factories. This analogue does not involve a network, but does involve laws and standards relating to by-products of burning fuels and the introduction of penalties for non-compliance (but without the use of subsidies).

Extrapolating 50 years into the future and looking back on the development of CO_2 transport and storage networks, there will probably be a close parallel to public demand for the collection, transport, processing and disposal of sewage, i.e. it became a human necessity and an obligation for governments to incentivise cooperation between industry and hydrocarbons producers to develop and operate networks funded by public money and managed by franchise.

4.2 Developing gas infrastructure for the Norwegian Continental Shelf

The organisation of gas sales from the Norwegian Continental Shelf, including the establishment and organisation of gas infrastructure, closely mirrors the business models for CO_2 – particularly in the early stages in which the sellers (equivalent to emitters) to a large degree cooperated (as monopolists). Liberalisation also came into effect following the development of a regulated infrastructure. The aim: to achieve the greatest possible value for Norwegian gas sales.

a) Initial period

The first fields developed had dedicated pipelines to customers (Ekofisk/Emden and Frigg/St.Fergus) and the following characteristics:

- Short distance from source to market – but still commercial
- No need to 'optimise' delivery vs. demand
- Owners of the various fields sold the gas as a single group (giving them a stronger position in the market).

Gas was sold as a 'depletion contract', i.e. buyers and sellers were obliged to sell all gas from the field in question.

The next step was the recognition that there were many fields on the Shelf which could be realised after the first 'source to market' fields, but none big enough to justify building its own infrastructure. Even though they were owned separately, they had to agree to build infrastructure in order to transport the gas to market. As the market was emerging, no company could accept the risk of committing to such huge investments without a corresponding long-term offtake agreement. By establishing such contracts, the respective gas sellers were collectively able to develop infrastructure and build production facilities.

b) Transition period

In order to secure an even stronger position in the market, the Gas Negotiating Committee (GFU) was then established, responsible for all gas sales on behalf of the Norwegian Government. Thereafter, offtake contracts were allocated to certain gas fields by the Norwegian Authorities and the licensees could embark on the development of production facilities and corresponding infrastructure expansions, as required. This meant that the Norwegian Authorities could develop those fields that gave the highest social economic benefits. As new fields and several new hubs developed into different markets, contracts changed from the previous 'depletion contracts' to 'supply/volume contracts' – giving the sellers the flexibility to optimise delivery from different sources and demand from various markets/buyers.

c) Final period

In the final period, a large gas market and corresponding infrastructure was established. There are now four receiving terminals for Norwegian gas on the Continent: two in Germany, one in Belgium and one in France. There are also two receiving terminals in the UK. The Norwegian gas transport system includes a network of pipelines with a length totalling more than 7,975 km – roughly corresponds the distance from Oslo to Beijing. From 1986 to 2001, Norway's gas sales were negotiated by the Gas Negotiating Committee which was permanently discontinued in 2002. After this, all licensees on the Norwegian continental shelf became responsible for selling their own gas and the different gas owners have separate sales agreements with different buyers in Germany, France, the UK, Belgium, the Netherlands, Italy, Spain, the Czech Republic, Austria and Denmark.

It has been important to ensure efficient operations in the Norwegian gas transport system, e.g. in the form of economies of scale. The authorities' tools in this regard are the operating company Gassco, the joint ownership of the Gassled system and regulated access to the transport system.

Gassco is the operator of the gas transport system with both special and public operator responsibility. Special operator responsibility entails the development of infrastructure, and operation and management of capacity in the gas transport system. Gassco studies transport solutions and advises the authorities, contributing to a holistic development of Norwegian gas infrastructure; Statoil act as a "technical service provider" for Gassco. In cases where major developments are considered, this means that other Norwegian gas fields – beyond those that trigger a gas transport need – must also be included in the assessments. Further development of the gas infrastructure must also take place in a manner that is beneficial for the existing gas infrastructure.

Gassled is a company with no employees, organised via various committees with specific tasks. The joint venture owns a majority of the transport system for Norwegian gas, i.e. pipelines and terminals. When a third party uses a pipeline or transport-related facility, the plan is for these to be included in Gassled and become part of the central upstream gas transport system.

The pipeline system is a natural monopoly, with significant infrastructure investments. The tariffs for gas transport are therefore regulated via separate regulations stipulated by the Ministry of Petroleum and Energy. This ensures that profits are extracted in the fields and not the transport system. The oil companies have access to capacity in the system based on the need for gas transport. To ensure good resource management, transport rights can be transferred between users when capacity requires change.

Joint ownership of the transport system also ensures that the gas is transported as efficiently as possible and provides the greatest value creation, partly by avoiding conflicts of interest regarding which is used. Gassco is the operator of Gassled by agreement with the owners. Gassco also manages the consideration for efficient transport of gas in the day-to-day operation of the facilities, as part of the special operator responsibility.

It should be noted that transport infrastructure in the final period also represents a long-term secured, but regulated, revenue stream; hence new investors have been entering the systems, e.g. international pension funds etc.

As with natural gas, CO_2 needs to be aggregated in the market and funnelled via trunk-lines to central storage facilities based on a long-term contract. CCS is not a commercial viable business – aggregating the CO_2, including developing the infrastructure, must necessarily be a state task.

4.3 Gasunie in the Netherlands: a 'Market Maker' in action

The Gasgebouw (gas building) was established in 1963 to ensure coordinated and efficient growth of the gas market and infrastructure in the Netherlands on the back of the Groningen gas field. An Agreement of Cooperation for life of field was signed between NAM and Dutch State Mines which created Gasunie and laid the ground for the evolution of EBN (then DSM), the State hydrocarbons upstream interest holder. NAM was the concessionaire responsible for upstream exploitation of Groningen (50:50 Bataafse Petroleum Maatschappij: Standard Oil Company, later Shell:ExxonMobil). NAM and DSM were the financial partners (60:40) in the Maatschap Groningen.

Gasunie was the gas purchaser, transport network developer and gas marketing entity, owned 50% by NAM owners, 40% by DSM and 10% by the State. The Gasunie statutes stated that it would always make exactly 80 million guilders a year for distribution to shareholders. This led to an unusual calculation for the actual price paid to Maatschap Groningen for the gas, which could only be known long after the end of each year. Gasunie has since been split into GasTerra (NAM owners) and GTS (the State).

The Gasgebouw ensured that supply grew as demand was created in the Netherlands (and neighbouring countries) and the grid was planned and constructed to match demand. It ensured that the bulk of the value of the field flowed back to the State.

Parallels with the early stages of the CCS market are not evident. A parallel approach would involve nominating or creating a single commercial entity or aggregator to manage the development of the collection, transport, and redistribution of CO_2, with the state shouldering more than 90% of the net loss involved. (Under the Gasgebouw, the state realised ~90% of the net profit from the exploitation of hydrocarbon resources.) There is no single source of CO_2 so the aggregator must bear a 'come and get CO_2' obligation similar to the Gasunie obligation to connect within four years of any discovery onshore. A broader obligation would be needed to 'go and deliver CO_2' to any party awarded a storage permit offshore. The queue for permits would need a national planning and coordination committee. This overall arrangement therefore sits best within the Market Maker model.

5 Financing CO_2 transport and storage

5.1 Provision of capital

Potential investors in transport and storage infrastructure require confidence in the *entire* CCS value chain. This section therefore considers how to make it a commercial and investible proposition for a broad base of capital providers.

5.1.1 Path to an established CCS industry

While many component CCS technologies are highly developed, their combination for the express purpose of low-carbon power generation is unproven at large scale. The returns needed to attract billions of euros of investment therefore depend largely on public policy decisions over extended timeframes.

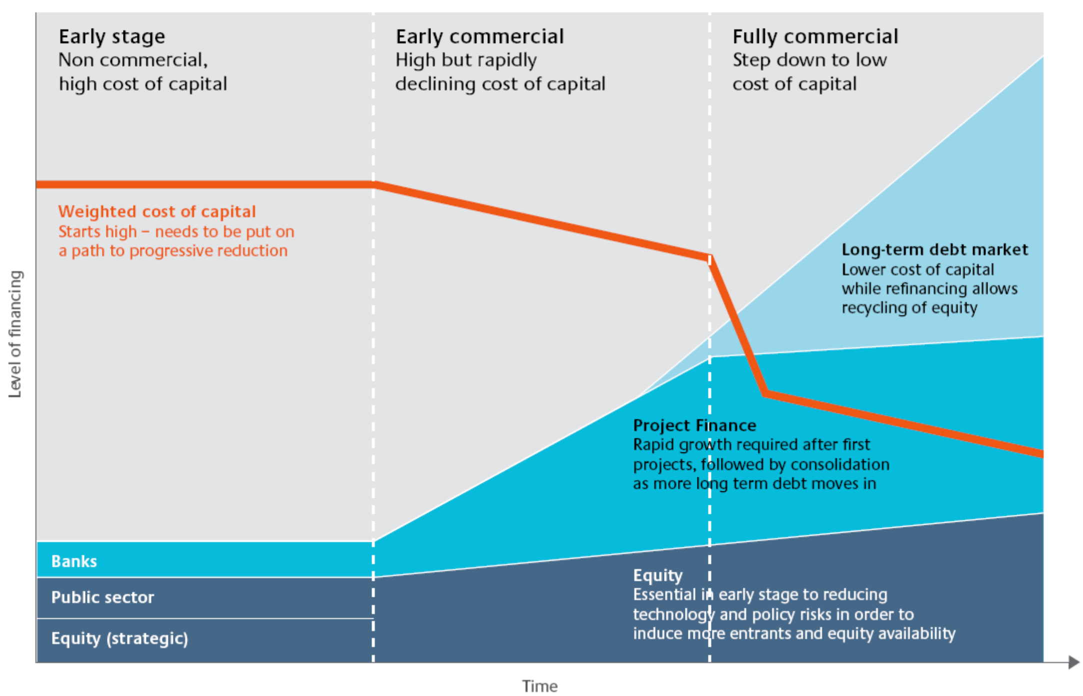


Figure 4: The path to a low-cost industry[11]

Moving CCS from a nascent technology to one that is commercially viable for private sector development means reducing overall costs sufficiently to make it competitive with traditional generating technologies. While costs are likely to be very high in the early, non-commercial phase, they will fall over time as technology, systems and industry integration are demonstrated. As the perceived risk associated with CCS declines, so too will the providers of finance, cost of capital and financing terms evolve. Early projects therefore require significant government support, concessional financing and committed equity.

[11] "Carbon Capture and Storage: Mobilising private sector finance for CCS in the UK", A joint report by the Energy Technologies Institute and the Ecofin ResearchFoundation: www.ecofinfoundation.org/assets/files/MobilisingFinanceForCCS.pdf

Once early projects have an operating track record, they should progressively attract lower-cost project finance. Indeed, once the industry is mature, CCS should be able to attract long-term debt on comparable terms to other power and infrastructure projects. Figure 4 above provides a stylised illustration of how the cost of capital and sources of finance may evolve as risks are addressed.

5.1.2 Sources of finance

There is a range of potential sources of finance for CCS projects and solutions must be sensitive to their different needs. Those 'most likely' to move CCS to commercial deployment include:

- *Public expenditure*: to support and demonstrate pre-commercial projects at scale in order to de-risk subsequent debt and equity investments
- *Equity*: provided by the companies involved in the project, institutional investors (e.g. pension funds) or third parties (e.g. venture capitalists). At pre- or early-commercial stage, the motivation for equity investors is likely to be strategic rather than project returns.
- *Project finance and project-specific bank loans*: project finance supports a specifically created project entity, without recourse to the sponsors' corporate balance sheets.

CCS will be competing for scarce capital and the role of debt will remain limited until significant work has been done to de-risk the full CCS value chain. Financial institutions will be more inclined to invest time and effort in preparing and negotiating CCS projects if they can see a potential 'pipeline' of future projects.

Regardless of the source of finance, visibility over future revenues (and, in particular, future returns) is critical. Private sector investors do not expect or want to be insulated from all risk, but they are particularly wary of risks that are, in themselves, artefacts of policy. Clear, reliable, longer-term revenue support measures will support the market for project refinancing and help attract upfront risk-bearing capital.

Financing will therefore be facilitated by:

- *Sharing risks*: policy can play an important role in reducing and sharing risk, particularly in the early stages, e.g. public sector participation through appropriately structured guarantee arrangements. A collaborative approach could also allocate risk to private sector investors where they are best placed to bear it, and remove or share risks which the public sector clearly has a role in shaping and bearing.
- *Assembling large-scale financing*: the scale of capital required is a key challenge. Banks often form syndicates or clubs, while still limiting their exposure against individual investment projects.
- *Engaging with financiers*: policy makers should engage in greater depth with financiers (as do UK regulators such as Ofgem or Ofwat) to understand the particularities of the funding environment, the risks financiers are willing and able to take, what policy makers can do to incentivise private sector investment and the scope for creating new investment or ownership vehicles.

5.1.3 Creating a long-term strategic vision for CCS finance

The scale and long-term investment needed to develop CCS, along with the unproven nature of the industry, demands a long-term strategic vision for the sector's financing. Figure 5 illustrates its potential evolution, where a 'waterfall' of funding for the sector (or individual project) cascades from one investor group to another over time, as the industry or projects are de-risked.

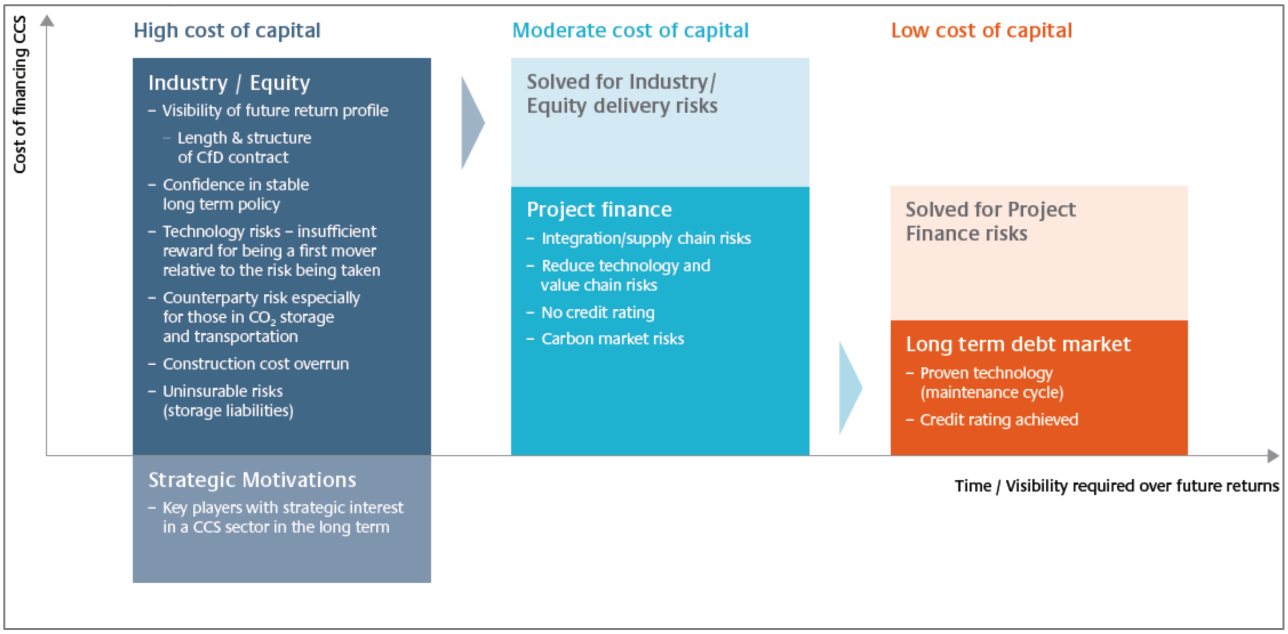


Figure 5: A financial vision for CCS[11]

However, for this evolution to take place there are various issues that must be addressed:

1. Create long-term confidence in the public policy regime

Creating long-term confidence in the public policy regime that underpins investor returns is key. However, there is currently insufficient evidence of a commitment to a CCS industry; indeed, in some cases it is the reverse. This would be addressed by:

- Policy makers taking decisive action to achieve the very demanding trajectory set within carbon budgets.
- Creating a level playing field with other low-carbon technologies: in many cases, support for CCS appears to be less firm than for other sources of power, such as wind or gas. At the same time, CCS is seen as vulnerable to competition from these technologies.
- Creating co-ordination mechanisms: capital providers need the strong involvement of private-sector project developers in developing the CCS industry. Confidence to invest will increase if the public sector leads, shapes and facilitates this to some degree at the outset.
- Developing the new skills, capabilities, infrastructure and markets needed for a successful CCS industry: while this will mainly be led by the private sector, there is still an important role for public support in key areas including:
  - Considering the case for further strategic public investment in key areas such as the proving of strategic storage sites in the North Sea, or in essential enabling infrastructure
  - Continued funding of research and development to increase cost-efficiency.

2. De-risk investment in CO_2 transport and storage

Private sector investors need confidence that the *entire* CCS value chain works before they invest in CCS infrastructure. Any business structure other than a fully integrated project requires multiple parties to work together, leading to complexity – not just in relation to risk allocation – that must be handled through commercial agreements. Reliance on multiple parties – even if a satisfactory working relationship, risk allocation and reward structure are agreed – also gives rise to 'counterparty risks' (see section 1.4). This would be addressed by:

- Taking a more co-ordinated or regulated approach: this makes sense for the transport and storage elements of CCS as they are of national interest and strategic clusters are likely to be important.
- Policy makers actively developing the future regulatory and market framework for investments in transport and storage to de-risk this part of the value chain.

3. Reduce operational and technology risks

Technology risk refers to the risk of the technology failing or underperforming (e.g. capture rates being lower than predicted). A greater, related concern is 'integration risk': when the different elements of CCS are combined, the various technologies do not produce the expected results. Storage risks are driven largely by policy and liabilities are a key concern as their potential size, and clarity over who bears the risks, remain uncertain. This would be addressed by:

- Insurance: however, the industry finds it hard to insure storage due to uncapped future EUA prices. To date there are no insurance products available to cover storage risks and appropriate products may never be available.
- Public support for de-risking key elements of the value chain, both in itself and in terms of signalling policy commitment. In particular, it is worth exploring how the public sector could support a co-ordinated approach to proving and de-risking strategic storage sites in the North Sea.

5.2 Investors – who and when?

Who invests, and when, also depends on the evolution of the business model. 'Contractor to the State' is likely to be the only model for early investors, with an 'Enabled Market' and 'Liberalised Market' introduced sequentially. It is also possible that earlier models (Contractor to the State and Enabled Market) will persist in the long term (Figure 6).

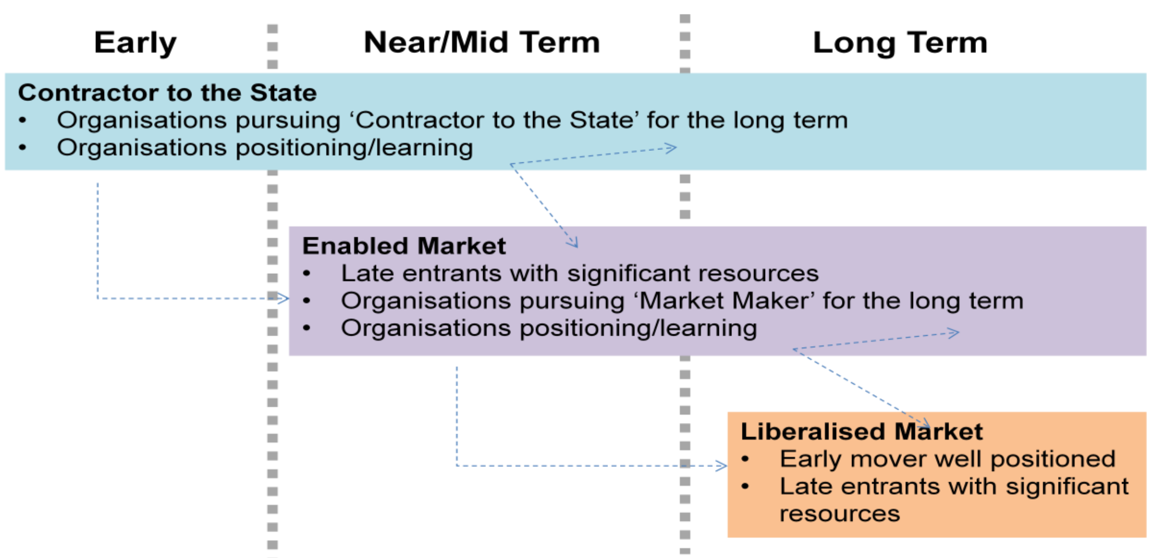


Figure 6: Who is likely to invest in CCS as it evolves into a mature industry

The characteristics of investors are likely to be as follows:

a) *Early investors*
Organisations participating in the early phase are those willing to play Contractor to the State, either because this is the model they desire long term or as a means to an end, e.g. positioning for future business in the Enabled Market model or learning about CCS in support of another business driver, e.g. companies with relevant expertise in managing sedimentary reservoirs, but could also be private equity with an oil and gas investment vehicle or supply chain with operator experience. Governments may also contract with small/start-up organisations without deep pockets if they bring relevant competence.

b) *Investors in the near/mid-term*
Organisations participating in the Enabled Market will be those with the technical competencies to manage a network, plus the capital to invest in strategic infrastructure projects (trunk pipeline and/or hub store), while another body (e.g. government counterparty for CfDs in the UK) takes on an aggregator role. This includes both those who acted as Contractor to the State while positioning, as well as new entrants to the Enabled Market model.

c) *Investors in the long term*
Organisations participating in a Liberalised Market will be those with experience in investing in hydrocarbon exploration/field extension. This includes both those who acted as Market Maker while positioning, but who wish to move into a Liberalised Market business model and new entrants to the Liberalised Market model.

6 EOR with CO_2 storage: supporting CCS development

Enhanced oil recovery (EOR) involves injecting CO_2 into wells to mobilise incremental amounts of oil and is deployed worldwide. Proliferation of EOR can stimulate and be stimulated by the development of CCS and CO_2 storage in Europe. EOR generates incremental revenue from oil production while effectively 'storing' quantities of CO_2. This form of storage may even result in the CO_2 provided by the emitter being attributed value to offset against the cost of capture and transport. Indeed, although EOR requires the combustion of fuels to capture and transport CO_2, leading to increased emissions elsewhere along the chains, the net benefit is energy positive with increased emissions reported and compensated for.

Today, most of the CO_2 captured in operational and near-operational large-scale integrated projects (LSIPs) is used for EOR in North America – there is a reported excess of demand for CO_2 over supply. EOR projects in the North Sea, however, have been under evaluation since the 1970s without moving past FID.

EOR in the North Sea will always be more expensive than similar scale projects onshore in North America and high costs, flood efficiency uncertainties and lack of reliable, plentiful supplies of CO_2 have led to slow progress. It would be boosted by a buoyant North Sea CCS industry providing high availability of CO_2, while EOR projects in turn would provide transport for, and access to, CO_2 supplies needed by other CO_2 storage facilities. EOR therefore offers a symbiotic relationship with CCS and CO_2 storage.

Key benefits include:

- The potential to deliver very low-cost transport and storage as CO_2 transport and storage is already an integral part of the EOR activity
- Revenue from incremental oil production, extended life for offshore facilities and jobs
- Well-understood storage locations that may not need the equivalent amount of appraisal and development costs and time, compared to unexplored deep saline aquifer storage sites

EOR projects require:

- Installation of new pipelines, platforms, wells and vents and replacement of existing production well completions and production processing equipment
- Recertification of installations and more complex operating and monitoring systems than conventional oil fields and other storage facilities
- Large-scale, reliable supplies of CO_2 coupled with suitable reservoir properties
- Clarity on the status of payments for CO_2 used for EOR and impact on ring-fencing and taxation
- Develop CO_2 accounting systems to account for small, occasional emissions of CO_2 at offshore installations and clarify the status of any CO_2 produced and then re-injected
- For the first North Sea EOR projects, specific incentives or commitments which recognise the hurdle of being first and the dependence on an untried source of CO_2 (counterparty risk with zero alternative)
- Arrangements to protect CO_2 suppliers from penalties related to increased emissions in the event of platform shut down or intermittent availability.

Annex I: The interdependency of the CCS chain

In order for each of the two major components of a CCS value chain – capture and storage – to succeed, it is necessary that the other component remains in operation throughout the life of the combined project. For the capture plant, this means that the storage site must be open on time, be able to guarantee storage for all of the CO_2 generated by the capture plant over its lifetime (or have a back-up in the event of failure). If the storage operator cannot provide guarantees, then the capture operator is exposed to transport and storage risks (including geological risk and offshore regulatory risk) which it has no ability to assess or manage.

For the storage site, it must be guaranteed that the capture plant will operate over a sufficiently long time period, generating sufficient CO_2 to store, and therefore sufficient revenue to cover the costs of storage. If the capture plant does not provide such guarantees, the storage operator is exposed not only to the technical reliability of the capture plant, but the long-term commercial viability of the capture industry, e.g. in the power industry, growth in renewable subsidies or changes in fuel prices/taxes may make one particular type of fossil power plant uneconomic. The storage provider is therefore also exposed to risks he cannot manage.

If the storage site for a capture plant is late, then the plant will not be able to store CO_2 and claim a premium for generating low-carbon power. Given the capital intensity of CO_2 capture, this reduction in revenue so early in the plant's life is likely to make it uneconomic. The same challenge faces a storage site if the capture plant is late – with all capital spent and no revenue from CO_2 storage, it will also quickly become uneconomic.

In a mature industry, the cluster effect of capture plants and storage sites should minimise this full chain development risk so that there are always alternative CO_2 sources or storage sites – and potentially a Market Maker guaranteeing revenue flows along the chain. For early projects, however, these risk-minimising options do not exist and the risks to project economics are too great for developers to bear on their own.

This therefore forms a considerable barrier to getting early projects through FID. There are several ways that full chain development risk can be mitigated, but require government or official lenders to provide support of one kind or another, for example, by:

- Guaranteeing that a power plant with capture would be entitled to receive a certain amount of low-carbon power premium, even if its CO_2 was not stored owing to a storage site being late or failing.
- Correspondingly guaranteeing that a storage site not receiving promised CO_2 would receive a certain amount of revenue if the capture plant was not sending the expected amount – either directly or by enabling the capture plan to receive some revenue even if it is not capturing CO_2.
- Guarding against power plants with capture becoming uneconomic and ceasing to operate by giving CCS-power preferential access to the grid ahead of other technologies, or by guaranteeing a fixed power premium (e.g. CfD in the UK).
- Providing substantial capex support to developers with obligations to run once constructed, where the failure in one part of the chain provides Force Majeure release to other parts of the chain from their obligations. (The ROAD project essentially follows this model.) This focus of support for capex, rather than an operating subsidy, considerably reduces the cost penalty of stranded assets for developers.
- Providing sufficient support to enable the development of back-up storage wells or sites to cover for loss of a primary storage well or facility.
- Official lenders (e.g. European Investment Bank, UK Green Investment Bank or similar) could also lend on terms that would allow for a freeze in repayments while the full CCS chain was not in operation.

Annex II: Robustness of business models to barriers and enablers

	Contractor to the State	Enabled Market	Liberalised Market
DESCRIPTION AND KEY CHARACTERISTICS			
What are the key features of the model?	• State acts as direct controller of CCS transport and storage infrastructure development either as: – Direct owner via a nationalised industry – Central procuring agency with private industry contracting to the state • Could be at regional or national level in line with anticipated hubs	• Regulated entities (Market Makers) established to manage distinct parts of the CCS system • Market Makers could self-promote as developers of hubs, selected through competition or created by the state • Market Makers act as an aggregator to manage intra-chain FID timing issues • Could exist at regional (hub) or national level, a 'Multi Market Maker' model • Market Makers would be regulated	• A competitive market in which pipelines, hubs and storage sites are developed case by case by interested parties, e.g. offshore North Sea oil and gas industry
At which stage is this suitable?	• Demonstration phase • Likely to transition into another model once the market matures	• Pre-commercial and mature markets • Could transition into a Liberalised Market model in a stable energy market if sufficient competition is established. • Complex, but possible for first demonstrations	• Mature market where risks are known and can be accurately priced into the market mechanism
Who would provide the capital?	• Predominantly state finance with supplementary capital from the contractor to demonstrate 'skin-in-the-game' and comply with State Aid requirements	• Market Maker may own the hub (trunkline + hub anchor store) and provide capital; or act as aggregator/ capacity booker while underwriting third party private companies as hub infrastructure owners • Private companies would invest in 'spoke' stores (as well as in spoke pipelines connecting to the hub) • Market Maker could choose to invest in spoke infrastructure • Financial community (including EIB) would fund private companies	• Capital provided by the market • Could include capital grants from the government if such market mechanisms exist
What is the likely ownership structure?	• The Contractor to the State is expected to own and operate, but could contract as an O&M operator if state allows	• The Market Maker could be 100% state owned, but likely to be private company – in which case, the state may wish to underwrite in a way that does not affect its balance sheet • The Market Maker could have direct ownership of hub infrastructure or sub-contract it • Private companies would own the 'spokes'	• Privately owned, state has no ownership and no central planning role
What is the likely role of the state?	• The state decides on each investment on its merits • State funding is in project-size pieces with the flexibility to 'adapt policy as you go'	• The Market Maker could be an arm of the state, with state intervening to the same extent as the Contractor to the State model, but it is expected to operate independently, under a regulated legal framework that provides the vehicle for state direction	• State has no ownership and no central planning role

What is required for this model?	• Requires semi-permanent role of the state and if adopted long term would rely on other Member States being aligned	• Some hubs will work better than others, so there should be sophisticated regulation	• Commercial business case for CCS must be established. This requires a market mechanism which gives long-term incentives that make CCS 'bankable'. • The CCS chain must be profitable in the long term for market participants. The model can therefore only work when ETS and CCS market can guarantee sufficiently high EUA prices. Measures such as subsidies, FiTs, CfDs etc. will be needed to drive development.
ADVANTAGES AND DISADVANTAGES			
What are the advantages?	• Demonstrates state commitment to CCS • Enables early full chain projects • Part funded through ETS auctions • Disseminates CCS learning widely • Can provide long-term contractual certainty • Can move very rapidly to develop storage if required in a crisis mode	• Provides a clear stepping stone to a Liberalised Market • Accelerates CCS deployment through removal of intra-chain FID timing issues and reduces reliance on political decision making • Allows management of infrastructure in systems (hubs) rather than projects • Less susceptible to budget cuts as keeps spending off state accounts • Transparent licences granted by the state ensures Market Makers perform/conform • Exploits opportunities for economies of scale	• Avoids need for state intervention beyond provision of the market mechanism to create the business case • Fits current government preference for Liberalised Market solutions • Should allow low costs and niche CCS projects to develop freely, with low barriers to entry • Competition should keep prices low and operators efficient • Avoids State Aid problems • Encourages innovation • Gives maximum access to capital for investment
What are the disadvantages?	• Not sustainable • Can be slow and expensive if Member State interprete EU State Aid and Procurement Directives rigidly • A less formal, faster and more flexible approach to EU Directives may have higher risk of legal challenge • No line of sight for follow on industry/business opportunities unless infrastructure oversizing is supported	• Risk of monopolies without appropriate regulation • Market Maker must be set up within EU State and Procurement Directives and in a way that allows it to make decisions without continual referral to Member State government or Brussels • Individual businesses in danger of being cut back/delayed, e.g. 'privatised' in order to transition to a Liberalised Market model • Danger that Market Maker can favour particular operators or types of store • Sophisticated regulation required	• Lack of long-term planning may give rise to higher long-term costs • Lack of consistent standards between pipelines and hub may prevent future integration • There is a tendency for natural monopolies to develop, which would then need to be regulated. However, this could evolve into a regulated Market Maker. • Absence of a natural mechanism to pool storage risks • High political risk for companies due to reliance on government market mechanisms for return on investment • Market mechanism may need regular, predictable and transparent adjustment to ensure it drives CCS development • A risk of insufficient pre-investment for future projects, resulting in an inefficient infrastructure in the long term

VALUE PROPOSITIONS			
What is the value proposition to emitters and storage operators?	• Sign of state commitment to CCS • State commitment through contract mitigates the risk of policy changes • Certainty of CO_2 supply to storage operator and CO_2 offtake for emitter • Upfront E&A risk for storage operator diluted	• Default mode of over investment in transport capacity should lower barriers to entry for spoke storage operators • Market Maker guarantees CO_2 offtake for emitters and CO_2 supply timing to storage operators to allow development at preferred pace • Allows aggregation of CO_2 to increase confidence in CO_2-EOR investment • All operators to bid store capacity into market and fixed rules declare the order	• Providers are free to allocate value (and risk) across the value chain and choose commercial strategies, including: – Rates of return – Short- or long-term investments, e.g. develop licences and then sell or own storage field for field life – Storage versus EOR – Whole chain projects or use of specialist companies for different segments – Storage risks can be passed to the CO_2 source or kept with the store and included in the tariff
What is the value proposition to the state?	• Establishes data point for costs of CCS to enable state to assess affordability of low-carbon policy • The state sets the direction and dictates the pace • Potential to provide stepping stone to create an Enabled Market as a credible path to CCS commercialisation • Keeps some spending off state balance sheet	• Matures the role of the state, but this clearly retains a caretaker role until a Liberalised Market • Reduces cost of CCS by exploiting economes-of-scale and introducing competition to some parts of the chain • Accelerates CCS investment by avoiding 'chicken and egg' timing risk	• Allows minimum state intervention • Contribution of the state is fixed by the market mechanism • No issues of State Aid or government procurement • Separates the state from companies doing the work and hence from blame/liability for delays, cost over-runs etc. • Expenditure is not on the government's balance sheet
THIRD PARTY ACCESS (TPA)			
How is third party access handled?	• TPA may be irrelevant for a small, point-to-point demonstration project • The state should review upside potential of each project it funds and remove barriers to enable TPA from the outset, including (e.g.) underwriting pre-investment in infrastructure to enable the move towards an Enabled Market	• Market Maker's main focus is to enable TPA. It is incentivised to ensure hub infrastructure is optimally utilised and private companies are enabled to develop spoke stores. • A long-term plan prepared by the Market Maker and submitted regularly to the state coordinator may attract new storage capacity • The creation of a new hub may call for a different Market Maker	• The market decides, so TPA is not guaranteed • The market should operate to minimise costs, so TPA should be in the interests of market players, enabling a commercial deal to be done • There is a risk that there will be insufficient pre-investment in future projects, resulting in an inefficient infrastructure for TPA
STORAGE LIABILITIES			
How are storage liabilities likely to be managed?	• Depends on negotiated state contract • Liabilities for 'normal business' risks likely borne by contractor, with 'CCS-specific risks' (that he is unwilling to accept) borne by the state, initially at least • Financial assurance required by CCS Directive for leakage liability may require state underwriting initially, at least until revenue is sufficient to self-fund if storage operators are unwilling to account for EUAs in unlikely event of leakage	• Separate business model developed to bundle storage leakage liability to satisfy financial requirements of CCS Directive and securitise across as large a portfolio as possible (certainly broader than the storage associated with one hub) • State support (or EOR revenue) may be required initially until there is sufficient revenue from the portfolio to self-fund	• Market participants are free to establish their own mechanisms to cover seepage/leakage liability. This could prove impossible, at least initially, and state support, EOR revenue or both may be required until sufficient revenue is generated and there is sufficient understanding of the risk. • Use of insurance products/pooling of risk amongst operators are two examples of how this risk could be managed in a mature, free market

Annex III: Glossary

Capex	Capital Expenditure
CCS	CO_2 Capture and Storage
CCS Directive	Directive on the geological storage of CO2
CfD	Contract for Difference
CO_2	Carbon Dioxide
DECOM	Decomissioning
E&A	Exploration & Appraisal
EC	European Commission
EEPR	European Energy Programme for Recovery
EIB	European Investment Bank
EMR	Electricity Market Reform
EOR	Enhanced Oil Recovery
ETS	Emissions Trading Scheme
EU	European Union
EUA	Emission Unit Allowance
Feasex	Feasibility Expenditure
FID	Final Investment Decision
FiT	Feed-in Tariff
FEED	Front End Engineering Design
Mt	Mega (million) tonnes
MS	Member State
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance
Opex	Operational Expenditure
TPA	Third Party Access
UK	United Kingdom
ZEP	Zero Emissions Platform

Annex IV: Members of ZEP's Temporary Taskforce CO_2 Transport and Storage

Name		Country	Organisation
Tim	Bertels	The Netherlands	Shell
Joris	Besseling	UK	Element Energy
Gerdi	Breembroek	Netherlands	Agency NL
George	Day	UK	Energy Technologies Institute
Clas	Ekström	Sweden	Vattenfall
Lamberto	Eldering	Norway	Statoil
Chris	Gittins	The Netherlands	TAQA
Praveen	Gopalan	UK	Ecofin Foundation
John	Hargreaves	UK	Peak LTD
Kristofer	Hetland	Norway	Statoil
Jim	Lorsong	UK	2CO
Dave	Mirkin	UK	2CO
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Henk	Pagnier	The Netherlands	TNO
Harsh	Pershad	UK	Element Energy
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