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 equity 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).

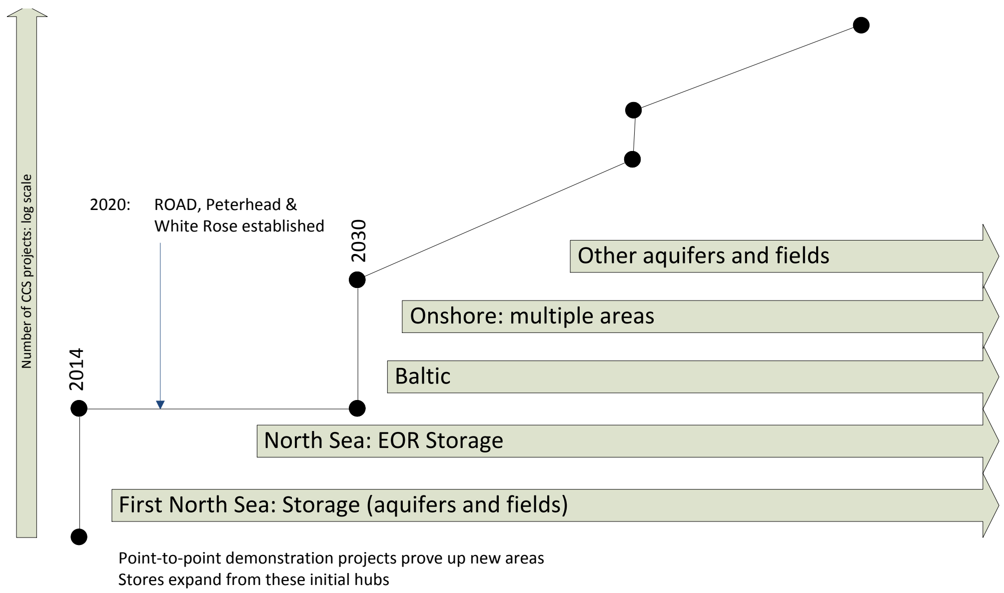

Figure 1: CO_2 transport and storage will focus on key hubs in a staged roll-out

[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 equity 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.

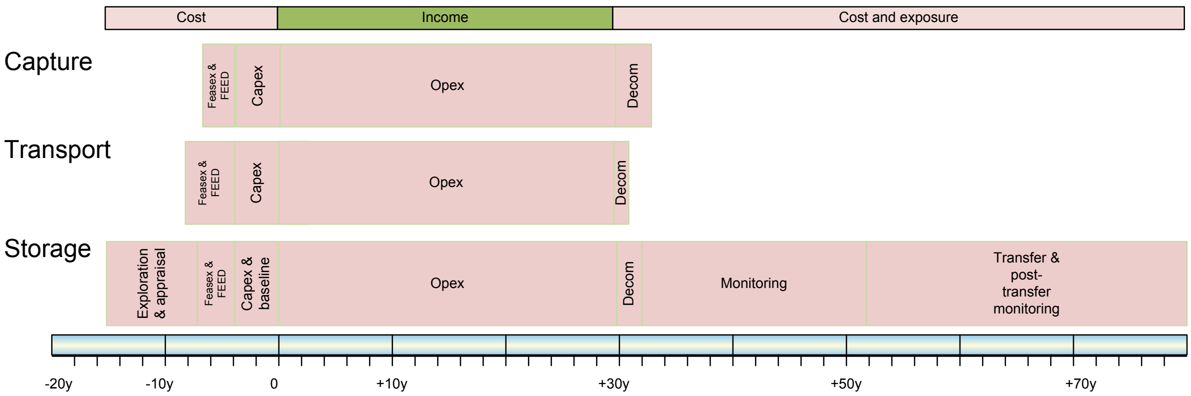

Figure 2: Timeline for income and expenditure for CO_2 capture, transport and storage

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 equity 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.

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[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.

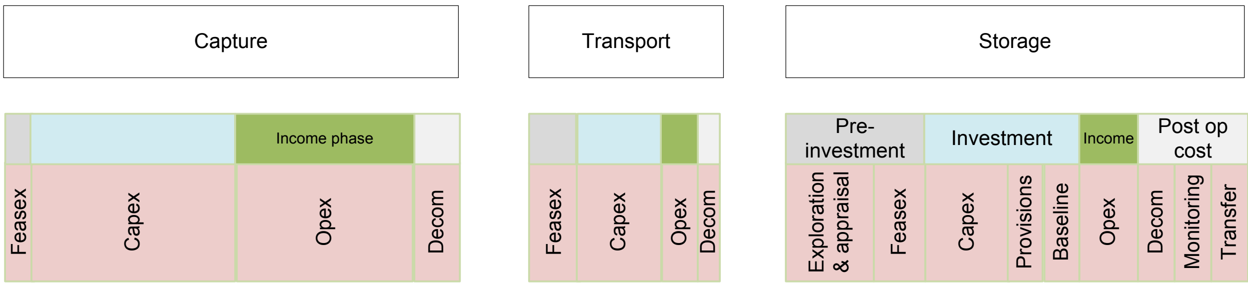

Figure 2: Schematic of cost breakdown between phases in CO_2 capture, transport and storage

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).

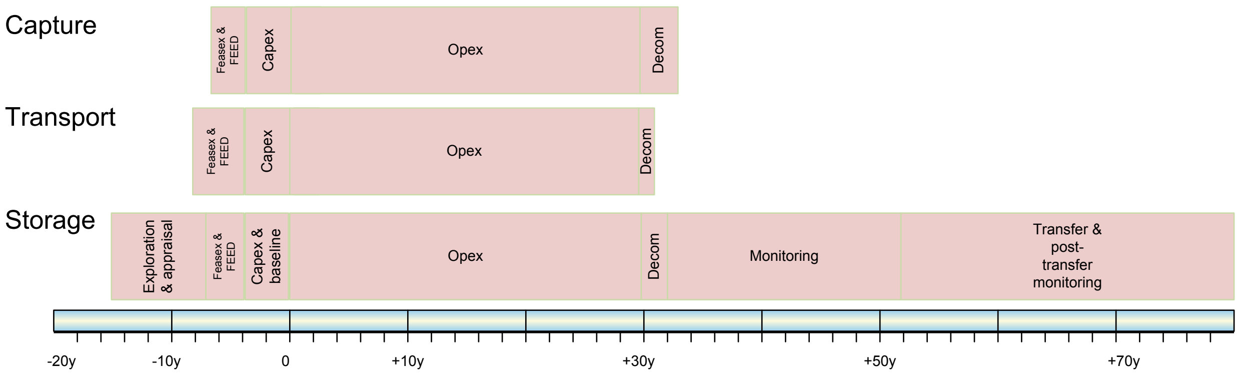

Figure 3: Timeline for expenditure for CO_2 capture, transport and storage

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.