Zero emissions platform

Building a CO_2 transport infrastructure for Europe

European Technology Platform for Zero Emission Fossil Fuel Power Plants

Contents

Executive summary

- **CCS is on the critical path to deliver the EU Energy Roadmap 2050**

The critical role of CO_2 Capture and Storage (CCS) in decarbonising Europe *cost-effectively* – is now indisputable: it can not only deliver substantial emission reductions across a range of industries,[1] but provide the catalyst for economic growth – creating *and* preserving jobs. Indeed, in some industries, such as steel and cement, it is the only means of achieving deep emission cuts. Combined with sustainable biomass, CCS can even remove CO_2 from the atmosphere – already recognised as a significant and attractive abatement solution.

Crucially, CCS can also complement intermittent renewable energy sources with low-carbon, baseload *and* balancing generation. As a key enabler in the shift to a green economy, CCS is therefore central to *every* energy scenario of the EU Energy Roadmap 2050.[2]

CCS is on the critical path and there is no doubt it can deliver, as shown by international developments where final investment decision (FID) has already been taken on large-scale demonstration projects worldwide. However, current policy measures in Europe have so far failed to deliver large-scale CCS demonstration at the speed and scale required: there was deep disappointment that none was selected in the first tranche of the 'NER 300'[3] – despite the fact that it was set up expressly to "help stimulate the construction and operation of up to 12 commercial (CCS) demonstration projects" (Article 10a.8, EU ETS Directive).

The window of opportunity is vanishing fast. Additional, short-term policy action is therefore vital to keep CCS on track to deliver the EU Energy Roadmap – *keeping pace with that of well-advanced projects*.

- **Developing a CO_2 infrastructure must start *now* – ahead of wide-scale deployment**

Large-scale CCS requires the development of a transport infrastructure on a scale comparable to that of the current hydrocarbon infrastructure, capable of transporting hundreds of millions of tonnes of CO_2 every year – from power plants and industrial sectors to suitable storage sites, EU-wide.

If different CO_2 sources are located in close proximity, they can share both CO_2 transport *and* storage infrastructure, thus benefitting significantly from economies of scale. Such clusters will also act as the launch pads for wider deployment by providing practical experience in the design and operation of shared CO_2 infrastructure.

However, both transport and storage infrastructure have very long lead times: characterisation of storage sites can take between 6 and 10 years, while transport infrastructure involves addressing a wide range of stakeholder interests, which itself can take between 6 and 10 years. This process will take even longer in Member States without strong planning legislation and/or the requisite national laws to confer rights for the development, ownership and operation of CO_2 infrastructure. Early strategic planning is therefore vital, with any cross-border restrictions removed.

- **The European Commission and Member States must provide a clear signal for investment**

It is essential to investor confidence that both the European Commission ("the Commission") and Member States demonstrate a clear, credible commitment to CCS, aligned at all levels of Government. This includes

[1] The application of CCS to industrial sectors beyond power (e.g. steel, cement, refining, chemicals, ammonia) is expected to deliver half of the global emissions reductions required by 2050 from CCS (International Energy Agency, IEA)
[2] http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf
[3] In 2008, the EU agreed to set aside 300 million Emission Unit Allowances (EUAs) from the New Entrant Reserve under the EU Emissions Trading Scheme (ETS) Directive to demonstrate CCS and innovative renewable energy technologies

ensuring it is fully represented in the Energy Infrastructure Package; undertaking urgent, structural reform of the EU carbon market; and establishing additional economic measures at national level.

National CCS Master Plans must also be established, with concrete arrangements for spatial planning and land use coordination (including the orderly transition of pore space from petroleum production to CO_2 storage). As part of a coordinated approach to pan-European CCS infrastructure development, this will ensure a level playing field for investors and the most effective long-term solutions.

- **Key actions to be taken as a matter of urgency**

In order to overcome or reduce existing barriers and accelerate the development of a CO_2 infrastructure, ZEP therefore recommends that the following actions are taken as a matter of urgency:

1. **Broaden the scope of the Energy Infrastructure Package** to a) support the development of CCS transport infrastructure and b) include CCS infrastructure located wholly in one Member State as this will contribute significantly to the future deployment of CCS in Europe. (A CCS project of "Common Interest" could be defined as one that involves the creation of CO_2 transport infrastructure with additional spare capacity *beyond* the needs of the first demonstration capture plant.)

2. **Establish short-term incentives in addition to the EU ETS** in order to make CO_2 infrastructure more attractive to investors, including:
    - Special support to de-risk transport investment for first movers
    - Funding towards the development of CO_2 infrastructure (transport and storage) in its own right, i.e. the funding instrument should not be tied to the identity of any given capture plant. However, tying funding to specific storage site(s) should be considered.
    - Strategic support for CCS projects of Common Interest that provide CO_2 transport and/or storage infrastructure with additional spare capacity *beyond* that required for any given first end-to-end demonstration project.

3. **Ensure consistent transposition of the CCS Directive**[4] by Member States in order to reduce investment risks. Third party access requirements should be initially waived for the transport infrastructure element of projects until regulatory clarity on this issue is achieved. Projects that receive public funding (e.g. for providing additional capacity above the project's need) should be excluded from this waiver.

4. **Ratify the OSPAR and London Protocol amendments** as a matter of urgency. Pending these ratifications, ZEP supports the IEA's working paper on options under international law to enable transboundary movement of CO_2 for sub seabed storage.[5]

The Zero Emissions Platform (ZEP)

Founded in 2005, ZEP represents a unique coalition of stakeholders united in their support for CCS as a critical solution for combating climate change. Indeed, CCS is the single biggest lever for reducing CO_2 emissions – providing almost 20% of the global cuts required by 2050 (IEA). Members include European utilities, oil and gas companies, equipment suppliers, national geological surveys, academic institutions and environmental NGOs. The goal: to make CCS commercially viable by 2020 and accelerate wide-scale deployment.

www.zeroemissionsplatform.eu

[4] Directive on Geological Storage of CO_2: 2009/31/EC
[5] "Carbon Capture and Storage and the London Protocol: Options for Enabling Transboundary CO_2 Transfer, OECD/IEA, 2011: www.iea.org/publications/freepublications/publication/CCS_London_Protocol.pdf

1 Objectives and scope

The aim of this report is to develop a powerful vision for CCS deployment, provide advice on demonstration execution and support the CCS community with a special interest in CO_2 infrastructure in Europe. This includes:

- Highlighting the critical importance of CO_2 transport infrastructure
- Explaining why investment in the development, planning and co-ordination of CO_2 transport infrastructure needs to happen *now* – ahead of wide-scale deployment
- Addressing key regulatory, technical, economic and social barriers to development
- Providing key recommendations on political, regulatory and monetary instruments that could lower these barriers
- Outlining business models for the development and operation of CO_2 transport infrastructure
- Demonstrating the case for CO_2 clusters as the launch pad for gaining practical experience in the design and operation of shared user CO_2 infrastructure.

CO_2 infrastructure comprises both CO_2 transport and storage infrastructure. Whilst this report is primarily focused on transport infrastructure, there is a close inter-relationship between the two: in order to make a successful investment case for large-scale CO_2 transport infrastructure, it is necessary to have confidence in both the volumes of CO_2 to be captured and the associated storage capability. Both capture and storage present uncertainties.

However, whilst anthropogenic CO_2 capture capability can be controlled by mankind, storage capability is intrinsically outside our control: it is a facet of geological conditions laid down in prior millennia. For this reason, identifying and having confidence in storage capability is of primary importance.

2 Why CO_2 infrastructure requires urgent attention in Europe

2.1 CCS is on the critical path to deliver the EU Energy Roadmap 2050

The critical role of CCS in decarbonising Europe is now indisputable: in the power sector it must account for 19-32% of the EU's total emission reductions by 2050,[6] according to the EU Energy Roadmap 2050. This means that "For all fossil fuels, Carbon Capture and Storage will have to be applied from around 2030 onwards".[7] The IEA has also confirmed that the global costs of meeting climate targets *without* CCS would be a stark 40% higher. Crucially, CCS will also complement intermittent renewable energy sources with low-carbon, baseload *and* balancing generation.

Yet the potential for CCS goes far beyond power, with other industrial applications expected to deliver half of the global emissions reductions required by 2050 from CCS (IEA). Indeed, in some industries, such as steel, cement and refining, it is the *only* means of achieving deep emission cuts as significant CO_2 emissions are related to the process itself, rather than to its energy consumption. Combined with sustainable biomass, CCS can even *remove* CO_2 from the atmosphere – already recognised as a significant and attractive abatement solution.

There is no doubt that CCS can deliver, as confirmed by international developments where FID has already been taken on large-scale demonstration projects in Australia, Canada and the U.S. The ZEP cost reports[8] also give confidence that following a successful demonstration, CCS will be cost-competitive[9] with the full range of low-carbon power options, including on-/offshore wind, solar power and nuclear.

Potentially worth billions of Euros annually, CCS will therefore enable significant investments in energy infrastructure at a difficult economic time for Europe – a true EU collaboration between companies, with the opportunity to export skills and technology on an international scale.

2.2 Development of a CO_2 infrastructure needs to start now – ahead of wide CCS deployment

Wide-scale deployment of CCS requires dedicated CO_2 transport grids that need to be financed, consented and constructed. In order to meet decarbonisation targets, the EU Energy Roadmap estimates a total of ~32 GW of CCS is needed by 2035, rising to 190 GW by 2050,[10] equivalent to 11,000 km and 20,000 km[11, 12] of CO_2 pipeline infrastructure, respectively. In keeping with other low-carbon technologies, CCS is therefore a complex and capital-intensive task.

However, there are opportunities for cost reduction: the largest step reduction can be achieved by investing in large, shared pipeline infrastructures together with large storage clusters serving multiple CO_2 sources.[13] This has the added benefit of providing a nucleus for the most expedient deployment of CCS for industrial applications. However, the need to develop large, shared infrastructure exacerbates first-mover disadvantage – with the highest market and regulatory risks and investment at the very beginning of the learning curve before experience brings costs down. This first-mover disadvantage itself acts as a positive

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6 The EU is committed to reducing GHG emissions by 80-95% by 2050 (versus 1990 levels)
7 http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf
8 www.zeroemissionsplatform.eu/library/publication/165-zep-cost-report-summary.html
9 €70-90/MWh for CCS with coal, €70-120/MWh with gas, operating in baseload (7,500 hours equivalent full load each year); fuel costs for hard coal and natural gas are 2.0-2.9 €/GJ and 4.5-11.0 €/GJ respectively
10 Diversifies supply technologies Scenario of the "Energy Roadmap 2050, Impact Assessment and scenario Analysis" European Commission SEC(2011) 1565: http://ec.europa.eu/governance/impact/ia_carried_out/docs/ia_2011/sec_2011_1565_en.pdf
11 "Feasibility Study for Europe-Wide CO_2 Infrastructures", ARUP October 2010: http://ec.europa.eu/energy/coal/studies/doc/2010_10_co2_infrastructures.pdf
12 "Development of a large-scale CO_2 transport infrastructure in Europe: matching captured volumes and storage availability", CO2Europipe, September 2010: http://co2europipe.eu/Publications/D2.2.1%20-%20CO2Europipe%20Report%20CCS%20infrastructure.pdf
13 "The potential for reducing the costs of CCS in the UK," UK Carbon Capture and Storage Task Reduction Task Force, November 2012: http://webarchive.nationalarchives.gov.uk/20121217152407/http:/www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-capture-storage/6987-the-potential-for-reducing-the-costs-of-cc-in-the-.pdf

disincentive to infrastructure investment. Demonstration will therefore play a vital role in reducing costs for subsequent CCS deployment.

ZEP believes that CCS infrastructure planning and development will follow the characteristics of the transmission infrastructure for electricity, oil and natural gas, where bulk transportation of the commodity in shared-use networks brings huge economies of scale for consumers. In the case of CCS, infrastructure will be driven by the location of the future storage destination rather than the future source of the energy. Fundamentally, the location of storage capability is a natural resource dictated by Mother Nature – the challenge is to understand and characterise the capability of this natural resource and the most efficient way to access it. Like the existing gas and electricity transmission infrastructure, CO_2 systems will be required to include transboundary as well as national infrastructure.

2.3 Long lead-times for CO_2 transport and storage infrastructure leave no margin for delay

The European Commission's Energy Infrastructure Package establishes the need for ~€200 billion of investment in gas pipelines, electricity grids and CO_2 transport infrastructure in the next 10 years.[14] However, it recognises that the investments needed to reach decarbonisation targets for mature energy infrastructure will not be made, or not be made in time, for two main reasons: 1) the length of time to obtain permits (over 10 years in some cases) and 2) current incentives do not attract sufficient private capital due to prevailing regulatory and market arrangements.

Unlike the mature sectors of natural gas and electricity transmission, CCS is in its infancy with an acute gap between Europe's policy aspiration, as indicated by the EU Energy Roadmap, and the reality that there are currently no commercial-scale CO_2 storage sites or transmission capability. Regulatory and incentive arrangements for stimulating investment are also still under development. CCS therefore has the strongest need for careful planning and prioritisation at both national and EU level.

The dilemma for CO_2 transport and storage is that whilst the availability of capacity is an enabler and will positively influence the roll-out of CCS, investment in infrastructure will depend on that roll-out. This results in the current impasse whereby investors are unwilling to invest in capture plant where there is an uncertainty regarding the availability of transport and storage infrastructure; and, conversely, infrastructure investors are unwilling to invest without the certainty that capture plants will emerge.

Co-ordinated planning of bulk transport CO_2 infrastructure linked to significant storage capability will unlock this impasse by providing the confidence for investment in capture facilities by point source emitters. Storage characterisation is therefore essential to provide the confidence to progress planning and investment in efficient CO_2 transport infrastructure. However, this can take between 6 and 10 years. (See section 5.2 for examples of actual storage development within clusters, including the development of Aquifer 5/42 in the Southern North Sea.)

Infrastructure such as cross-country pipelines involves consultation and consideration of a wide range of stakeholder interests and can also potentially take between 6 and 10 years. For CCS, this process will be longer in Member States that do not have strong planning legislation to facilitate the development of such infrastructure and/or have not passed the requisite national laws to confer rights for the development, ownership and operation of CO_2 infrastructure. In short, Europe's CCS ambition for the 2020s and 2030s is already becoming undeliverable due to time constraints. With CCS on the critical path to deliver the EU Energy Roadmap 2050, there is no margin for further delay[15] – acting now will also ensure a lower, overall decarbonisation cost for Europe.

A new sense of urgency and collective responsibility must therefore be brought to bear on the development of CO_2 transport and storage infrastructure.

[14] COM/2011/658, October 2011:http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0658:FIN:EN:PDF
[15] "EU CCS Demonstration Projects. Challenges and Blockers on the way to FID," ZEP, May 2012: www.zeroemissionsplatform.eu/downloads/1088.html)

3 Removing the barriers to development

In order to advance the development of a European CO_2 infrastructure, it is essential that action is taken to overcome the following barriers.

3.1 Ensure CCS is fully represented in the European Energy Infrastructure Package

The proposed trans-European Energy Infrastructure package has the limitation that *it focuses on cross-border infrastructure only*. This threatens to render it ineffective as a stimulus for CCS infrastructure as there is a need for both national *and* cross-border CO_2 transport *and* storage, with national hubs forming the foundation for cross-border transport at a later date.[14]

The Energy Infrastructure Package proposes only that a number of projects of "Common Interest" are selected; these should display economic, social and environmental viability and involve at least two Member States, with additional sector-specific criteria.

ZEP believes that the scope of the Energy Infrastructure Package should be widened to support the development of CO_2 transport infrastructure and acknowledge that CCS infrastructure located wholly in one Member State can have wider benefit for the future deployment of CCS in Europe and therefore also be of common interest.

ZEP also proposes that a suitable definition for a CCS project of "Common Interest" would be one that involves the creation of CO_2 transport infrastructure with additional spare capacity *beyond* the need of the first demonstration capture plant.

A further test could be that the proposed infrastructure is located in a cross-border priority corridor, to be defined by the EU (e.g. a geographic area of need consistent with the recommendations of earlier work undertaken by the Commission, e.g. the Joint Research Centre (JRC)[16] and Europe Wide CO_2 Infrastructures Feasibility Study[11]). This proposal would directly address the current policy and incentive gaps and promote the sharing of common transport infrastructure by multiple capture projects, with attendant economy-of-scale benefits. The strong point of common European interest is that by including provision of spare capacity,[17] the barrier to deployment of follow-on CCS projects is reduced.

Where it is not possible to provide future capacity within the infrastructure of the first projects, steps should be taken to ensure that barriers to future infrastructure are reduced and removed. For example, it is very likely that CO_2 infrastructure will run through areas with a limited number of pipeline corridors; areas available for shipping hubs due to urban population constraints; or environmentally sensitive areas. It should therefore be ensured that, during the design of projects, routing restrictions are identified and steps taken to ensure that specific corridor space can be reserved for later pipeline additions.

3.2 Establish incentives beyond the EU ETS to support first movers

The risk of investing in the development of a CO_2 transport infrastructure is too high for any single private investor to bear: whilst the capital needed is high, the probability that a significant number of CCS projects will be completed by 2020 is low, with the risk of significant under-utilisation of the infrastructure.

At present, the market and regulatory framework does not support development in these circumstances: there are no support mechanisms specifically targeted at providers of CO_2 infrastructure, with most focused on the delivery of an incentive (either an avoided cost or subsidy) to the upstream part of the CCS chain,

[16] "The evolution of the extent and the investment requirements of a trans-European CO_2 transport network", Joint Research Centre (JRC) 2010: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/15100/1/ldna24565enn.pdf
[17] Spare capacity would not fall under the proposed waiver for third party access requirements

e.g. the power plant that creates the value to support the rest of the chain. This approach will result in the development of infrastructure that is only sized to meet the needs of the host plant.

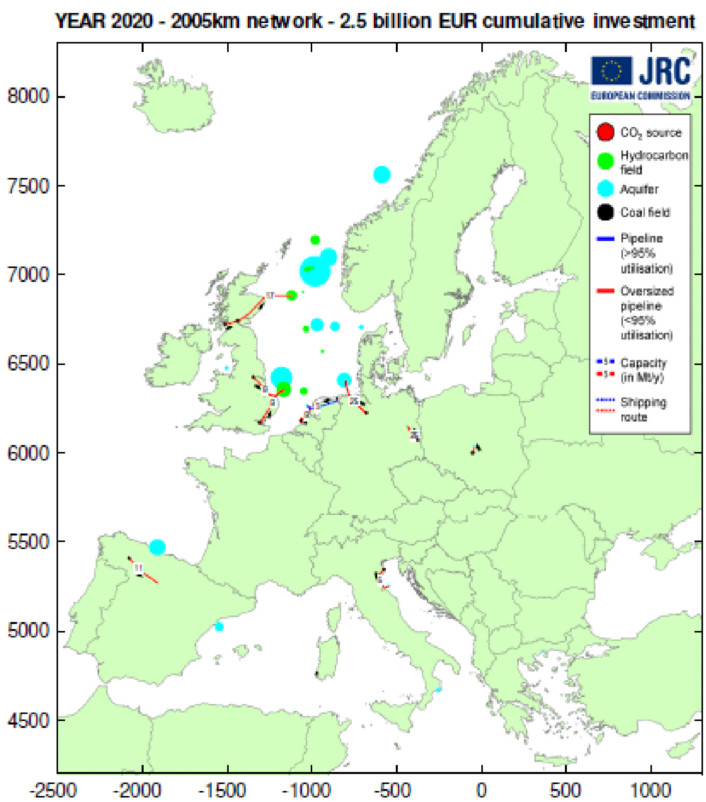
Furthermore, the anticipated users of CO_2 infrastructure are both power generation *and* industrial sectors. The absence of any support measures directed towards industry means that Europe is not tapping into as much as 50% of the customer base.

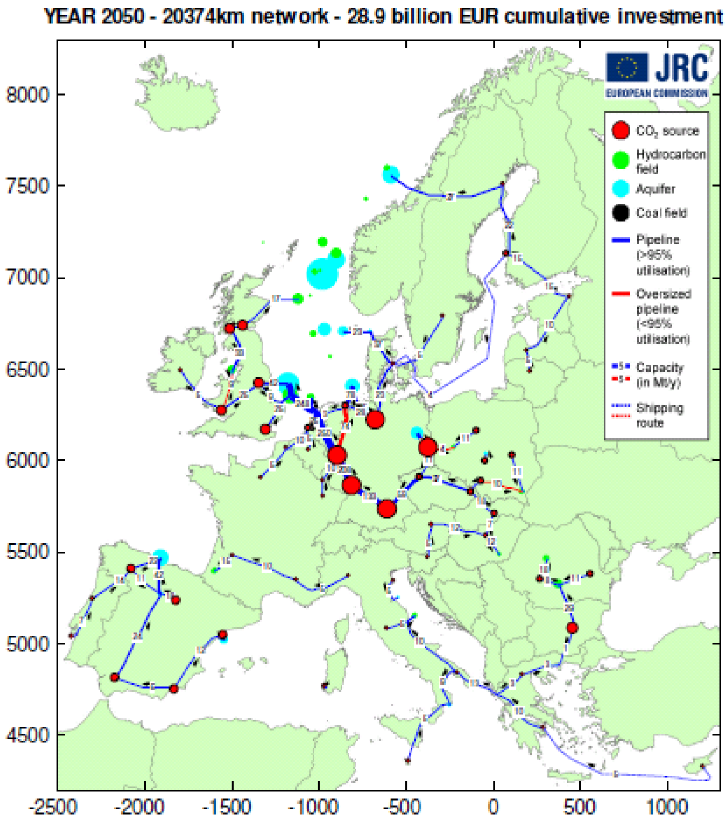
It is therefore vital that financial support is provided for this critically needed investment at this early stage of development. This should focus on regions identified as having both high concentrations of emitters and storage sites, and the greatest potential to deliver economies of scale (see Figure 1).

Short-term incentives beyond the EU ETS are therefore needed to make CO_2 infrastructure more attractive to investors. These should include:

- **Special support to de-risk transport investment for first-movers**
- **Funding (i.e. seed money) towards the development of CO_2 infrastructure (transport and storage) in its own right, i.e. the funding instrument should not be tied to the identity of any given capture plant. However, tying funding to specific storage site(s) should be considered.**
- **Strategic support for CCS projects of Common Interest that provide CO_2 transport and/or storage infrastructure with additional spare capacity (e.g. capital grant for incremental cost) *beyond* that required for any given end-to-end demonstration project.**

Figure 1: Scenarios identified by the EU's Joint Research Centre for the development of a trans-European CO_2 transport network[16]





3.3 Provide clarification on third party access provisions and regulatory status

The CCS Directive contains Third Party Access (TPA) provisions to ensure that all potential operators can obtain “fair and open” access to CO_2 transport and storage infrastructure. However, the Directive provides little detail on the nature of these arrangements, with Member States given the discretion to determine the precise means of providing such access.

Due to delays or incomplete transposition by Member States,[18] significant uncertainty exists for potential investors over how TPA will be implemented in practice. There is also a concern that differences between national legal cultures and administrative structures could lead to discrepancies in third party access requirements between Member States. Given the need for significant upfront investment, investors need to know the conditions under which they can run their business. In the absence of greater regulatory clarity, such investments will be perceived as high risk and therefore not be undertaken at all, or will need a high return on investment to be attractive.

To reduce investment risks, ZEP recommends that the EU drives for consistent transposition of the CCS Directive by the Member States and clarifies the regulatory status of CO_2 transport and storage infrastructure.

It can also be argued that it would be better to have no TPA regulation, rather than the current situation of having regulation but no clarity. At present, first movers face the entire burden of breaking through the “investment impasse”; carry all the first-of-a-kind permitting burden; and run the gauntlet of potentially

[18] As of May 2012, only nine had transposed the Directive despite a deadline of June 2011: Spain, Denmark, the Netherlands, Italy, France, Lithuania, Malta, Slovenia and the U.K. Based on the status update provided in the EU CCS Communication (COM(2013) 180 final, 27.03.2013), only one Member State has not indicated to the Commission any transposition of the Directive; however, checks by the Commission on the completeness and correctness of the transpositions are not yet complete.

negative reputational impact associated with adverse public perception. At the same time, they face serious commercial risks of being disadvantaged, e.g. in relation to transport, the first user would be disadvantaged if he carried the burden of fixed transport investment costs while follow-on users benefited from lower incremental tariffs. In storage, the first mover could be disadvantaged if follow-on customers triggered the onset of additional or longer-term storage liabilities that are disproportionate to the activity in question.

ZEP therefore recommends that the TPA requirements of the CCS Directive should initially be waived for the transport element of infrastructure projects until regulatory clarity is achieved. However, projects that receive public funding (e.g. for providing additional capacity beyond a project's need), should be excluded from this waiver.

The ZEP is currently supporting the forthcoming review of the CCS Directive.

3.4 Demonstrate a clear commitment to CCS at all levels of government

A disconnect currently exists between Member States engaged in CCS demonstration projects and a public that remains largely unaware of CCS and why it is urgently needed. Lack of public acceptance is currently one of the major reasons for the failure of all kinds of large investment projects in the power, industry and infrastructure sectors. It is therefore crucial that governments articulate a clear vision and strategy for energy and climate change as a whole, including the critical role of CCS in line with the EU Energy Roadmap.

Several hurdles remain for public engagement and most are inextricably linked to the challenges facing CCS in general. These include improving understanding of the unique societal benefits of CCS and its critical role within the energy system; making the business case for CCS at national *and* local level; and providing tangible demonstration experience to build industry, government and public confidence. A large energy education effort, in conjunction with stakeholder dialogue, is therefore essential.

All communication and engagement activity surrounding first-mover CCS projects should be designed to build and reinforce trust and understanding between a developer and its stakeholders. Public engagement work must therefore start early and demonstrate commitment, consistency, respect and honesty.

While individual infrastructure developers have the main responsibility for achieving public support for their projects, a key success factor is the alignment and shared vision of key government bodies (EU, national, region, local). Once the EU and Member States communicate their clear support for CCS, achieving public acceptance for individual CCS projects will be much easier.

The European Commission and Member States must demonstrate a credible commitment to CCS and ensure alignment between different levels of government.

3.5 Establish National CCS Master Plans to provide clarity for future markets

The urgent, *timely* delivery of an EU CCS demonstration programme is critical to achieving the EU Energy Roadmap 2050. However, unless there is additional, short-term policy action, that delivery remains uncertain – with disastrous consequences for Europe's energy and climate goals.

Indeed, there was deep disappointment that no CCS project was selected in the first tranche of the 'NER 300' – despite the fact that it was set up expressly to "help stimulate the construction and operation of up to 12 commercial (CCS) demonstration projects" (Article 10a.8, EU ETS Directive). In addition to structural reform of the EU carbon market, Member State support in the form of grants, feed-in tariffs and shaping an appropriate framework is therefore urgently required.

National CCS Master Plans should also be established to provide clear signals on CCS in each Member State and provide meaningful co-ordinated arrangements for spatial planning of CO_2

transport and storage infrastructure, both onshore and offshore (including the orderly transition of pore space from petroleum production to CO_2 storage).

3.6 Ratify OSPAR and London Protocol to allow cross-border CO_2 transport and subsea storage

Cross-border transport and sub-seabed injection of CO_2 still faces significant legal hurdles. Whilst the 2007 OSPAR Convention[19] amendment formally entered force in July 2011, enabling sub-seabed injection of CO_2 for the purposes of storage, it has not yet been ratified by eight Member States,[20] where CO_2 sub-seabed storage is therefore still not permissable.

The London Protocol[21] was also amended in 2009 to allow cross-border transportation of CO_2 for the purposes of storage. The amendment requires ratification by two-thirds of the contracting parties, i.e. 27 out of 40, but to date only Norway and the U.K. have done so. The London Protocol therefore restricts the movement of CO_2 across borders for the foreseeable future. N.B. These constraints do not apply if the CO_2 is used under the auspices of a "working fluid" in Enhanced Oil Recovery (EOR) operations; however, the vast majority of suitable storage sites are deep saline aquifers.

ZEP recommends that the European Commission and Member States accelerate efforts towards the ratification of the OSPAR and London Protocol amendments.

Given the current rate of ratifications, consideration of interim options is required to facilitate export of CO_2 for offshore storage in the near to mid-term. **ZEP supports the IEA's working paper[22] on options under international law to enable transboundary movement of CO_2 for sub seabed storage, pending ratification of the London amendment**. This includes:

- An interpretative resolution based on the general rule of interpretation
- Resolving to provisionally apply the 2009 amendment
- Subsequent agreement between contracting parties (bilateral or multilateral)
- Modification of the operation of the relevant aspects of the London Protocol as between two or more contracting parties
- Suspension of the operation of the relevant aspects of the London Protocol as between two or more contracting parties.

3.7 Promote pan-European coordination to optimise planning and investment

Introducing common principles on EU CO_2 reduction policies into regulatory frameworks of EU neighbouring and partner countries should be encouraged in order to facilitate climate change mitigation and ensure a level playing field for investors. Indeed, the installation and deployment of a commercial CO_2 infrastructure is expected to be driven by regulatory intervention and support across Member States, in terms of both policy development and funding.

Each Member State must therefore be aware of CCS projects in all the other States, as future interconnections must be considered between the projects and the most effective solution selected for each new CCS development. It should also be clear which regional, local and national governments are responsible for the permitting process.

[19] OSPAR Commission: http://www.ospar.org/welcome.asp?menu=0
[20] Spain, Portugal, France, Belgium, Austria, Sweden, Finland, Ireland
[21] London Protocol and Sequestration of CO_2: www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx
[22] "Carbon Capture and Storage and the London Protocol: Options for Enabling Transboundary CO_2 Transfer, OECD/IEA, 2011: www.iea.org/publications/freepublications/publication/CCS_London_Protocol.pdf

4 Creating effective business models

At the present time, it is very difficult to point towards an optimum structure for the ownership and operation of CO_2 transport infrastructure: there is no pre-set, definitive or successful formula for such issues as the ownership boundary between capture, transport and storage assets, or the commercial arrangements that should apply across the chain.

4.1 Potential business models

The business models below briefly describe which parties would be interested in investing into a CO_2 infrastructure and how it would be financed from the current CO_2 market perspective.

1. **Emitters invest in building an infrastructure**
   The main reason for emitters to invest in a CO_2 infrastructure is the need to transport CO_2 from their site to a suitable storage location. In this business model, the monetary value of the CO_2 is currently defined by the Emission Unit Allowance (EUA) price. The EUA price therefore needs to be sufficient not only to finance the transportation of CO_2, but also the rest of the CCS process chain (capture, compression, storage etc). At current EUA prices (below €5 in January 2013), this is not economical.
2. **Storage providers/oil and gas companies invest in building an infrastructure**
   Storage providers and oil and gas companies invest in building an infrastructure for the purposes of bringing CO_2 to a developed storage location, or to prolong the life span of oil/gas fields by using CO_2 for EOR/EGR.[23] The monetary value in this business model is defined by the payments of emitters for the disposal of their CO_2, or in the case of EOR/EGR, via the additional oil/gas production.
3. **Consortia/transport providers invest in building an infrastructure**
   Consortia or independent transport providers invest in building and operating a CO_2 infrastructure based on the prospective revenue stream from charges levied on its users. This is secured via long-term service contracts with connected capture and storage operators, or option agreements with potential future users.
4. **National or EU-wide initiative of investing in infrastructure**
   Member States appoint a company to build, own and operate CO_2 infrastructure, providing it with a mandate to recover a revenue stream commensurate with the risks involved, e.g. via general taxation or a levy imposed on fossil fuel-based electricity generators.

4.2 Common issues to be addressed

CO_2 transport infrastructure is currently being developed in Europe on a merchant basis: no utilities have franchises to operate CCS infrastructure or recover costs from energy consumers, although some consider it likely that in time CO_2 transport infrastructure will become regulated in a similar way to electricity and natural gas transmission. Irrespective of the form of economic regulation (merchant or fully regulated), the same underlying issues must be addressed, namely:

- How will the infrastructure be financed?
- How will the capital and operating costs for multi-user networks be divided between its users?
- How will liabilities be divided between investors, owners and users?
- How will first movers be incentivised to help deliver climate and energy policy goals and drive down unit costs for the benefit of consumers?

As the CCS industry develops, it is clear that there is no common or standard approach across projects – let alone Europe – to constructing viable and appropriate business models. Industry is starting to identify the key issues, but **further work needs to be done to explore and define business models**.

[23] Enhanced Gas Recovery

5 Utilising CO_2 clusters as launch pads for wider deployment

A CCS cluster constitutes the sharing of transport and/or storage infrastructure by more than one capture proponent – a nucleus for “first-mover” projects to gain a critical mass. It is also a platform from which the CCS industry can develop from demonstration to wide-scale deployment – either by providing spare transport or storage capacity, or technical solutions and business models that can be readily extended or up-scaled to accommodate follow-on demand, or replicated elsewhere.

The merits of CO_2 clusters are manifold, including their ability to:

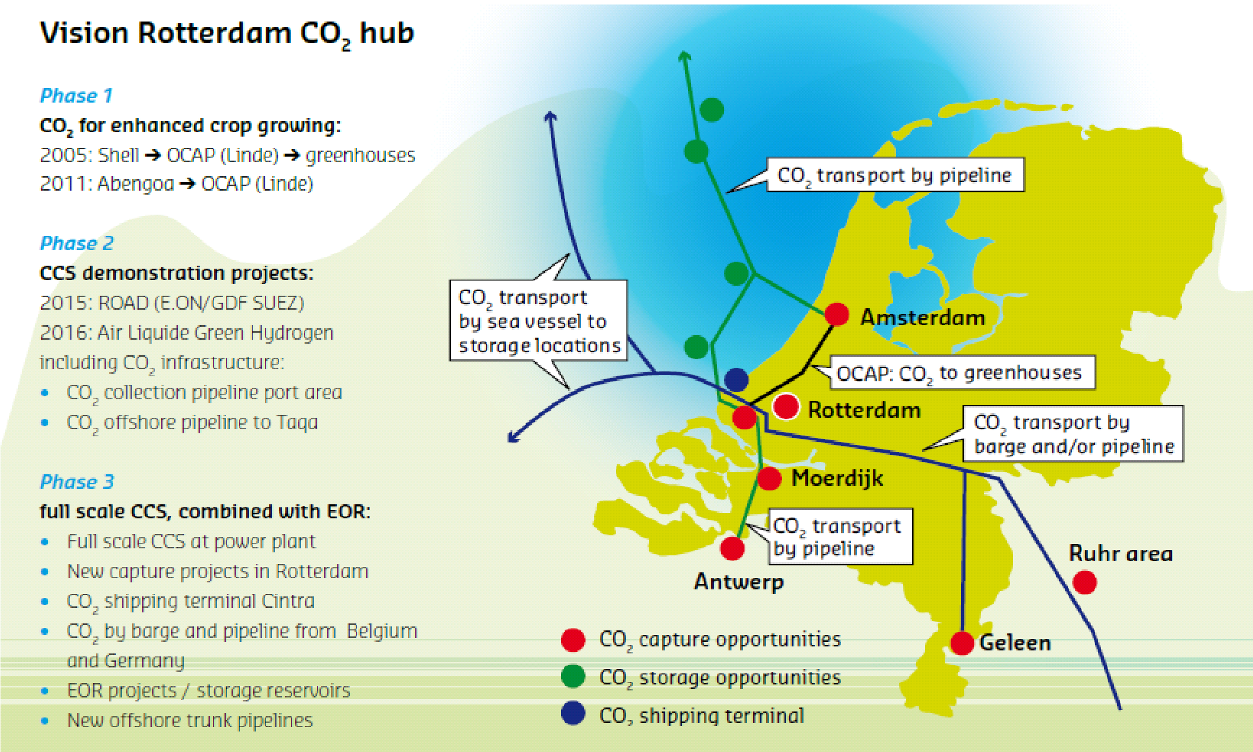
- Achieve economies of scale where unit costs are substantially lower than stand-alone projects
- Minimise the environmental impacts associated with infrastructure development, as well as the impact on communities
- Minimise and streamline efforts in relation to planning and regulatory approvals, negotiations with landowners and public consultations
- Lower entry barriers for all participating CCS projects, including emitters that do not have to develop their own separate transportation and storage solutions – especially important for industrial sources
- Enable industrial sources to utilise CCS and, in turn, further reduce overall costs (as a broader number of different sources are expected to lead to a smaller variation in flow and hence increased system stability).

The economies of scale that can be achieved and the benefits of integrated CO_2 transportation networks are evidenced in the many proposals for CO_2 hubs, networks and clusters currently in development. Two such examples are discussed below: the Port of Rotterdam CO_2 Hub and the Yorkshire and Humber CCS Cluster.

5.1 Port of Rotterdam CO_2 Hub

Rotterdam aims to make its port the CO_2 hub of North-west Europe, facilitating the transport of captured CO_2 by pipelines, barges and sea vessels to offshore reservoirs for permanent storage and/or EOR (see Figure 2 below). It envisages a multi-stage expansion of the CO_2 hub over the next 15 to 20 years – from transporting 1 million tonnes of CO_2 annually to greenhouses for enhanced crop growth, to 3 million tonnes annually, including the first CCS demonstration projects; and eventually to dozens of millions of tonnes annually, including large-scale storage and EOR projects with captured CO_2 from North-west European industrial clusters.

Figure 2: Vision of the Port of Rotterdam CO_2 Hub[24]



5.2 Yorkshire and Humber CCS Cluster

The Yorkshire and Humber region is an ideal location for CCS due to its high concentration of power stations and large industrial plants in close proximity to offshore storage opportunities beneath the North Sea. The region produces more than 45 Mt CO_2 per year from large point sources, including fossil fuel power stations, oil and gas refineries and industrial processes – equivalent to around a third of the total annual emissions from the U.K. energy production sector. National Grid is therefore proposing to establish a shared user CO_2 pipeline and large-scale storage facility to serve the Yorkshire and Humber region.

In early 2010, National Grid began screening the southern North Sea for high quality candidate storage sites to serve the Yorkshire and Humber Cluster, as part of the EEPR programme together with Powerfuel, Hatfield (now the 2Co Energy Don Valley Power Project). The preferred storage site is a deep saline aquifer known as 5/42.

[24] "Port of Rotterdam CO_2 hub: crucial stepping stone towards sustainable economic growth", Rotterdam Climate Initiative, July 2012: www.rotterdamclimateinitiative.nl/ccs

The preferred onshore route corridor for the initial backbone pipeline and locations of associated above-ground transport infrastructure were also selected (see Figure 3 below), based on feedback from two rounds of public consultation during 2011 and 2012.

Finally, in February 2013, intensive discussions with the relevant regulatory authorities resulted in the award of the U.K.'s first ever CO_2 appraisal and storage licence and an associated Agreement for Lease from The Crown Estate. This process has taken approximately three years (against a backdrop where the U.K. has a mature offshore industry and pro-active implementation of the CCS Directive).

The next stage is to carry out intrusive exploration drilling of the target structure during 2013. Following analysis of the results, it will then be possible to further define storage capability, design requirements for the facilities and details of the storage permit.

The final design concept is to admit multiple sources of CO_2[25] into the common pipeline infrastructure via an onshore hub, with potential future links to the South Humber Bank. Provision will also be made for an offshore hub near the 5/42 storage location to facilitate the reception and distribution of CO_2, which may include future connections to emitters from mainland Europe and/or to EOR areas and other storage sites.

Figure 3: Yorkshire and Humber CCS Cluster – pipeline corridors and storage location[26]

[25] E.g. from the Don Valley Power Project near Doncaster and from other emitters in the region, including the White Rose CCS project at Drax and C.Gen's proposed new IGCC plant at Killingholme)

[26] Source: National Grid

5.3 Objective criteria for developing shared user CO_2 transport infrastructure

Table 1 summarises objective criteria for developing shared user CO_2 transport infrastructure, against which the characteristics of the Port of Rotterdam CO_2 Hub and Yorkshire and Humber CCS Cluster were discussed (see Annexes I and II). These criteria cover the distribution of sources and sinks; connecting CO_2 transport infrastructure; and the stakeholder and regulatory framework within which each cluster must operate.

Table 1: Objective criteria for developing shared user CO_2 transport infrastructure

Item	Criteria
Catchment of CO_2 Emitters	A high geographic concentration of large point source CO_2 emitters is required to achieve economies of scale.
	Presence of both incumbent power generation and industrial CO_2 emitters, including a diverse spread of primary fuel types, is preferred to provide a diverse customer base.
	Active participants, preferably multiple parties already interested in developing capture facilities (active project developers contributing to the advancement of CCS builds momentum).
Catchment of CO_2 Storage Sites	A high geographic concentration of large, certified storage capacity is needed to provide confidence that there is a sufficiently large storage capability to support the development of the emitter cluster.
	Active participants, preferably multiple parties already interested in developing storage facilities (active project developers contributing to the advancement of CCS builds momentum).
	Early availability of offshore storage is preferred as there is more positive stakeholder acceptance.
	Access to storage rights within suitable timeframe.
Transport Solution	Short distances between the emitter gathering point and storage offtake location (lower capital and operating costs). Consideration should also be given to transport solutions which connect sources to large sinks or sink clusters.
	Transport solution should be suitable for the volumes of CO_2 required.
	Possibility of ship import/export terminals enhances future options.
	A broad and diverse potential customer base for transportation service is preferred (reduces asset stranding risk – provides resilience for potential transportation revenue in an uncertain future).
Local Stakeholders	Community support
	Local government support
	Support of Regional Development Agencies
National Government	Positive policy support is essential because early CCS will need an element of Member State co-funding and various regulatory permissions.
Regulatory and Permitting Framework	Clear transposition of CCS Directive into National Law is desired to provide a clear regulatory and permitting framework within which CCS infrastructure can be developed.
	Clear framework for obtaining land use planning approval for linear infrastructure is desired (otherwise high risk that development investment could be wasted).

Annex I: Port of Rotterdam CO_2 Hub

Table 2: Objective criteria for developing shared user CO_2 transport infrastructure – an assessment of Port of Rotterdam CO_2 Hub

Item	Criteria	Port of Rotterdam CO_2 Hub Link to North Sea Storage
Catchment of CO_2 Emitters	A high geographic concentration of large point source CO_2 emitters is required to achieve economies of scale.	When the Rotterdam Climate Initiative (RCI) was founded in 2007, Rotterdam's CO_2 emissions totalled ~29 Mt. If no action is taken, these are expected to rise to between 39 and 46 Mt in 2025. One of the key objectives of the RCI is to limit CO_2 emissions to 12 Mt in 2025 – a 50% reduction over 1990 levels. This means CCS must abate 17.5 Mt per annum (p.a.) by 2025.
	Presence of both incumbent power generation and industrial CO_2 emitters, including a diverse spread of primary fuel types, is preferred in order to provide a diverse customer base.	New/recently built, E.ON MPP3 1100 MW coal, Electrabel 800 MW coal, Enecogen 800 MW gas, Intergen 1200 MW gas. Existing installations E.ON Maasvlakte 1100 MWe. E.ON Capelse vaart 300 MWe, E.ON Galileistraat 300 MW. Largest sources of CO_2 (2010): Refineries 11 Mt p.a., Power sector 10 Mt p.a. Chemicals 4 Mt p.a.
	Active participants, preferably multiple parties already interested in developing capture facilities (active project developers contributing to the advancement of CCS builds momentum).	Current situation: • OCAP delivers CO_2 from the Shell refinery and Abengoa bio-ethanol plant to greenhouses • E.ON's CHP plant (RoCa) also delivers CO_2 to greenhouses • A pilot capture plant at the E.ON Maasvlakte coal-fired power plant (part of the CATO-2 R&D programme) CO_2 capture and reuse projects in development are: • ROAD large-scale demonstration project (EEPR and national government funded); FID expected in Q2 2013 • Green Hydrogen (Air Liquide project); applied for NER 300, not granted in 2013 • Cintra terminal for ship to EOR-fields projected in the new Maasvlakte area
Catchment of CO_2 Storage Sites	A high geographic concentration of large storage sites is needed to provide confidence that there is a sufficiently large storage capability to support development of the emitter cluster.	For Rotterdam, the demonstration projects are the first step to becoming a CO_2-hub for North Western Europe. The location of the hub makes it the shortest way for large emitters in the German Ruhr area to access available storage sites in the North Sea. Storage capacity based on (to be) depleted gas reservoirs is ~900 Mt. Feasibility studies of CO_2 storage have been done for several gas reservoirs, as well as for a deep saline aquifer, increasing the level of confidence in future offshore storage capacity.
	Active participants, preferably multiple parties already interested in developing storage facilities (active project developers contributing to the advancement of CCS builds momentum).	TNO has performed 3 Independent Storage Assessments, followed by the development of a computer cost model for transport and storage. These studies were supervised by an independent steering committee whose members included E.ON, GdF Suez, Vattenfall, Air Liquide, Stedin, Shell, CINTRA, TNO, Ecofys, Taqa, Chevron, Total, Anthony Veder, VOPAK a Linde gas.
	Early availability of offshore storage is preferred as there is more positive stakeholder acceptance.	Only offshore storage is mandated in the Netherlands.

Item	Criteria	Port of Rotterdam CO_2 Hub Link to North Sea Storage
	Access to storage rights within a suitable timeframe	The ROAD project holds the first CO_2 storage permit issued under the CCS Directive. The national government has processes in place for subsequent storage permit applications.
Transport Solution	Short distances between emitter gathering point and storage offtake location (lower capital and operating costs). Consideration should also be given to transport solutions which connect sources to large sinks or sink clusters.	Rotterdam is located near the shore and nearby offshore storage opportunities.
	Transport solution should be suitable for the volumes of CO_2 required.	Pipelines are already available or being developed (e.g. as part of ROAD); connection with the Ruhr area is also possible by ship.
	Possibility of ship import/export terminals enhances future options.	A terminal facility is possible as part of the new area development of Maasvlakte.
	A broad and diverse potential customer base for transportation service is preferred (reduces asset stranding risk – provides resilience for potential transportation revenue in an uncertain future)	Companies present and interested include, i.a., Shell, Linde Gas, GdF Suez, ROAD, Port of Rotterdam Authority, Taqa, Chevron, Total.
Local Stakeholders	Community support	Industry is very much interested. Deltalinqs (employer's organisation) holds regular meetings of CCS business platform; also separate working groups.
	Local government support	Public Private Partnership – RCI
	Support of Regional Development Agencies	Long-standing support for CO_2 infrastructure from industrial community within the Port of Rotterdam. Collaboration through RCI.
National Government	Positive policy support is essential because early CCS will need an element of Member State co-funding and various regulatory permissions.	The ROAD project and Green Hydrogen project are fully supported by the Dutch government.
Regulatory and Permitting Framework	Clear transposition of CCS Directive into National Law is desired to provide a clear regulatory and permitting framework within which CCS infrastructure can be developed.	CCS Directive has been implemented in the Netherlands.
	Clear framework for obtaining land use planning approval for linear infrastructure is desired (otherwise a high risk that development investment could be wasted).	The national 'Spatial Vision for Pipelines' supports special planning for new pipelines for CO_2 pipelines in preserved corridors.

Further information on the Rotterdam Port CO_2 Hub can be found as follows:

- CCS as a part of the Rotterdam Climate Initiative approach: www.rotterdamclimateinitiative.nl/EN/english_2011_design/50_reduction
- ROAD CCS demonstration project, E.ON/GDF-Suez: www.road2020.nl/en/
- Green Hydrogen Project (Air Liquide): www.globalccsinstitute.com/projects/12706
- CINTRA Project Summary (Ship transport and CO_2 hub: facilities): www.rotterdamclimateinitiative.com/documents/Factsheets/CINTRA.pdf

Annex II: Yorkshire and Humber CCS Cluster

Table 3: Objective criteria for developing shared user CO_2 transport infrastructure – an assessment of Yorkshire and Humber CCS Cluster

Item	**Criteria**	**Yorkshire and Humber CO_2 Emissions Linked to Southern North Sea CO_2 Storage**
Catchment of CO_2 Emitters	A high geographic concentration of large point source CO_2 emitters is required to achieve economies of scale.	The Yorkshire and Humber region in the North East of England has the largest cluster of CO_2 industrial emitters in the U.K., including a number of the U.K.'s top 50 emitters. The region produces ~90 Mt of CO_2 p.a. with more than 45 Mt emitted from large point sources, including fossil fuel power stations, oil and gas refineries and industrial processes. This is equivalent to around a third of the total annual emissions from the U.K. energy production sector.
	Presence of both incumbent power generation and industrial CO_2 emitters, including a diverse spread of primary fuel types, is preferred to provide a diverse customer base.	Existing large power stations in the area include: Drax 3906 MW coal, Ferrybridge 1986 MW coal, Eggborough 1940 MW coal, Brigg 268 MW CCGT, Keadby 735 MW CCGT, Saltend 1100 MW CCGT, Killingholme E.ON 900 MW CCGT, Killingholme Centrica 665 MW CCGT, Immingham 1218 MW CHP, South Humber Bank 1285 MW CCGT. Existing large industrial emitters in the area include: Tata Steel Scunthorpe (iron and steelworks) 5.1Mt CO_2 p.a., Humber Oil Refinery 1.8 Mt CO_2 p.a., Lindsey Oil Refinery 1.4 Mt CO_2 p.a.
	Active participants, preferably multiple parties already interested in developing capture facilities (active project developers contributing to the advancement of CCS builds momentum).	CCS capture projects in development include: • 2Co Power (Yorkshire) Ltd – Don Valley Power Project, 900 MW IGCC at Stainforth (formerly Powerfuel Hatfield) under development since 2006 and recipient, together with National Grid, of €180m EEPR funding • Capture Power Ltd – White Rose CCS project at site of Drax power station, 426 MW oxy-fuel; shortlisted by DECC in October 2012 to progress in its CCS Commercialisation Programme competition and supported by UK Government for NER 300 funding (although no award conferred); • C. GEN 470 MW CCGT/IGCC project at Killingholme on south Humber bank. An applicant in the first NER call and commenced planning approval process for the power plant in 2012 • SSE Ferrybridge CC Pilot 100+ project, opened in 2011. At 5 MW equivalent and capturing 100 tonnes of CO_2 per day, it is the U.K.'s largest capture pilot
Catchment of CO_2 Storage Sites	A high geographic concentration of large storage sites is needed to provide confidence that there is a sufficiently large storage capability to support the development of the emitter cluster.	Potential nearby storage capability of ~3 Gt/CO_2 in hydrocarbon reservoirs and ~14Gt/CO_2 in deep saline aquifers (based on British Geological Survey data) with a potential for future connection to central North Sea storage and to Dutch or Norwegian waters. Potential for the development of clusters of storage sites in the same way as clusters of emitters.

Item	Criteria	Yorkshire and Humber CO_2 Emissions Linked to Southern North Sea CO_2 Storage
Catchment of CO_2 Storage Sites	Active participants, preferably multiple parties already interested in developing storage facilities (active project developers contributing to the advancement of CCS builds momentum)	During 2010, National Grid undertook a comprehensive screening of all potential storage sites in the southern North Sea (both depleted hydrocarbon reservoirs and deep saline aquifers). A preferred target aquifer storage site, known as 5/42, was subsequently chosen for further development and in 2012, DECC awarded National Grid a CO_2 appraisal and storage licence, with intrusive exploration (drilling) planned for 2013. This storage site is expected to act as the anchor storage site for investment in the Humber cluster of shared user CO_2 transportation infrastructure.
	Early availability of offshore storage is preferred as there is more positive stakeholder acceptance.	Only offshore storage is mandated in the UK.
	Access to storage rights within a suitable timeframe	DECC and The Crown Estate are together facilitating access to CO_2 storage rights and tackling new issues arising from interactions with other sectors, such as hydrocarbon extraction and offshore wind generation.
Transport solution	Short distances between the emitter gathering point and storage offtake location (lower capital and operating costs). Consideration should also be given to transport solutions which connect sources to large sinks or sink clusters.	Distance of trunkline from onshore common gathering point to offshore storage offtake point is ~150 km.
	Transport solution should be suitable for the volumes of CO_2 required.	Pipeline is the chosen solution.
	Possibility of ship import/export terminals enhances future options.	Terminal facility is a possibility, but not currently envisaged in initial infrastructure to be developed.
	A broad and diverse potential customer base for transportation service is preferred (reduces asset stranding risk – provides resilience for potential transportation revenue in an uncertain future).	Within the Yorkshire and Humber CO_2 emitter base, there are at least 10 different incumbent companies, including both independent generators (e.g. Drax Power Ltd) and large energy/industrial corporations (including E.ON, SSE, Centrica, GDf Suez and Tata Steel Europe).
Local Stakeholders	Community support	Generally positive community attitude towards project. Long industrial heritage in the area. Prospect for job creation and retention is generally understood and welcomed.
	Local government support	Positive engagement from Local Authorities and local Members of Parliament
	Support of Regional Development Agencies	Long-standing advocacy support for a CO_2 infrastructure cluster from CO2Sense Yorkshire (formerly Yorkshire Forward, the regional development agency). A recent study suggests that the CCS cluster could create ~4,000 jobs and provide wider, local economic benefits.

Item	Criteria	Yorkshire and Humber CO_2 Emissions Linked to Southern North Sea CO_2 Storage
National Government	Positive policy support is essential because early CCS will need an element of Member State co-funding and various regulatory permissions.	Humber was designated the first U.K. Low-carbon Economic Area for CCS in 2010. UK Government has strong cross-party policy support for low-carbon generation, including CCS. Launched in April 2012, the UK Government is currently conducting a competitive CCS Commercialisation Programme with up to £1bn capital grant funding available to support commercial-scale CCS projects. In November 2012, the UK Government announced a tripling of support for low-carbon generation via a rise (to £7.6bn) in the budget for the Levy Control Framework. Through the Energy Bill introduced to Parliament in November 2012, CCS projects will have access to long-term Contract for Differences in order to provide a premium electricity price for CCS-generated electricity.
Regulatory and Permitting Framework	Clear transposition of CCS Directive into National Law is desired to provide a clear regulatory and permitting framework within which CCS infrastructure can be developed.	Energy Act 2008 asserts U.K. right to use Exclusive Economic Zone for CO_2 storage and sets environmental permitting regime. Storage of Carbon dioxide (Licensing etc) Regulations 2010 implements substantive provision of CCS Directive. Storage of Carbon Dioxide (Access to Infrastructure) Regulations 2011 regulates third party access arrangements. Further work anticipated in certain areas, e.g. transition of hydrocarbon reservoirs for CO_2 storage, guidelines for implementation of third party access, treatment of storage liabilities.
Regulatory and Permitting Framework	Clear framework for obtaining land use planning approval for linear infrastructure is desired (otherwise a high risk that development investment could be wasted).	Planning Act 2008 sets out prescribed procedure for Government and applicants, and sets expectations for thoroughness of community consultation. National Policy Statements identify long CO_2 pipelines as Nationally Significant Infrastructure Projects (NSIP).

Further information on the Yorkshire and Humber CCS Cluster can be found as follows:

- National Grid website for cross-country Yorkshire and Humber CO_2 capture, transportation and storage project: www.ccshumber.co.uk
- White Rose CCS project website: www.whiteroseccs.co.uk
- 2Co Energy project website, developers of the Don Valley Power Project: www.2coenergy.com
- C.Gen project website for North Killingholme Power Project: www.cgenpower.com/kgh/index.html
- Co2Sense report: www.co2sense.co.uk/files/2113/5031/6058/CCS_CO2Sense_Exec_summary_FINAL.pdf

Annex III: Members of ZEP's Taskforce on CCS Demonstration and Implementation

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