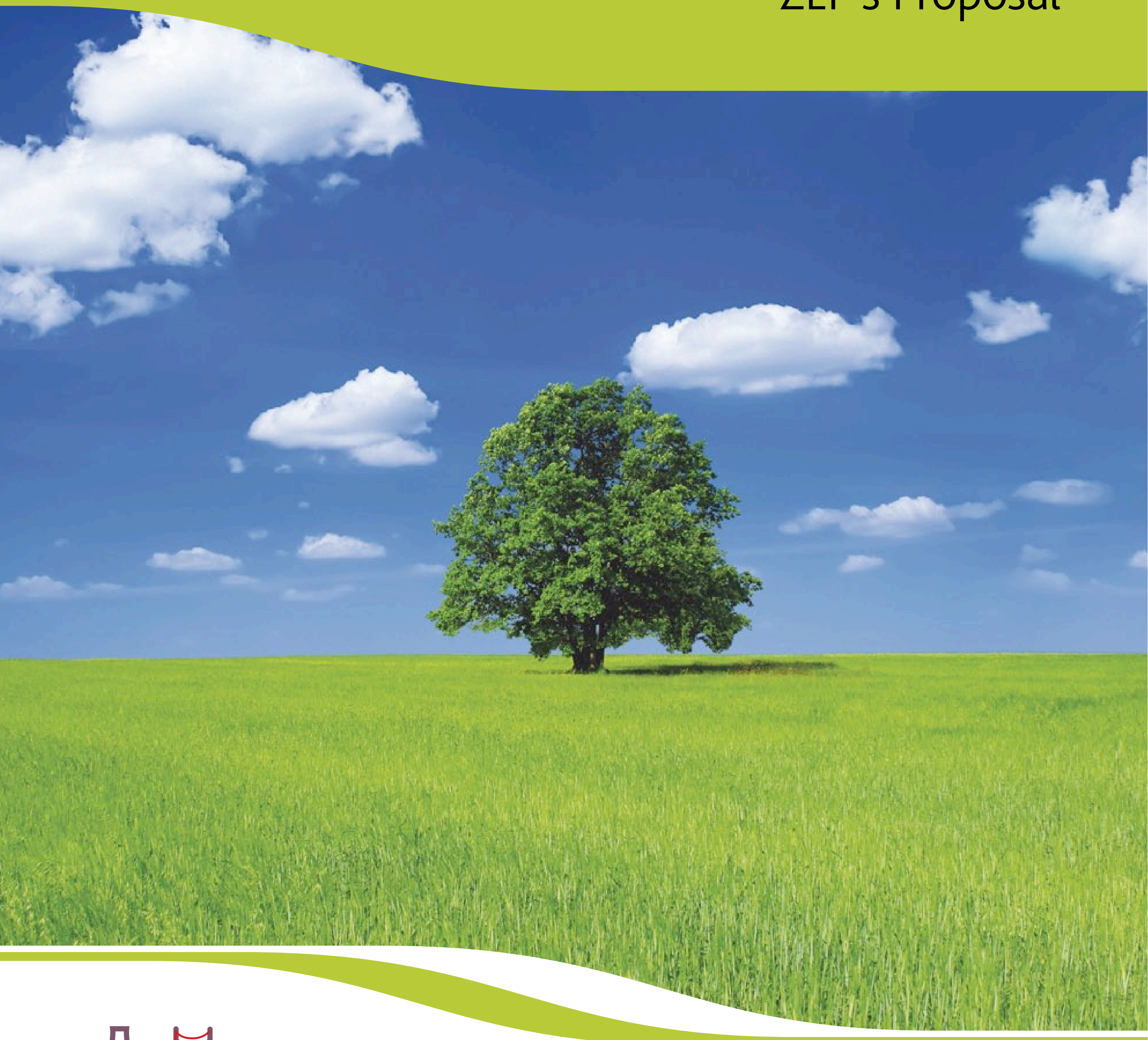
European Technology Platform for
Zero Emission Fossil Fuel Power Plants (ZEP)

EU Demonstration Programme for CO_2 Capture and Storage (CCS)

ZEP's Proposal



Work to develop this document was facilitated by McKinsey & Company, who also provided fact-based input. The views in the report are solely those of ZEP and not those of McKinsey & Company.

Introduction

Founded in 2005, *the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP)* is a broad coalition of stakeholders united in their support for CO_2 Capture and Storage (CCS) as a key technology for combating climate change.[1] Indeed, *if implemented without delay*, CCS could reduce CO_2 emissions in the European Union (EU) by 400 million tonnes a year by 2030, even before its full potential is realised.[2]

Our members include European utilities, petroleum companies, equipment suppliers, scientists, geologists and environmental NGOs. Our goal: to make CCS commercially viable by 2020 and kick-start its wide-scale deployment.

In 2006, ZEP outlined the technology and deployment roadmap necessary to achieve this goal.[3] In 2007, we then presented our vision for an EU Flagship Programme of large-scale CCS demonstration projects as the next – and final – step. This will ensure the implementation of complete CCS value chains – from the capture of CO_2 at large emission sources, its transportation to storage sites, to its storage in geological formations deep underground. This has now been re-named an "EU[4] Demonstration Programme".

Now, in 2008, ZEP has carried out an in-depth study into how such a demonstration programme could work in practice, from every perspective – technological, operational, geographical, political, economic and commercial – backed up by robust R&D activity. It is the most extensive ever undertaken on the subject, anywhere in the world.

Over several months, we have engaged with a comprehensive range of experts and stakeholders – not only within ZEP, but also the wider CCS community, including trade associations, other European Technology Platforms and Governments. We have conducted interviews, organised workshops and employed sound, fact-based analysis.

This report describes the results of that investigation – what an EU Demonstration Programme should cover; how it could be funded; and what steps must be taken to ensure it is up and running by 2015 in order for CCS to be commercially viable by 2020. At its heart is the optimal portfolio of projects necessary to cover the full range of CCS technologies and fuel sources, geographies and geologies, Europe-wide.

Time, however, is running out. If we are to achieve our goal, investment decisions must be made *imminently*. With over 40 European CCS demonstration projects already planned or being considered, Industry is more than ready.

1 See "CO_2 Capture and Storage: why it is essential to combat global warming", published by ZEP, May 2008

2 Estimates of the size of the annual contribution by 2050 range from 0.6 GT in the EU and 9 GT worldwide (International Energy Agency (IEA) Blue Map scenario from their report, "CO_2 Capture and Storage – a Key Carbon Abatement Option"), to 1.7 GT in the EU and 16 GT worldwide (The Bellona Foundation, "A Model for the CO_2 Capture Potential", by Dr Aage Stangeland, published in the International Journal of Greenhouse Gas Control, Volume 1, Issue 4, August 2007; see also page 27

3 Strategic Deployment Document (SDD) and Strategic Research Agenda (SRA), November 2006

4 A project should not be excluded if it is partly or wholly within the European Economic Area (EEA)

Advisory Council Members of the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP)

Eloy Alvarez, Union Fenosa
Olivier Appert, Institut Français du Pétrole
Pietro Barbucci, ENEL
Rudolph Blum, DONG Energy Power
Niels Peter Christensen, Vattenfall
Martin Cmiral, CEZ
Ricardo Cordoba, GE Energy
Józef Dubinski, CMI
Jürgen Eikhoff, RAG Aktiengesellschaft
John Farley, Doosan Babcock Energy Ltd
Bernhard Fischer, E.ON Energie AG
Roberto Garosi, ANSALDO ENERGIA S.p.A.
Georg Gasteiger, Austrian Energy & Environment AG
François Giger, EDF/DPIT
David Gye, Morgan Stanley
Reinhardt Hassa, Vattenfall
Frederic Hauge, The Bellona Foundation
Martha Heitzmann, Air Liquide
Gardiner Hill, BP
Emmanuel Kakaras, Institute for Solid Fuels Technology & Applications
Alfons Kather, Hamburg University of Technology
Sanjeev Kumar, WWF International
Johannes Lambertz, RWE Power AG
Harry Lampenius, Foster Wheeler Power Group Europe
Ruud Lubbers, Dutch National Taskforce on CCS
John Ludden, British Geological Survey
Nick Mabey, E3G
Luc de Marliave, TOTAL SA
Jorge Martínez Jubitero, ENDESA Generación
Nils Røkke, NTNU-SINTEF
Charles Soothill, ALSTOM Power
Michael J. Suess, Siemens AG
Trude Sundset, StatoilHydro
Graeme Sweeney, Shell Intl Petroleum Co Ltd
Antonio Valero, Fundación CIRCE
David White, Schlumberger

Contents

Executive summary

• With CCS, Europe can grow its economy, enjoy a secure energy supply – *and* meet its CO_2 reduction targets

Scientists have confirmed that unless we stabilise CO_2-equivalent concentrations at their current level of 450 parts per million (ppm), average global temperature is likely to rise by 2.4°C to 6.4°C by 2100.[5] If we *fail* to keep below 2°C, devastating – and irreversible – climate changes will occur.

This means reducing CO_2-equivalent emissions by 50% by 2030.[6] Yet with world energy demand expected to double by this date[7] and renewable energy to make up only ~30%[8] of the energy mix, only a *portfolio* of solutions will achieve this goal. This includes energy efficiency, a vast increase in renewable energy – and CO_2 Capture and Storage (CCS). Indeed, if implemented without delay, CCS could reduce annual CO_2 emissions by 0.6-1.7 billion tonnes in the EU and by 9-16 billion tonnes worldwide by 2050 (see footnote 2).

As a safe and efficient method of capturing and storing billions of tonnes of CO_2 underground for thousands of years, CCS therefore represents the bridge to a truly sustainable energy system. It will enable Europe to grow its economy, enjoy a secure energy supply – *and* meet its CO_2 reduction targets.

Time, however, is of the essence. CO_2 concentrations are already rising at over 2 ppm a year and it is estimated that delaying the implementation of CCS by just 6 years would mean CO_2 concentrations increasing by around 10 ppm by 2020.[9]

The European Council has therefore called for a demonstration programme of up to 12 large-scale CCS projects to be operational by 2015 in order to kick-start its urgent, wide-scale deployment. This reflects the recommendations of the *European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP)*, a broad coalition of stakeholders united in their support for CCS and its leading authority in Europe.

• An EU Demonstration Programme: the key to kick-starting CCS in Europe – and beyond

In 2007, ZEP presented its vision for an EU demonstration programme on CCS, integrating *all* aspects of CO_2 capture, transport and storage – including technology, infrastructure, the environment, health & safety, legal and regulatory issues and funding. At its heart is a network of large-scale demonstration projects covering the full range of CCS technologies, Europe-wide.

This major European technology initiative is essential in order to accelerate technology development, drive down costs, build public confidence – and ensure CCS is commercialised by 2020. As importantly, it will spur action by other countries – especially large CO_2 emitters, such as China, India and the United States. As a global solution to combating climate change, CCS could therefore also boost European industry, creating new jobs and promoting technology leadership.

5 Intergovernmental Panel on Climate Change (IPCC)

6 Compared to business-as-usual: Meinshausen (2004); European Environment Agency; Stern Review; OECD; Van Vuuren; IEA World Energy Outlook (WEO), 2007; US EPA 2006; Houghton 2005; IPCC

7 IEA WEO, 2007

8 Average taken across multiple estimates: IEA WEO 2008; European Commission baseline scenario; German Ministry of Environment, EUROPROG

9 Shell Energy Scenarios

• Establishing the optimal portfolio of demonstration projects

Now, in 2008, ZEP has carried out an in-depth investigation into precisely how a demonstration programme could work in practice, consulting an extensive range of experts and stakeholders. Our aim: to establish the optimal portfolio of projects necessary to cover a full range of CCS technologies and fuel sources, geographies and geologies, Europe-wide.

The conclusion: a total of 10-12 demonstration projects is required in order to de-risk CCS for all players within the value chain and achieve commercialisation by 2020.

This is the result of a clear, three-step process:

i. Identify the technological gaps within the CCS value chain
ii. Define the selection criteria necessary to meet Programme objectives
iii. Determine the number of projects required to satisfy these criteria.

Experts within ZEP and the wider CCS community have now identified the functional, operational and technical specifications for the technologies that require validation and integration across the entire CCS value chain. Known as Technology Blocks, these were a key driver in establishing all the technical and commercial criteria that needed to be fulfilled by the Programme – by both the portfolio as a whole and individual projects in particular.

In an ideal world, only 7 projects would be needed to satisfy these criteria. However, an ideal combination does not exist and the high-risk profile of some of these 'archetypal' projects[10] means they are unlikely to materialise. When matched against the list of currently announced projects in the EU and EEA, it is therefore found that 8 projects will satisfy the vast majority of the criteria; while an additional 2-4 projects will cover the remainder that cannot yet be assessed (because the information is not available). This brings the total to 10-12 projects.

Time, however, is running out. If our goal is to be achieved, investment decisions must be taken *imminently*. Yet as of today, the incentive mechanism first called for by the European Council in 2007 to "stimulate construction and operation by 2015 of up to 12 demonstration plants" is still not available.

• An EU Demonstration Programme needs an EU-wide funding mechanism

Like all major new technology initiatives, the cost of an EU Demonstration Programme will be high, but experience, technology development and economies of scale should drive the cost of CCS down. It is expected to fall from its current level of €60-€90 per tonne of CO_2[11] to €35-€50 per tonne of CO_2 in the early commercial phase (2020+) and to €30-€45 per tonne of CO_2 when total installed capacity increases to ~80 GW (giga watt).

Without CCS, however, abatement costs would be far higher. According to the European Commission, "the costs of meeting a reduction in the region of 30% GHG[12] in 2030 in the EU could be *up to 40% higher than with CCS*";[13] while in the IEA's Blue Map[14] scenario, which halves CO_2 emissions between 2005 and 2050, the costs of doing so *without CCS* would be USD 1.3 trillion per year – a stark 71% more!

Nevertheless, the incremental costs of the first large-scale CCS demonstration projects will be exceptionally high – too high to be fully justifiable to shareholders. This is because all 'First Movers' will incur:

- *Unrecoverable costs* from making accelerated investments in scaling up the technology
- *Significant risk* because it is not yet known which CCS technologies will prove the most successful; the future CO_2 price is highly uncertain; and construction and operational costs are highly unpredictable.

10 Projects that are technically feasible but not necessarily proposed
11 Based on new-build coal-fired power plants: "Carbon Capture & Storage: Assessing the Economics", published by McKinsey and Company, September 2008
12 Greenhouse gas emissions
13 EC Communication on "Supporting Early Demonstration of Sustainable Power Generation from Fossil Fuels", 23 January 2008
14 IEA, "CO_2 Capture and Storage – A Key Carbon Abatement Option"

In fact, the risk is of an order of magnitude similar to the total incremental costs of CCS.

Based on an independent study recently undertaken by McKinsey and Company[15] it is therefore estimated that an EU Demonstration Programme of 10-12 CCS projects requires €7-€12 billion[16] additional funding in order to close the economic gap.

Industry has already declared its willingness to cover a major portion of the costs and risks of implementing an EU Demonstration Programme. However, given that it will bring incalculable benefits to both the public and European industry, ZEP asks that these costs and risks be shared through private and public co-investment.

This means Industry taking on the base costs of the power plant and the risks outlined above, while the incremental costs of CCS are covered by public funding. (A competitive tender process will incentivise companies to submit their most competitive bid with regard to risk/cost sharing.) This is in line with the precedent set by other new low-carbon technologies – and requires the urgent implementation of national and European funding mechanisms.

• Achieving 80-120 commercial CCS projects by 2030

Without a demonstration programme, the commercialisation of CCS will undoubtedly be delayed – until at least 2030 in Europe. Even if it does take place, however, delays in the decision-making process could significantly affect the end result.

Building a CCS project is a lengthy process: a fully integrated project can take 6.5-10 years. However, final investment decisions can only be made once permits have been awarded across the entire value chain. This means that even a commercial project started as early as 2016 may not become operational until 2024. There are several ways Industry can accelerate this process, such as condensing feasibility studies and making faster investment decisions. But the EU can also play its part, accelerating the process for obtaining both building permits and public funding.

Early business models also need to be developed on optimal CCS value chains – including a CO_2 transport infrastructure, based on a comprehensive assessment of large CO_2 point sources and storage sites. This, in turn, will enable us to determine the potential and cost of developing CCS clusters in specific regions within Europe.

If such steps are taken and an EU funding mechanism is rapidly established, the outlook for CCS is highly favourable. Indeed, we could see 80-120 commercial projects in Europe by 2030[17] – avoiding ~ 400 million tonnes of CO_2 per year, with the potential to reduce annual global CO_2 emissions by 9-16 billion tonnes by 2050 (see footnote 2).

15 "Carbon Capture & Storage: Assessing the Economics", published by McKinsey and Company, September 2008

16 Includes capital and operational costs over the lifetime of the project

17 Including retrofit; see also footnote 8

1. An EU Demonstration Programme: the key to commercialising CCS by 2020

The EU has made its position on CCS very clear: as a critical solution to combating climate change, its wide-scale deployment is essential. Indeed, without CCS, the EU's CO_2 emission targets are simply not achievable. This was endorsed by the European Council in March 2007, which confirmed that up to 12 demonstration projects should be operational by 2015. The goal: to ensure CCS is commercially viable by 2020.

It means implementing an EU-wide initiative which integrates *all* aspects of CO_2 capture, transport and storage – including technology, infrastructure, the environment, health & safety, legal and regulatory issues, funding and public communication. At its heart is an EU Demonstration Programme of large-scale CCS projects covering the full range of technologies, Europe-wide (Exhibit 1).

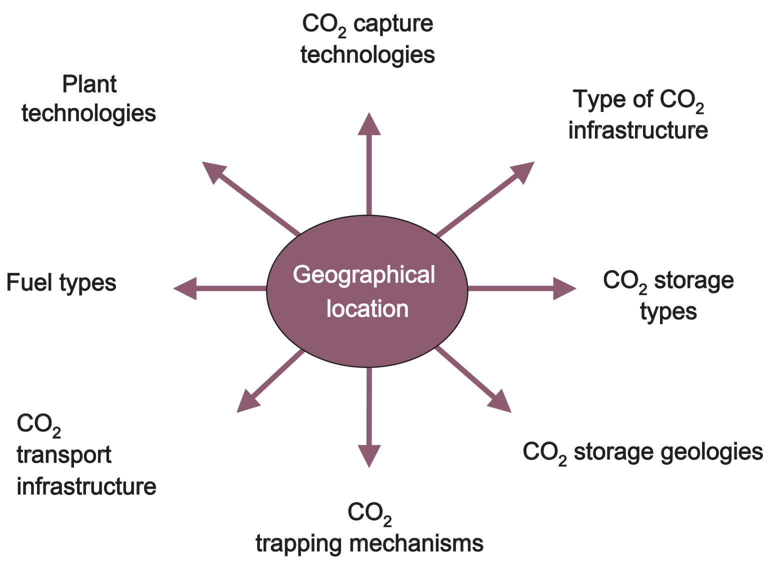


Exhibit 1: An EU Demonstration Programme will ensure the validation of a full range of CCS technologies, Europe-wide

Why an EU-wide approach is essential

This major European technology initiative is essential in order to:

- **Achieve the optimal geographical and technological spread of projects**

As it is not yet known which CCS technologies will prove the most successful, it is vital that the full range is tested – including higher-risk technologies – optimised across projects and locations. This includes the three main CO_2 capture technologies (post-combustion, pre-combustion, oxy-fuel) and the two main options for CO_2 storage (depleted oil & gas fields and different types of deep saline aquifers). As each region has its own challenges, local demonstration is also important in order to maximise public and political support.

While ZEP welcomes the decision to amend EU guidelines for State Aid – whereby CCS demonstration projects are given "préjugé favorable" status – it is therefore no substitute for an EU Demonstration Programme, as Member State projects will be tailored to suit their own environments, with no guarantee of covering the range of technologies required.

As importantly, an EU-wide programme will ensure that cross-border projects – where CO_2 is stored in a different country or region to where it is captured – are not excluded. As capture and storage locations are unevenly distributed throughout Europe, cross-border pipelines will play a crucial role in the wide-scale deployment of CCS and the development of clusters in major industrial areas as the next key step.

- **Accelerate technology development and drive down costs**

A diverse spread of geographical and technological projects will also accelerate cost discovery and technology development, as companies will be able to benefit from the knowledge sharing of multiple projects.

- **Prove that CCS works and is safe**

CO_2 capture is already practised on a small scale, while the technology for CO_2 storage is almost identical to that used by the oil and gas industry for decades – to store natural gas or for enhanced oil recovery (EOR). In fact, it uses the same natural trapping mechanisms which have already kept huge volumes of oil, gas and CO_2 underground for millions of years.[18]

CO_2 transportation is also well understood: it has been shipped regionally for over 17 years, while a 4,000km onshore network has been operating in the US for over 30 years.

The next step is therefore to scale up the technology – including full process integration and optimisation – with demonstration projects of a size large enough to allow subsequent projects to be at commercial scale. This will also build public confidence, as it is seen that CO_2 storage is both safe and reliable: while it has been taking place successfully in Europe for over 12 years, CO_2 storage projects are not widely known to the general public.

- **Demonstrate Europe's leading edge technology and spur action by other countries**

An EU Demonstration Programme will not only prove the EU's commitment to delivering on its own CO_2 reduction targets, but spur other countries to do the same – especially large CO_2 emitters, such as China, India and the United States.

Scientists have confirmed that unless we reduce CO_2 emissions by 50% by 2030, average global temperature is likely to rise by 2.4°C to 6.4°C by 2100. If we *fail* to keep below 2°C, devastating – and irreversible – climate changes will occur.

Yet with world energy demand expected to double by 2030, and renewable energy to make up only ~30% of the energy mix by this date, fossil fuels will be an important energy resource for many years to come. Around 750 new coal power plants are already planned for the period 2005-2018, totalling more than 350 GW, of which 50 will be in Europe, almost 300 in China, 200 in India and 50 in the US.[19]

As a global solution to combating climate change, CCS could therefore also boost European industry, creating new jobs and promoting technology leadership.

Why time is of the essence

Time, however, is of the essence. Any delay in the roll-out of CCS could not only lead to unnecessary CO_2 emissions, but additional costs, as instead of being able to apply it to the current pipeline of coal plants, a retrofit would be required, increasing the cost of achieving the same emissions reduction. With decisions on new plant build being made now in Europe, it is therefore vital we are not locked into an infrastructure that is not optimised for CCS.

18 See "What is CO_2 Storage?" published by ZEP, August 2008
19 Platts UDI Database

Indeed, every year that CCS is delayed is a missed opportunity to reduce CO_2 emissions. CO_2 concentrations are already rising at over 2 ppm a year and it is estimated that delaying the implementation of CCS by just 6 years would mean CO_2 concentrations increasing by around 10 ppm by 2020 (Exhibit 2).

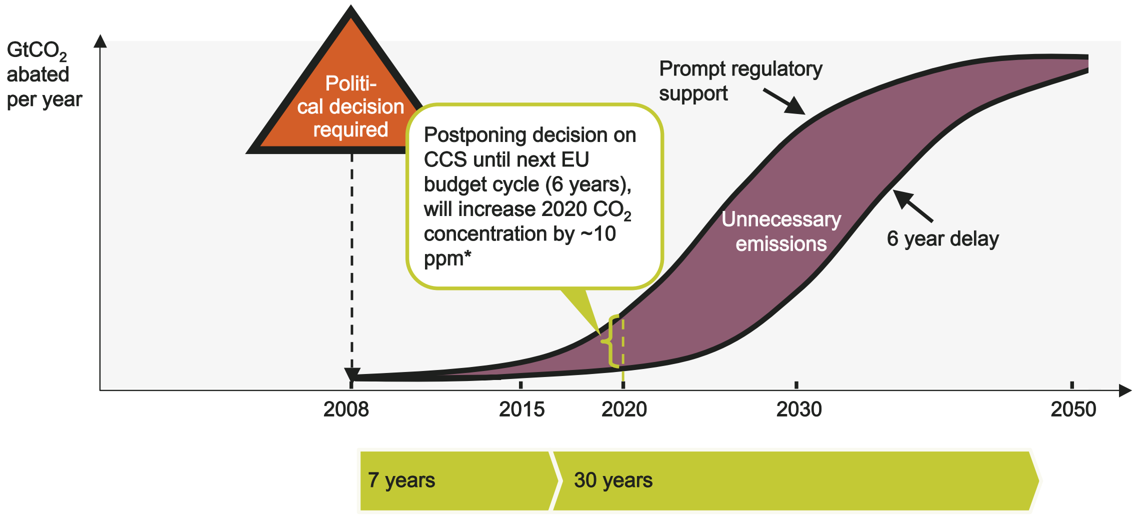


Exhibit 2: Just a 6-year delay in the implementation of CCS in Europe would mean CO2 concentrations increasing by around 10 ppm by 2020

In short, an EU Demonstration Programme will prove that CCS is a real, timely and significant solution to combating climate change. With an EU-level CCS plan currently under consideration in two important EC directives,[20] the period from now until March 2009 is therefore a crucial opportunity to advance to the next – and vital – stage of CCS development.

20 Directive on the Geological Storage of CO_2 and a revision of the European Union Emissions Trading Scheme (EU ETS) Directive

2. Establishing the optimal portfolio of demonstration projects

In order to determine the optimal portfolio of CCS projects for an EU Demonstration Programme, ZEP has engaged in extensive dialogue with a broad range of stakeholders, via both interviews and expert workshops.

The conclusion: 10-12 demonstration projects are required in order to de-risk CCS for all players within the value chain and achieve commercialisation by 2020.

This is the result of a clear, three-step process:

i. Identify the technological gaps within the CCS value chain

ii. Define the selection criteria necessary to meet Programme objectives

iii. Determine the number of projects required to satisfy all criteria

- In an ideal world, only 7 projects would be needed
- *In reality*, 8 currently announced projects will meet the vast majority of the criteria
- 2-4 additional projects will cover the remainder that cannot yet be assessed (because the information is not available).

This brings the total number of demonstration projects to 10-12. N.B. This assumes all projects will be fully successful. If some fail significantly, more projects may need to be added later to the Programme.

A full description of this process is outlined below.

i. Identify the technological gaps within the CCS value chain

Experts within ZEP and the wider CCS community[21] have undertaken ground-breaking work in identifying the functional, operational and technical specifications for the technologies that require validation and integration within the CCS value chain (excluding emerging technologies, e.g. membranes for air separation). Known as Technology Blocks, they cover:

- The three main CO_2 capture technologies (post-combustion, pre-combustion, oxy-fuel)
- The two main storage options (deep saline aquifers and depleted oil & gas fields)
- The two main transport options (ship and pipeline)
- Improvement in plant efficiency (to compensate for losses due to the CO_2 capture process).

As a key driver for the portfolio and project criteria, each Technology Block has been assessed for its:

- Importance within the overall CCS value chain
- Proven capacity today and expected performance by 2012 for meeting the overall objectives of an EU Demonstration Programme
- Potential to reduce costs, improve performance and reduce risk
- Trade-off risk when integrated with other Technology Blocks in specific demonstration projects (i.e. higher performance may be offset by higher technical risk due to less proven technology).

A full presentation on Technology Blocks can be found at www.zero-emissionplatform.eu/ZEP_Technology_Matrix.pdf.

21 38 technology specialists from over 13 companies, including utility and oil & gas companies, equipment suppliers, national geological institutes and environmental NGOs

ii. Define the selection criteria necessary to meet Programme objectives

The selection criteria needed to meet the objectives of an EU Demonstration Programme (see chapter 1) were then defined and divided into:

- ***Portfolio criteria*** (which must be met by the portfolio as a whole)
- ***Project criteria*** (against which individual projects will assessed).

These address all parts of the CCS value chain – from fuel types and CO_2 capture technologies, to CO_2 transportation and storage options. They also address the geographical spread of projects, knowledge sharing, R&D, plant-wide efficiency, monitoring, commercial structures, costs, timing, international cooperation and the ability to accelerate deployment.

Each project/party also needs to satisfy ***Eligibility criteria*** in order for their proposal to be considered (Exhibit 3).

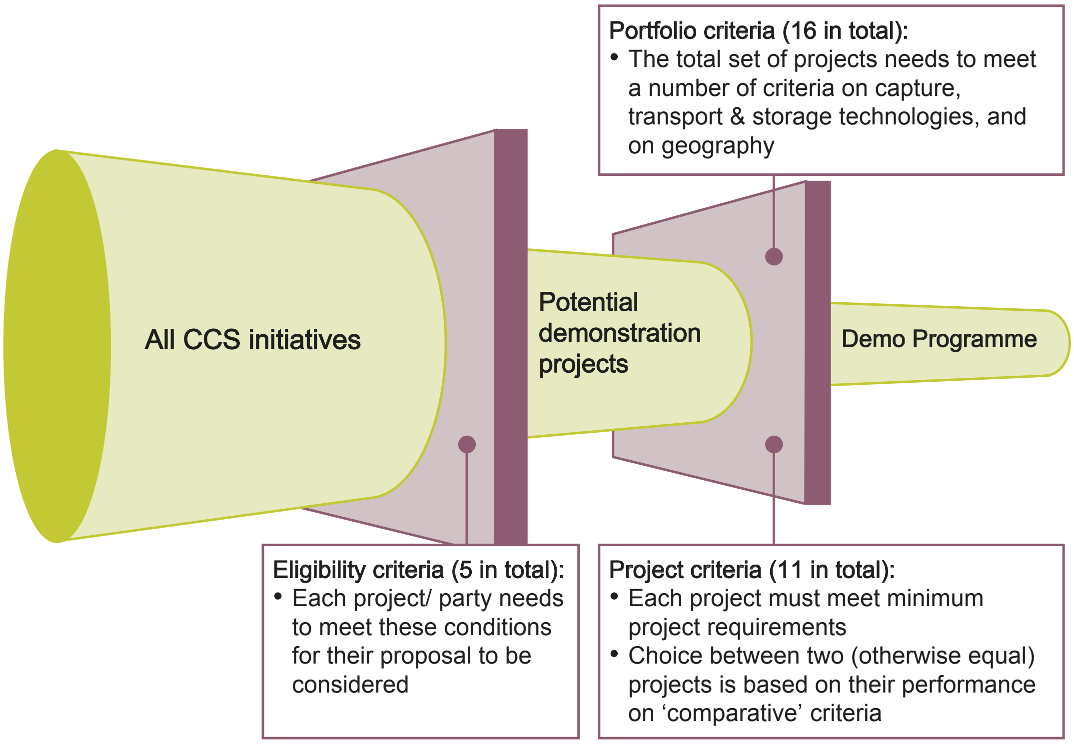


Exhibit 3: Three types of criteria have been developed in order to select projects for an EU Demonstration Programme

Portfolio criteria

The portfolio should…	Rationale
Include (a variety of hard coal and lignite) power plants	• Coal is the largest source of static point emissions in Europe and worldwide • Different coal types result in substantially different emission streams, requiring separate tests
Include the following capture technologies: pre-combustion, post-combustion and oxy-fuel	• All three capture technologies are very different and proven on a pilot scale • A clear winner cannot (yet) be identified as each has its own (dis-)advantages on costs, total potential applicability, estimated potential for cost breakthrough and maturity of the technology
Include the following storage technologies: depleted oil and gas fields and deep saline aquifers, including Measurement, Monitoring and Verification (MMV)	• Both storage options will be needed to provide sufficient storage capacity in the short and long term: – Deep saline aquifers have the largest storage potential, but the availability and technical feasibility still needs to be tested for most areas – Depleted oil and gas fields are most likely available sooner, so can provide storage in the short term
Include both onshore and offshore storage options	• Both storage types are likely to be needed for CCS implementation, depending on the location
Include a project with cross-border pipeline transport	• Cross-border transport is likely to be needed to develop large-scale CCS in Europe, as capture and storage locations are not evenly distributed • Testing this specific setting is helpful to explore and develop the specific legal and organisational requirements, and stimulate resolution of potential issues
Include a gas-fired power plant	• After coal and lignite, gas is the largest source of static point CO_2 emissions in Europe • Gas-fired power generation has different flow and heat dynamics compared to coal, thus requiring separate testing
Include different capture technology variations for each of pre-combustion, post-combustion and oxy-fuel, taking into account the ZEP Technology Blocks	• Among the variants for each of the technologies there is no clear winner yet and each variant might have benefits for specific applications
Include co-firing biomass	• With biomass co-firing, you can achieve negative net emissions, which will increase political/public support for CCS • Testing biomass co-firing can address the technical CCS challenges with different percentages of biomass co-fired

<table>
<tr><th>The portfolio should…</th><th>Rationale</th></tr>
<tr><td>Include transportation by ship</td><td>• Transportation by ship could be interesting as it could offer a number of advantages:
– Greater flexibility
– Potential to transport over longer distances (e.g. EOR in other continents)
– Different economics for using many smaller storage fields and sources
– Faster realisation, given less permitting obstacles
• Transportation by ship requires further technical development and cost recovery</td></tr>
<tr><td>Include open and structural deep saline aquifers and multiple geological settings</td><td>• Multiple types of deep saline aquifers will need to be used for storing CO_2
• Different types of deep saline aquifers have different technological challenges</td></tr>
<tr><td>Include a project with CCS retrofitting on an existing plant</td><td>• Retrofitting can provide for large applicability both within and outside Europe, as the only solution for CCS for the existing power plants
• Retrofitting requires technical development and cost recovery</td></tr>
<tr><td>Include a power plant including CCS with improved plant-wide (or overall) efficiency</td><td>• CO_2 capture process results in loss of efficiency, therefore proving efficiency improvement measures will increase public and political acceptance, and accelerate the commercial development of these technologies</td></tr>
<tr><td>Include international cooperation and a project in an emerging economy (if certain conditions are met – to be defined)</td><td>• Implementation of CCS outside of Europe provides very large CO_2 abatement potential, given reliance of coal in e.g. China and India. Technological cooperation is an important first step</td></tr>
<tr><td>Have sufficient geographical spread</td><td>• Local demonstration increases public and political support – ‘seeing is believing’
• Member States’ willingness to cooperate increases with demo projects in their own country
• Each region will have its own challenges (geological, legal and societal)</td></tr>
<tr><td>Explore commercial structures</td><td>Finding a sound commercial structure will require further examination as many potential variations exist in e.g. risk allocation, sharing of funding, sharing of revenues and legal jurisdictions</td></tr>
<tr><td>Include at least one project which allows large stationary point source emitters outside the power sector to be connected to its transport and storage system</td><td>• Inclusion of other industries will contribute to:
– Economies of scale in transport and storage
– Fast roll-out of CCS in Europe due to synergies in permitting
– Faster roll-out potential for other sectors</td></tr>
</table>

Project criteria

Criterion	Rationale
Each project should **be at a scale that will allow the next project to be at commercial scale**	• Technology is ready for the final step to de-risk: large scale and integrated • Timeline allows for only one more intermediate step of demonstration projects, if goal of commercial readiness by 2020 is to be achieved
Each project should **minimise any release of CO_2 captured**	Clear commitment to minimise any release of CO_2 captured, without ruling out the possibility of temporary (technological) disruptions in part of the chain
If two projects are equal**, a project is preferred over another if it has an earlier operational start date**	Speed is of the essence if the ambition of full economic readiness by 2020 is to be met
If two projects are equal**, a project is preferred if it has an R&D programme**	An R&D programme will encourage further knowledge sharing stimulating wide CCS implementation
If two projects are equal**, a project is preferred over another if it has a lower centrally managed EU contribution per tonne of CO_2 stored or MWh of power delivered with CCS**	The effectiveness of public funding is maximised
If two projects are equal**, a project is preferred if it allows large stationary point source emitters outside the power sector to be connected to its transport and storage system**	• Inclusion of other industries will contribute to: – Economies of scale in transport and storage – Fast roll-out of CCS in Europe due to synergies in permitting – Faster roll-out potential for other sectors
If two projects are equal**, a project is preferred if it contributes to the development of a large-scale transportation infrastructure in Europe**	Future infrastructure sharing will reduce the cost and lower barriers of additional CCS projects in the same region
If two projects are equal**, a project is preferred if it is able to expand CO_2 capture and storage in a second phase on a commercial basis**	Expansion potential allows for fast and cost-effective scale-up to commercial scale with fewer risks
If two projects are equal**, a project is preferred over another if it has a higher chance of success (within budget and timeline)**	Minimises the risk in the portfolio
If two projects are equal**, a project is preferred if it includes more EU companies**	Including more EU companies strengthens knowledge building and sharing within the EU, giving more companies the chance to gain hands-on experience.
If two projects are equal**, a project is preferred if it maximises the internal and external knowledge sharing for CCS early deployment**	• Accelerates the commercial deployment of CCS • The effectiveness of public funding is maximised

Eligibility criteria

- Each project must meet agreed information disclosure and knowledge sharing requirements
- Each project must have a good stakeholder management process defined to achieve maximum public acceptance
- Each project must demonstrate its technical construction feasibility
- Each project must demonstrate safe, long-term storage by adequate, independently verifiable monitoring at CO_2 storage systems
- The obligation of delivery of an agreed project will lie with industrial sponsors subject to certain specified force majeure events; the projects will receive financial support only on the basis of actual performance – per tonne of CO_2 stored or MWh of power delivered with CCS.

iii) Determine the number of projects required to satisfy all criteria

In order to determine the number of projects needed to satisfy these criteria, we first considered the minimum required in an ideal world, i.e. if one could 'pick and choose' from building blocks (e.g. fuel types, storage options) to create an archetypal portfolio.

– In an ideal world, only 7 projects would be needed

It was found that, technically, only 7 'archetypal'[22] projects would be required to satisfy all portfolio and project criteria (Exhibit 4). These archetypes are, of course, examples and other combinations of building blocks will be possible.

Archetype 1	• Lignite/co-firing with Biomass	• Pre-combustion, variant A	• Cross-border pipeline	• Offshore depleted oil & gas field	• International cooperation
Archetype 2	• Gas	• Post-combustion, variant A	• Pipeline	• Onshore structural deep saline aquifer	• Retrofit
Archetype 3	• Hard Coal	• Oxy-fuel, variant A	• Ship	• Offshore open deep saline aquifer	
Archetype 4	• Hard Coal	• Post-combustion, variant A	• Pipeline	• Onshore depleted oil & gas field	• Improved efficiency
Archetype 5	• Lignite	• Oxy-fuel, variant B	• Pipeline	• Onshore structural deep saline aquifer	
Archetype 6	• Hard Coal	• Pre-combustion, variant B	• Pipeline	• Offshore depleted oil & gas field	
Archetype 7	• Hard Coal	• Post-combustion, variant B	• Pipeline	• Onshore open deep saline aquifer	

Exhibit 4: 7 archetypal projects could, in theory, satisfy all portfolio and project criteria. N.B. 'Additional requirements' could, in principle, be realised by all the archetypes

22 Projects that are technically feasible but not necessarily proposed

– In reality, 8 currently announced projects will meet the vast majority of the criteria

The good news is that even before these criteria have been published, Industry has proposed projects able to fulfil almost all of them – a clear indication of their feasibility.

Nevertheless, such an ideal combination of projects does not exist and the high-risk profile of some of these 'archetypal' projects means they are unlikely to materialise. When matched against the list of currently announced projects, it is therefore found that, *in reality,* 8 projects will meet the vast majority of the criteria.

– 2-4 additional projects will cover the remainder that cannot yet be assessed

A further 2-4 projects will then the cover the remaining criteria which are not satisfied by current projects or which cannot yet be assessed, e.g. cross-border transport, different types of open and structural deep saline aquifers.

Conclusion: a total of 10-12 projects is required to achieve the goal of an EU demonstration Programme to commercialise CCS by 2020 (Exhibit 5)

N.B. If some projects experience significant failure, it may be necessary for further projects to be added later to the Programme.

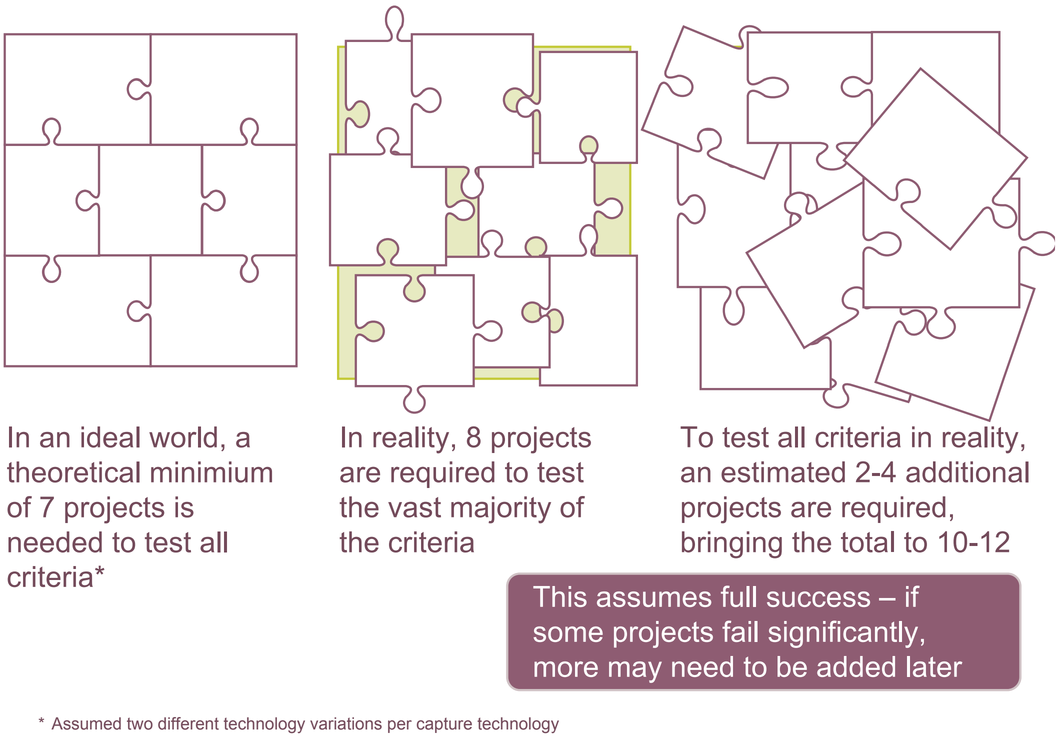


Exhibit 5: 10-12 demonstration projects are needed to satisfy all selection criteria

Now that it has been established that achieving the optimal portfolio of CCS demonstration projects is feasible – using real projects available today – there is no reason why an EU Demonstration Programme cannot be implemented as a matter of urgency.

It is therefore essential that an EU-wide funding mechanism is agreed; the principles of tendering, funding allocation and knowledge sharing established; the building of all CCS projects fast-tracked; and a CO_2 *transport infrastructure put in place.*

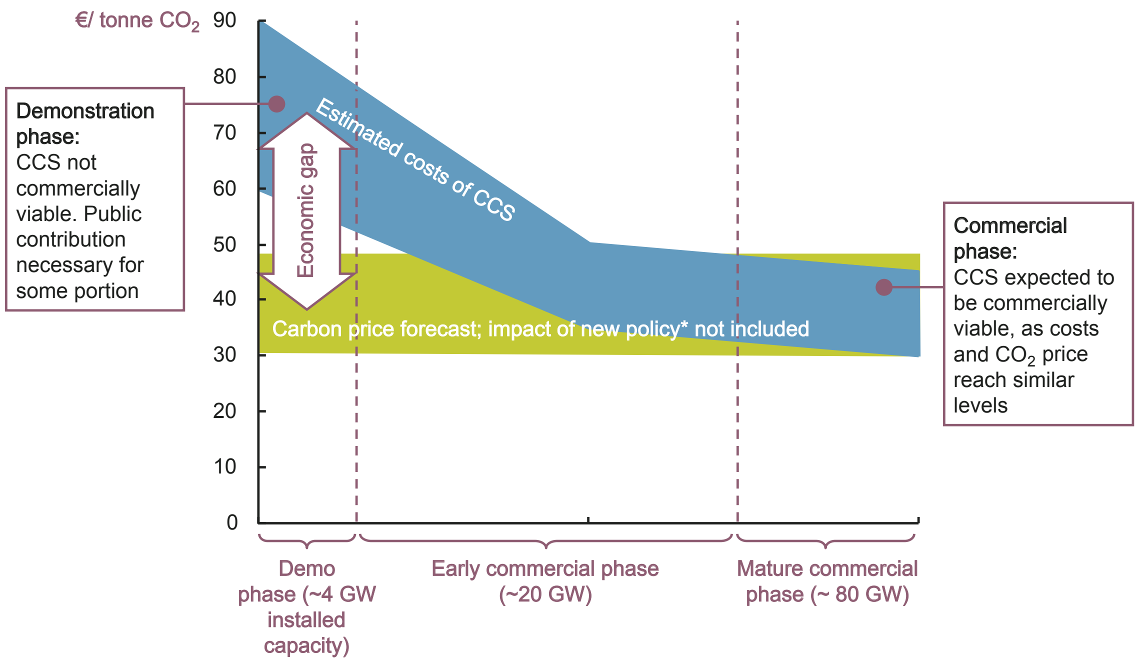
Recommendations on how these steps may be fulfilled are outlined in the chapters below.

3. Funding an EU Demonstration Programme

Like all major new technology initiatives, the cost of a European demonstration programme will be high, but experience, technology development and economies of scale should drive the costs of CCS down. Indeed, the current level of €60-€90 per tonne of CO_2 for CCS (see footnote 15), based on new-build coal-fired power plants, is expected to fall to €35-€50 per tonne of CO_2 in the early commercial phase, when total installed capacity will be ~20 GW (Exhibit 6).

This cost range is driven mainly by the different CO_2 capture technologies, transportation distances, CO_2 storage types and efficiency penalties. Some projects may therefore be fully covered by the CO_2 price during this phase (e.g. where there are short transport distances, well-developed infrastructure and, especially, positive technology developments); but others may not.

Further increase in the installed capacity to ~80 GW will mature the learning curve, after which CCS costs are expected to fall even further to €30-€45 per tonne of CO_2.



* Carbon price band for 2015 from 2008-15 estimates from Deutsche Bank, New Carbon Finance, Soc Gen, UBS, Point Carbo. Impact of the (possible) new ETS directive and the Copenhagen conference are not included in the analysis

Source: McKinsey & Company “CCS – Assessing the Economics” for the cost numbers; policy implications drawn by ZEP

Exhibit 6: CCS projects built during the demonstration phase will require funding to close the economic gap

Without CCS, however, abatement costs would be far higher. According to the European Commission, “the costs of meeting a reduction in the region of 30% GHG in 2030 in the EU could be *up to 40% higher than with CCS*”; while in the IEA’s Blue Map scenario, which halves CO_2 emissions between 2005 and 2050, the costs of doing so *without CCS* would be USD 1.3 trillion per year – a stark 71% more! (see footnotes 13 and 14). The earlier Europe starts investing in CCS, the greater the benefit it can therefore derive from these investments, until renewables are sufficiently developed to take over in the long term.

10-12 CCS demonstration projects require €7-€12 billion in additional funding

McKinsey and Company recently undertook an independent study into the costs of CCS, expressed as the difference between the total lifetime costs of a power plant *with* CCS versus one without (see footnote 11).

The study took into account the range of costs between fuel types and the three main capture technologies, as well as the CO_2 price forecast for the period 2012-2015.[23] Based on this, it is estimated that as a result of the additional CCS installations and reduced plant efficiency – and taking into account permit costs avoided for CO_2 stored – an EU Demonstration Programme of 10-12 CCS projects requires €7-€12 billion in additional funding in order to close the economic gap.[24] The precise size of this gap, however, is related directly to the CO_2 price (Exhibit 7).

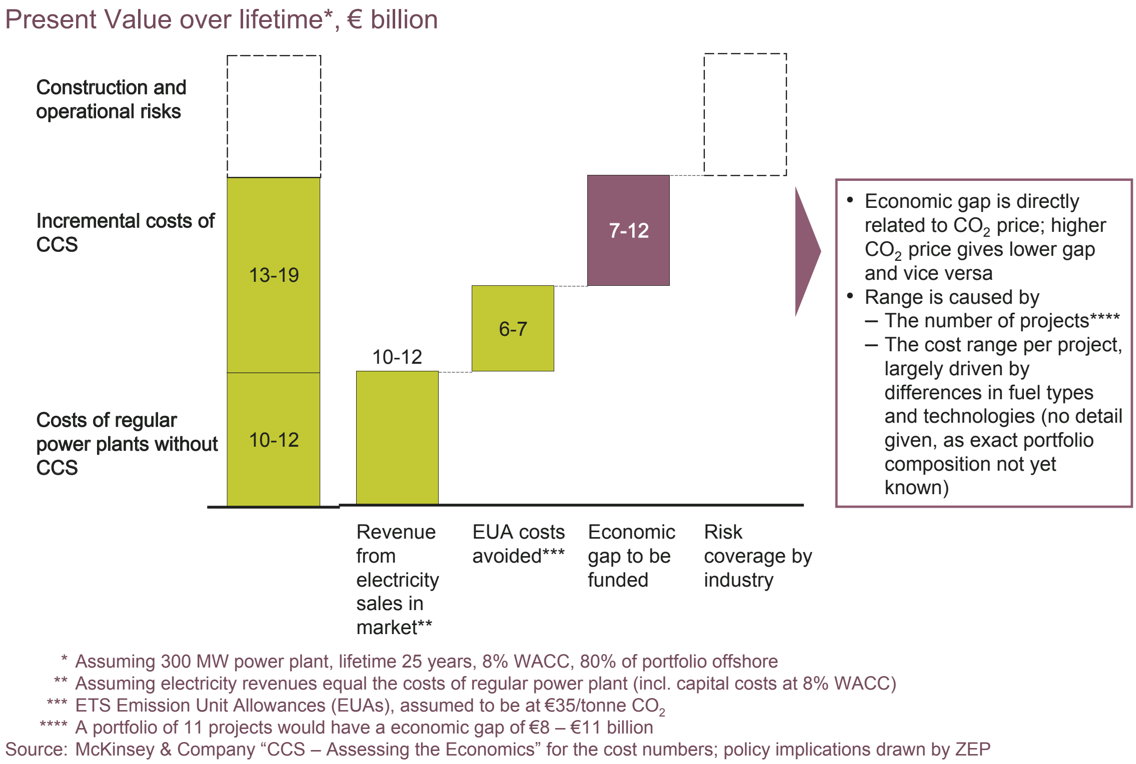


Exhibit 7: An EU Demonstration Programme of 10-12 CCS projects requires €7-€12 billion in additional funding, strongly dependent on CO_2 price expectations

23 Deutsche Bank estimates €40 per tonne/CO_2; UBS €35; Point Carbon €32; Fortis €48.

24 Net Present Value

Industry to cover a major portion of the costs and risks

Industry has already declared its willingness to cover a major portion of the costs and risks of implementing an EU Demonstration Programme; but they are exceptionally high – too high to be fully justifiable to shareholders. This is because all 'First Movers' will incur:

- *Unrecoverable costs* from making accelerated investments in scaling up the technology, i.e. instead of building several consecutive pilot projects, companies will move straight to demonstration scale. This is essential in order to fast-track technological development and ensure CCS is commercially viable by 2020.
- *Significant risk*[25] because:
  - It is not yet known which CCS technologies will prove the most successful
  - The future CO_2 price is highly uncertain
  - Construction costs could increase, e.g. a rise in the cost of materials (which has almost doubled over the last two years). These could translate into a 25% increase in the total CAPEX[26] cost – or around €300 million[27]
  - A final efficiency which is lower than planned will increase OPEX,[28] e.g. an additional efficiency reduction of just 10% would translate into a loss of €130 million.

In fact, the risk is of an order of magnitude similar to the total incremental costs of CCS.

Given that this demonstration programme will bring incalculable benefits to both the public and European industry, ZEP therefore asks that these costs and risks be shared through private and public co-investment. Without such funding, it is clear that few CCS demonstration projects will materialise.

It means Industry taking on the base costs of the power plant and the significant risks outlined above, while the incremental costs of CCS are covered by public funding. A competitive tender process will incentivise companies to submit their most competitive bid with regard to risk/cost sharing.

This is in line with the precedent set by other new low-carbon technologies. Indeed, technological breakthroughs have traditionally received public funding in order to overcome the first 'hump' of development – in biotechnology, pharmaceuticals, IT and aerospace, to name a few. For example, in nanotechnology, global public investment of $6.4 billion (plus $6 billion private investment) enabled key technical hurdles to be overcome. The result: over 600 products are now on the market, with global revenues estimated at $50 billion in 2006.[29]

An EU Demonstration Programme needs an EU-wide funding mechanism

Time, however, is running out. If our goal is to be achieved, key investment decisions must be taken imminently. Yet as of today, the incentive mechanism first called for by the European Council in 2007 to "stimulate construction and operation by 2015 of up to 12 demonstration plants" is still not available. It means:

- Clarifying the rules on State Aid with respect to CCS demonstration projects
- Urgently implementing stable national and European funding mechanisms which *complement* the industrial financing of CCS projects.

25 Based on a 300 MW coal/lignite power plant, with a lifetime of 25 years, 8% WACC

26 Capital expenditure

27 NPV with WACC (Weighted Average Cost of Capital) 8%

28 Operational expenditure

29 Source: Congressional Research Service (CRS) report on nanotechnology and US competitiveness

There are several possible options:

	Description	Available when?	Advantages	Disadvantages
EU budget	Direct grant from EU budget, e.g. from Strategic Energy Technology (SET) Plan	Next EU budget allocation in 2014. Possible interim reallocation (as for Galileo space project). Limited funds from SET Plan available earlier.	Can be coordinated centrally	Not enough available as main EU budget frozen until 2013
New Entrants Reserve of EU Emissions Trading Scheme (ETS)	EUAs from New Entrants Reserve allocated to CCS for subsequent monetisation	Final decision could be made early 2009	Can be coordinated centrally. Could be available as early as 2009, accelerating investment decisions which need to be taken *imminently*.	Creates precedent for other technologies. Potential disruption to the ETS, but unlikely as the 500 million EUAs proposed for CCS demonstration projects represents only 3% of the total number of EUAs.
ETS auction revenues	ETS auction revenues allocated to CCS	Next full auction for 2012-15 phase of the ETS. Possibility of early auction.	Can be coordinated centrally. Will not interfere with the ETS.	Central coordination difficult as ETS auction revenues are currently under Member State control.
Member State budget	Additional funding for an EU Demonstration Programme	Varies on a national basis	Reduces need for European funding. Benefits projects with most support at home.	Limited centralised coordination over technology choices.
Consumer electricity prices	Guaranteed price on electricity market for power produced using CCS	Varies on a national basis	Reduces risk for investors	Lack of EU coordination. Difficult to differentiate subsidy between different cost technologies.

ENVI[30] votes in favour of using up to 500 million EUAs from the ETS New Entrants Reserve to fund a CCS demonstration programme

On 7 October 2008, the Environment Committee of the European Parliament voted in favour of Amendment 56[31] (previously 500) to the revised ETS Directive to award a maximum of 500 million Emission Unit Allowances (EUAs) from the new entrants reserve to large-scale CCS demonstration projects. ZEP welcomes such a mechanism, although we note that its adoption does not commit the EU to that precise form of words in the final legislative act. Discussions with relevant MEPs, the Council of Ministers and the European Commission (the 'Trilogue') are therefore ongoing with the aim of fine-tuning this approach.

How should funding be allocated?

It is essential that public funding for an EU Demonstration Programme is allocated in a fair and transparent way. ZEP therefore recommends that it be based on four key principles:

1. As each project will be unique, it should be judged on its own merits. After a transparent procedure – with room for negotiation and an 'open book' setting, where appropriate – the project should then be allocated the quotation agreed. (N.B. An upfront agreement to allocate only a part of the quotation should be avoided at all costs, as it would create the incentive to adapt the initial bid, thereby reducing transparency.)
2. Funding should be distributed to consortia (i.e. projects covering an integrated CCS value chain), as opposed to individual companies, in order to stimulate close cooperation between companies. However, its distribution *within* a consortium should be the responsibility of the consortia themselves.
3. If part or all of the funding is provided via EUAs, a price-underpinning mechanism should be established to ensure both tradeability *and* the prevention of windfall profits, as the carbon market is still immature and therefore highly unpredictable. A potential mechanism could include setting a price floor and ceiling.
4. Companies should only receive financial support on the basis of actual performance – tonnes of CO_2 stored or MWh of clean power delivered – except in the case of force majeure events. (N.B. This requirement is explicitly included in the Eligibility Criteria, see page 13.)

The combination of principles 2 and 4 creates a risk that companies may select partners that provide the highest chance of success for the CCS value chain – and therefore payment, e.g. if a transportation company is invited to join two different consortia, it may choose that with the most mature CO_2 capture technology. To ensure higher risk technologies are also tested, appropriate economic incentives should therefore also be put in place.

30 The Environment Committee of the European Parliament

31 See Annex I on page 29 for the full text

4. Maximising the benefit of knowledge sharing

Knowledge sharing is central to an EU Demonstration Programme on CCS, to accelerating technology development and driving down costs. Indeed, future investment decisions will depend on the experience gained by the demonstration projects, the ability to improve the design and operation of future projects – and build competitive advantage.

It will also facilitate public support for the demonstration programme and enable the effectiveness of public funding to be properly evaluated. Its scope will therefore extend beyond existing national and EU legal requirements (including EU Directives).

In principle, knowledge sharing will aim to maximise the benefits of public funding, while respecting the Intellectual Property (IP) rights of individual companies. There are three key steps:

i. Establish categories of knowledge

Knowledge sharing can be split into four main categories: technological, commercial and regulatory, environmental and stakeholder engagement (Exhibit 8).

Technological

- Capture
  - Technical
  - Operational
  - Safety
- Transport
  - Technical
  - Operational
  - Safety
- Storage
  - Technical
  - Operational
  - Safety

Commercial & regulatory

- Commercial/financial
- Regulatory
- Legal
- Planning and progress

N.B. Commercial/financial knowledge can only be shared where this does not lead to diminished competition

Environmental

- Environmental impact assessment
- Performance reports on environmental aspects, e.g.
  - Water usage
  - Impact on direct local environment

Stakeholder engagement

- Stakeholder identification & interest mapping
- Approach to stakeholders (including active involvement when needed)
- Public and political acceptance

Formal IP

- All knowledge in these categories can be subject to formal IP (Intellectual Property)
  - Patents
  - Technology transfer (licensing)
  - Copyrights
  - Trade secret rights
  - Confidential knowledge

Exhibit 8: Knowledge sharing can be divided into four main categories

ii. Define categories of stakeholders

In order to maximise global knowledge development and sharing on CCS, three levels of stakeholder involvement are proposed:

a. *Public and Government/EU*, who will receive synthesised general knowledge , including the timely disclosure of any safety-related operational issues.

b. *CCS projects which have not received public funding*, which may benefit from knowledge sharing on a reciprocal basis

c. *EU Demonstration Programme projects,* which will share and receive knowledge as agreed.

iii. Agree levels of knowledge sharing for both categories and stakeholders

For each combination of knowledge category/stakeholder, the right level of knowledge sharing – what, how and when – then needs to be defined (Exhibit 9). The impact of multiple IP regulations (EU, Member State and State Aid) also needs to be assessed and, if necessary, an overarching approach developed. N.B. All knowledge sharing must comply with competition laws, e.g. participation in other projects will only be permitted where this does not lead to diminished competition.

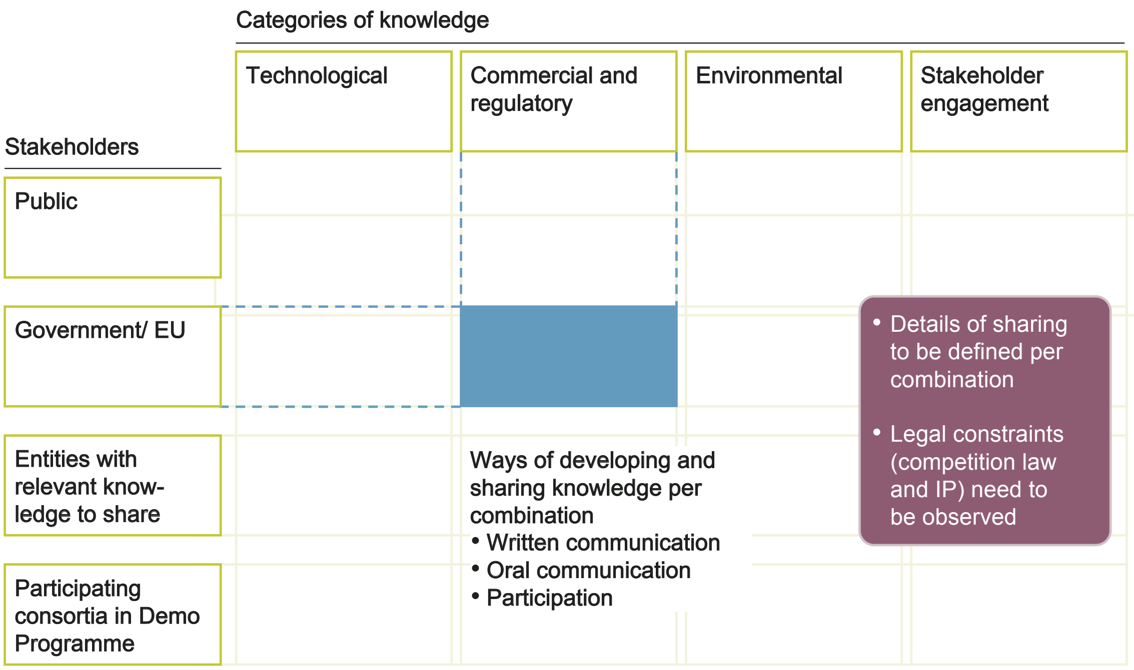


Exhibit 9: Levels of knowledge sharing need to be defined for each combination of stakeholders and knowledge categories

Employing a wide range of communication channels

Once levels of knowledge sharing for categories and stakeholders have been established, there are numerous ways in which a comprehensive and timely exchange of information can take place. Exhibit 10 shows just one example.

		Frequency	
		Semi-annually	Annually
Written Communication	Access to real-time performance data		
	Reports	• Storage pressure • Environmental effects • # of incidents • % of leakage in storage	• # of tonnes of CO_2/hour stored • % of uptime • Energy use • Maintenance information, e.g. pigging, corrosion
	Publications		• Lessons learned on storage technologies and capacity • R&D results • Unexpected challenges and solutions
Oral Communication	Presentations/ seminars	• Lessons learned on storage technologies and capacity • R&D results • Unexpected challenges and solutions	
	Trainings	• Lessons learned on storage technologies and capacity • R&D results • Unexpected challenges and solutions	
	Open house visits		• Type of storage • Capacity of storage • # of storage monitoring wells • # of tonnes of CO_2/hour stored • Environmental effects
	Contact between consortia		
Participation	Participation in other projects		

- For each combination of stakeholders and knowledge categories, knowledge sharing needs to be defined in detail
- Responsibility for this detailing needs to be assigned

EXAMPLE

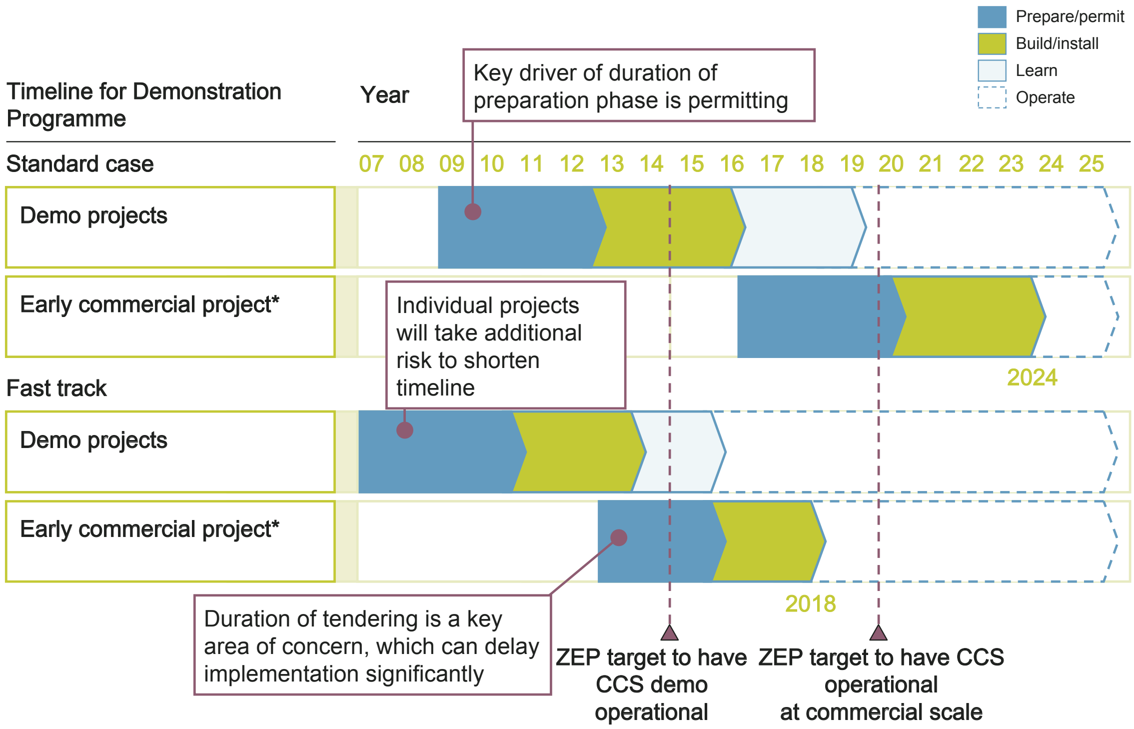
Exhibit 10: An example of how knowledge on CO_2 storage could be shared among willing parties

5. Accelerating the time to market

If the EU does not implement a demonstration programme and waits until CCS is commercially proven elsewhere, the first commercial CCS project in Europe is not likely to become operational until at least 2030. Even if a demonstration programme does take place, however, delays in the decision-making process can significantly affect the end result.

How can we fast-track the building of CCS projects?

Building a CCS project is a lengthy process: a fully integrated project can take 6.5-10 years before it becomes operational. However, final investment decisions can only be made once permits have been awarded across the entire CCS value chain. In the case of CO_2 storage, this can take as long as 6.5 years. In such a scenario, even a commercial project started as early as 2016 would not itself become operational until 2024 (Exhibit 11).



* Commercially available (e.g. at scale and with supplier performance guaranteed but not yet necessarily economically viable)

Exhibit 11: In order to meet the ambitious timeline, Industry needs to take risks – and policymakers to shorten permitting and tendering processes

How can we accelerate this process? There are several actions that can be taken by both Industry and Government. For example:

Industry

- Starting a commercial project as early as possible during the construction of the demonstration project so that – for example – building can start after just one year of the demo being in operation. In this case, the commercial project would benefit from obtaining permits sooner and still integrate some learning gained at both the design and operational stages of the demonstration project.

- Accelerating feasibility studies etc.
- Making faster investment decisions

Government

- Shortening the tender process
- Introducing special measures to shorten the permitting process.

Some projects, by their very nature, will of course be quicker to build than others, e.g. retrofitting existing power plants with CCS; using well-known oil and gas fields with infrastructure and seismic data already available; those with only a short distance from the power plant to the storage site etc.

Shortening the tender process

While the tender process for participation in an EU Demonstration Programme must follow certain key steps, those currently underway in Canada and the UK indicate that this could take anything from nine months to over two years respectively – from announcement of the tender, to the selection of projects. This is mainly due to the level of detail required from participants and their interaction with Government during the process.

For example, in the UK tender,[32] the initial compulsory questionnaire is 60 pages long – compared to the 10 pages Canada asks bidders to submit in the first phase.[33] The decision-making process also differs widely: in the UK, it includes four steps and extensive two-way negotiation; while in Canada it includes two steps and has more of a one-way nature.

If an EU Demonstration Programme is to be up and running by 2015, an accelerated tender process is essential. Taking the best of both the UK and Canada's proposals, it is estimated that this could be reduced to 15-18 months – excluding the set-up of the tender organisation. In addition to the work already undertaken by ZEP, we will therefore engage with both the European Commission and Member States to continue exploring the best options for meeting Programme objectives, while maintaining the quality of the process (Exhibit 12).

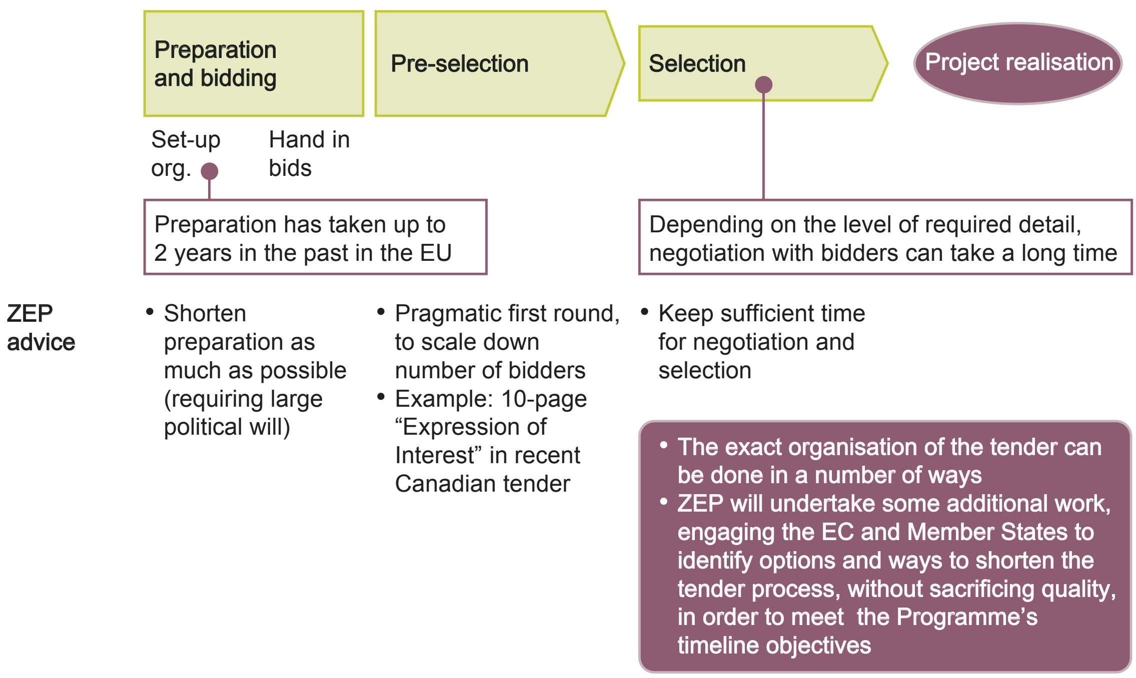


Exhibit 12: As a rapid tendering process is critical to the CCS timeline, ZEP has developed suggestions for achieving this – and will continue to work on it

32 Up to 100% funding available

33 USD 2 billion funding available

Establishing a CO_2 transport infrastructure

The early development of business models on optimal CCS value chains is also required – including a European CO_2 transport infrastructure, to which common codes and standards should be applied. In the first instance, this should be based on connecting multiple CO_2 point sources to multiple storage sites in order to accelerate CCS deployment.

While ships are a flexible and potentially cost-efficient method of transporting CO_2 for offshore storage in the early stages, pipeline systems will be the principal method of transportation and must therefore be included in an EU Demonstration Programme – with additional capacity in anticipation of an industrial roll-out.

It means accelerating the assessment of large CO_2 point sources and storage sites – particularly deep saline aquifers – with several European initiatives already underway.[34]

ZEP therefore proposes that the European Commission initiates a feasibility study for establishing the most economically feasible routes and infrastructure. This should be financed through the existing EU instrument on Trans-European Networks (TEN-C) as exists today for electricity, road and rail transportation, as well as telecommunication.

Building up expert knowledge in CCS

Finally, the building up of all the necessary resources, such as equipment supplies and technical specialists, is also essential. For the latter, dedicated training and education are needed so that the next generation of professionals can continue the work (whether it be with industrial companies or regulators).

Geo-science and engineering disciplines are currently dominant within CO_2 capture and storage, and these will need to be supplemented by a broader range of other professionals within biology, social sciences, communications, legal and financial issues etc.

34 For example, the EU GeoCapacity Project: www.geology.cz/geocapacity

6. Looking ahead to 2030 and beyond

80-120 commercial CCS projects in Europe by 2030

If an EU Demonstration Programme takes place, depending on the aggressiveness of the roll-out, 80-120 large-scale CCS projects could be operational in Europe by 2030 – representing a reduction in CO_2 emissions of ~400 million tonnes per year (Exhibit 13; see also footnote 15). The range depends on several factors:

- The speed with which regulatory support is established
- The speed with which public funding is allocated and permitting processes are obtained
- The extent to which CCS is retrofitted to existing power plants and applied to other large industrial emitters.

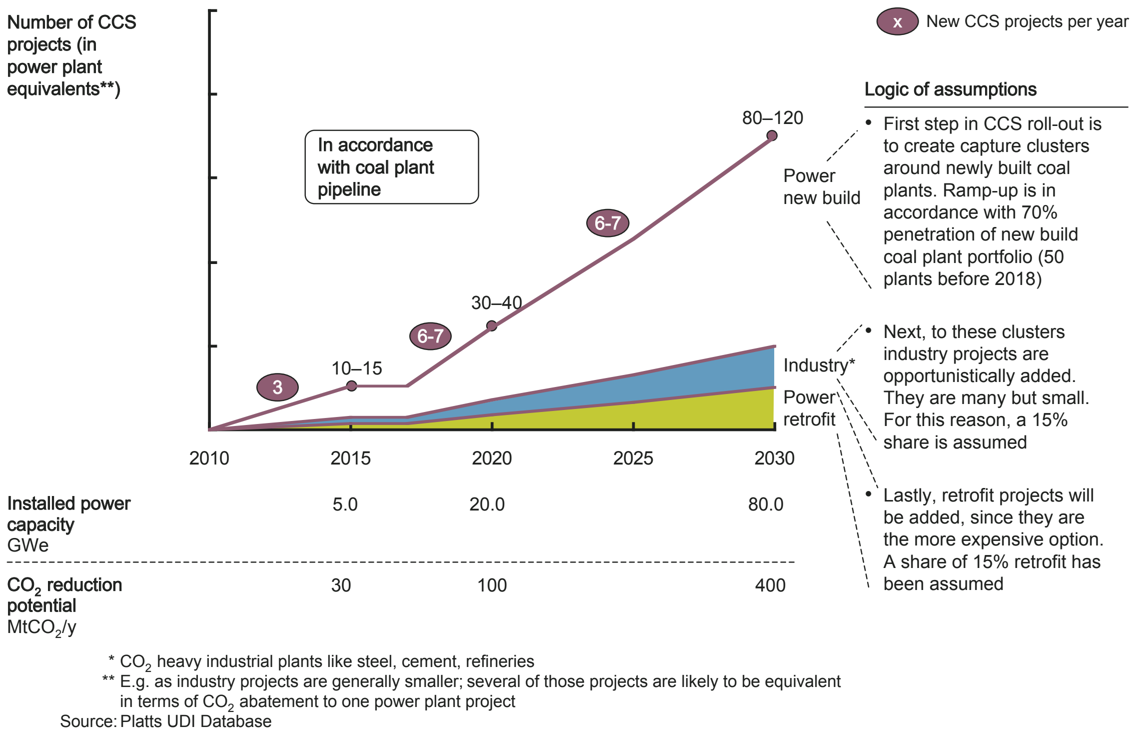
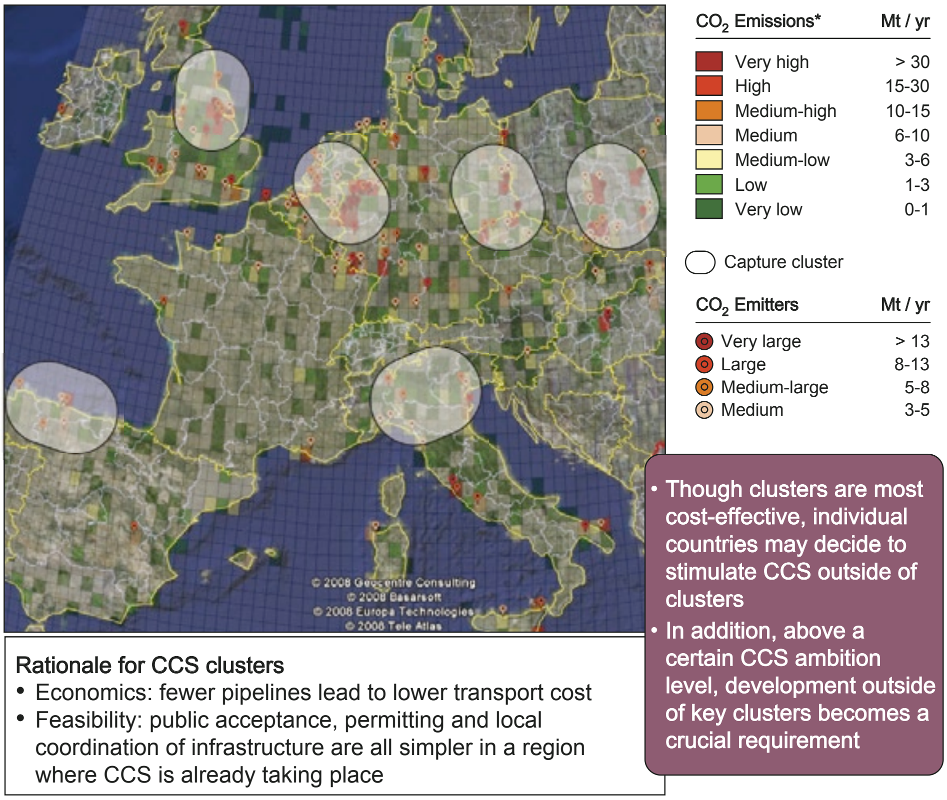


Exhibit 13: If EU funding for a CCS demonstration programme is rapidly established, total installed capacity could reach 80-120 commercial-scale projects by 2030

The most efficient way to achieve such a roll-out is to group projects in a series of CCS clusters around major industrial areas: a focused pipeline infrastructure will lead to lower transport costs; while public support, permitting and local coordination of infrastructure will obviously be simpler where CCS is already taking place (Exhibit 14).



* Emissions from stationary point emitters

Source: IEA GHG Emissions database; Google earth; NASA; Tele Atlas; Europe Technologies & TerraMetrics

Exhibit 14: CCS is likely to develop via a series of CCS clusters around major industrial areas in Europe

By 2050, CCS could reduce CO_2 emissions in the EU by 0.6-1.7 billion tonnes a year

Although the impact of CCS by 2050 is difficult to predict – as it largely depends on overall ambitions and the willingness to act – there is no question that its potential as a carbon mitigation technology is significant.

Currently, two estimates on the abatement potential of CCS exist.[35] In the IEA's Blue Map scenario, which halves CO_2 emissions between 2005 and 2050, CCS has the potential to reduce annual CO_2 emissions by 0.6 billion tonnes in the EU and 9 billion tonnes worldwide.

Bellona has also estimated the potential impact of a more aggressive scenario for CCS deployment.
If CCS is applied to all fossil fuel power plants and to almost all other large industrial emitters – with large volumes of hydrogen produced used for transport fuel – CCS could reduce annual CO_2 emissions by 1.7 billion tonnes in the EU and 16 billion tonnes worldwide.

35 Some publications quote these estimates as percentages. The IEA and Bellona estimates, however, depart from a different starting point, making the percentages hard to compare. Referencing against the IEA Alternative Policy Scenario, which already takes into account maximum energy efficiency and renewables, Bellona's estimate of the CCS abatement potential is over 50% of the remaining emissions. IEA compares to the 'reference scenario' which indicates business as usual (BAU). Of that BAU emission level, their CCS estimate translates to ~15% abatement (bringing the largest abatement from one measure, contributing ~20% of the total abatement potential)

7. Next steps

In order to ensure an EU Demonstration Programme is up and running by 2015 – and CCS commercially viable by 2020 – steps must be taken urgently at EU level:

- Ensure an EU funding mechanism is available for CCS demonstration projects within the EU Flagship Programme based on, for example, Amendment 56 to the ETS Directive – or equivalent.
- Ensure the clarification of public funding for CCS demonstration projects under the new Environmental Guidelines for State Aid.
- Accelerate the mapping and assessment of CO_2 storage sites – especially deep saline aquifers – in order to determine the potential and cost of developing CCS clusters in Europe.
- Ensure the successful adoption of the EC Directive on Geological Storage of CO_2.
- Establish a Europe-wide CO_2 transportation network (TEN-C) – ZEP looks forward to the European Commission's forthcoming report.
- Support Member States in implementing measures to accelerate the permitting process for *all* CCS projects.
- Ensure that the European Industrial Initiative on CCS – which will implement an EU Demonstration Programme – is established by December 2009 *at the latest*.

Annexes

Annex I: Amendment 56 (previously 500) of the Environment Committee of the European Parliament to the revised EU Emissions Trading Scheme Directive

Article 1 – point 8

Directive 2003/87/EC

Article 10a – paragraph 6b (new)

6b. Up to a maximum of 500 million allowances in the new entrant reserve shall be awarded to large-scale commercial demonstration projects that are undertaking the capture and geological storage of carbon dioxide in the territory of the EU or in developing countries and countries with economies in transition outside the EU that ratify the future UNFCCC international agreement.

The allowances will be awarded to projects that provide for the development, at best value costs and in geographically balanced locations across the EU, of a wide range of CCS technologies making use of diverse geological storage sites. Their award shall be dependent upon the verified avoidance of CO_2 emissions through the use of geological storage.

The Commission shall propose structures and procedures for identifying the projects and awarding allowances. It shall strive to ensure that convincing progress towards letting contracts for the construction of 12 large-scale commercial demonstration projects can be displayed before the meeting of the Conference of the Parties to the UNFCCC to be held in Copenhagen in November 2009.

Annex II: Current list of announced European CCS demonstration projects

ZEP undertook to build a list of large-scale EU CCS demonstration projects that aimed to include a CO_2 capture, transport and storage component. The resulting list consists of 43 projects, of which 34 were tested against the selection criteria (9 projects were not taken into account, either because they were smaller than 100 MW, outside the power sector, or did not have sufficient information available at the time of the analysis).

	Overview				CO_2 capture
Project name	**Partners/participants**	**Country**	**Location**	**Industry**	**Capture technology**
MARITSA		Bulgaria	Maritsa	Power	Pre-combustion
HODONIN CEZ	CEZ	Czech Republic	Hodonin, SE	Power	Post-combustion
LEDVICE CEZ	CEZ	Czech Republic	Ledvice, N	Power	Post-combustion
KALUNDBORG DONG	DONG Energy	Denmark	Kalundborg	Power	Post-combustion
AALBORG V.FALL	Vattenfall	Denmark	Aalborg	Power	Post-combustion
MERI PORI FORTUM	Fortum, TVO	Finland	Meri Pori	Power	Oxy-fuel or post-combustion
LACQ TOTAL	Total, ALSTOM, Air Liquide	France	Lacq plant and Rousse field	Power	Oxy-fuel
FLORANGE ARC.MIT	ArcelorMittal	France	France	Steel	Post-combustion
JANSCHWALDE V.FALL	Vattenfall	Germany	Jänschwalde, Brandenburg	Power	Oxy-fuel & post-combustion
WILHELMSHAVEN E.ON	E.On CE	Germany	Wilhelmshaven	Power	Post-combustion
EISENHUTTENSTADT ARC.MIT	ArcelorMittal	Germany	Eisenhüttenstadt	Steel	Post-combustion
GREIFSWALD DONG	DONG Energy	Germany	Greifswald, Mecklenburg	Power	Post-combustion
HUERTH RWE	RWE	Germany	Huerth, North Rhine-Westfalia	Power	Pre-combustion
ENEL CCS1	ENEL	Italy		Power	Post-combustion
ENEL CCS2	ENEL	Italy		Power	Oxy-fuel
SALINE JONICHE SEI	SEI (Rätia Energie & Partners)	Italy	Saline Joniche (RC)	Power	Post-combustion
BARENDRECHT SHELL	Shell	Netherlands	Barendrecht (storage), Pernis (capture)	Chemicals, Refinery	H2 production
EEMSHAVEN RWE	RWE Power, BASF, Linde	Netherlands	Eemshaven	Power	Post-combustion
ROTTERDAM E.ON	E.On Benelux	Netherlands	Maasvlakte, Rotterdam	Power	Post-combustion
ROTTERDAM ENECO	ENECO, International Power	Netherlands	Pistoolhaven, Rotterdam	Power	Post-combustion
EEMSHAVEN NUON	Nuon	Netherlands	Eemshaven	Power	Pre-combustion
ROTTERDAM CGEN	CGEN NV	Netherlands	Europoort Rotterdam	Power	Pre-combustion
ROTTERDAM ESSENT	Essent	Netherlands	Rotterdam	Power	Pre-combustion

					CO_2 transport and storage				Implementation
	Fuel type	**New vs. retrofit**	**Plant size (MW)**	**CO_2 produced (Mt/yr)**	**Transport**	**Storage**	**On-/ offshore**	**Storage rate (Mt/yr)**	**Start of operation**
	Lignite	New	650	3.43	Pipeline		Onshore		
	Lignite, biomass	Retrofit	105	0.5	Pipeline	Depleted oil & gas field	Onshore	0.3	2015
	Lignite	Retrofit (CCS-ready)	660	3.48	Pipeline	Saline aquifer (structural)	Onshore	0.9	2015
	Hard coal	Retrofit	600	3.58	Pipeline	Saline aquifer	Offshore		2015
	Hard coal	Retrofit	470 (310 after retrofit)	1.8	Pipeline	Saline aquifer (structural)	Onshore		2013
	Hard coal	Retrofit	560 (400-450 after)	3.35	Shipment		Offshore		2015
	Gas	Retrofit	30		Pipeline	Depleted oil & gas field	Onshore		2010
	Hard coal, petcoke	Retrofit			Pipeline	Saline aquifer	Onshore		
	Lignite	New & retrofit	250 (Oxy), ≤ 250 (post)	1.79	Pipeline	EGR or Saline aquifer	Onshore		2015
	Hard coal	New	500 (100 captured)	0.6	Pipeline	Saline aquifer	Onshore	0.6	2015
	Hard coal, petcoke	Retrofit			Pipeline	Saline aquifer	Onshore		
	Hard coal	New	1600	8	Pipeline				
	Lignite	New	450	2.8	Pipeline	Saline aquifer	Onshore	2.8	2014
	Hard coal	Retrofit	242 MWe net	1.5	Pipeline	Saline aquifer	Offshore	1.5	2014
	Hard coal	New	320 MWe net	2.1	Pipeline	Saline aquifer	Offshore	2.1	2016
	Hard coal	New (CCS-ready)	1320	3.94	Pipeline			up to 3.55 (90%)	
	Heavy oil			0.4	Pipeline	Depleted oil & gas field	Onshore	0.4	2011
	Hard coal	Retrofit	40	0.2	Pipeline	Depleted oil & gas field	Onshore	0.2	2015
	Hard coal	New (CCS-ready)	1070 (100 captured)	5.6	Pipeline	Depleted oil & gas field	Offshore		
	Gas	New	845		Pipeline				2011
	Hard coal, biomass	New	1200	4.14	Pipeline	Depleted oil & gas field			2013
	Hard coal, biomass	New	450	2.5	Pipeline/ Shipment	Depleted oil & gas field	Offshore	2.0	2014
	Hard coal, biomass	New	1000	4	Pipeline	Depleted oil & gas field		4	2016

	Overview				CO_2 capture
Project name	**Partners/participants**	**Country**	**Location**	**Industry**	**Capture technology**
MONGSTAD STATOIL	StatoilHydro, Gasnova	Norway	Bergen	Power, refinery	Post-combustion
HAMMERFEST H.ENERGI	Hammerfest Energi, Sargas, Siemens	Norway	Hammerfest	Power	Post-combustion
HUSNES TINFOS	Tinfos, Sør-Norge, Eramet, Sargas	Norway	Husnes	Various	Post-combustion
KARSTO AKER	Aker, Fluor, Mitsubishi	Norway	Karsto	Oil/gas	Post-combustion
MONGSTAD BKK	BKK	Norway	Mongstad	Power	Post-combustion or pre-combustion
HAUGESUND HAUGALANDKRAFT	Haugaland Kraft	Norway	Haugesund	Power	
SIEKIERKI V.FALL	Vattenfall	Poland	Warsaw	Power	Post-combustion
KEDZIERZYN PKE	PKE/ ZAK	Poland	Kedzierzyn Kozle, Slaskie	Power/ Chemical	Pre-combustion
BELCHATOW BOT	PGE, ICPC, CMI, PGI	Poland	Belchatow	Power	Post-combustion
COMPOSTILLA ENDESA	Endesa	Spain	Compostilla, Leon	Power	Oxy-fuel (CFB)
UNION FENOSA	Union Fenosa	Spain		Power	Post-combustion
KINGSNORTH E.ON	E.ON UK	UK	Kingsnorth, South East England	Power	Post-combustion
SCUNTHORPE CORUS	CORUS	UK	Scunthorpe	Steel	Post-combustion
COCKENZIE SCOT.PWR	Scottish Power	UK	Scotland	Power	Post-combustion
FERRYBRIDGE S&S ENERGY	Scottish and Southern Energy	UK	Ferrybridge, West Yorkshire	Power	Post-combustion
TILBURY RWE	RWE nPower	UK	Tilbury, Thames Estuary	Power	Post-combustion
KILLINGHOLME E.ON	E.ON UK	UK	Humberside, Lincolnshire	Power	Pre-combustion
HATFIELD P.FUEL PWR	Powerfuel Power Ltd	UK	Hatfield, South Yorkshire	Power	Pre-combustion
TEESSIDE PROG.EN	Centrica, Progressive Energy, Coastal Energy	UK	Teesside, Northeast England	Power	Pre-combustion
DRYM PROG.EN	Progressive Energy, BGS, CO2STORE	UK	Onllwyn, South Wales	Power	Pre-combustion

					CO_2 transport and storage				Implementation
	Fuel type	**New vs. retrofit**	**Plant size (MW)**	**CO_2 produced (Mt/yr)**	**Transport**	**Storage**	**On-/ offshore**	**Storage rate (Mt/yr)**	**Start of operation**
	Gas	New	280 electricity + 350 heat	1.5	Pipeline	Saline aquifer	Offshore	1 - 3	2014
	Gas	New	100		Pipeline	Saline aquifer	Offshore		
	Hard coal	New	400	2.5	Shipment	Saline aquifer			
	Gas	Retrofit (CCS-ready)	420	1.2	Pipeline	Saline aquifer	Offshore		2012
	Gas	New	450	1.2	Pipeline	Saline aquifer	Offshore	1.05	2014
	Hard coal	New	400-800				Offshore	2-2.5	2015
	Hard coal	New	480	2.87	Pipeline		Onshore		2015+
	Hard coal	New	500 MWth syngas + 250 Mwe	3.4	Pipeline	Saline aquifer	Onshore	2.4	2014
	Lignite	New	858 MWe (1/3 CCS)	5.1	Pipeline	Saline aquifer	Onshore	1.7	2015
	Sub-bit, bit & anth coal, pet coke, biomass	New	500 (400 MWe, net CCS)		Pipeline	Saline aquifer	Onshore	2.75	2015
	Hard coal	New	800 MWe (200 MWe CCS)		Pipeline	Saline aquifer	Onshore	1.0	2016-2017
	Hard coal	New (CCS-ready)	300	2	Pipeline	Depleted gas field	Offshore	2	2014
	Hard coal, petcoke	Retrofit			Pipeline	Depleted oil & gas field	Offshore		
	Hard coal	New			Pipeline	Saline aquifer			
	Hard coal (UK)	Retrofit (CCS-ready)	500		Pipeline	Saline aquifer		1.7	2015+
	Hard coal	New (CCS-ready)	1600	9.56	Pipeline	Saline aquifer			2016
	Hard coal	New	350	2.5	Pipeline	Depleted oil & gas field	Offshore	2.5	2016+
	Hard coal	New	900	4.75	Pipeline	Depleted oil & gas field	Offshore		2012-2014
	Hard coal, petcoke	New	800	4.22	Pipeline	Depleted oil & gas field	Offshore	4.22	2013
	Hard coal	New	450	2.4	Pipeline				

This publication is printed using environmentally friendly inks on 100 per cent recycled paper.

November 2008

European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP)

Contact: Eric Drosin, Director of Communications

E-mail: edrosin@zero-emissionplatform.eu

Website: www.zero-emissionplatform.eu