Zero emissions platform

Strategic Deployment Document II

Moving forward with CO_2 Capture and Storage (CCS)

European Technology Platform for Zero Emission Fossil Fuel Power Plants

“Europe can only meet its CO_2 reduction targets using a portfolio of technologies. In this context, the potential of CCS looks promising and needs to be fully explored.”

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Introduction

In September 2006, the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) – known as the Zero Emissions Platform – launched its Strategic Deployment Document (SDD) and Strategic Research Agenda (SRA) for CO_2 Capture and Storage (CCS).

The goal: to provide a clear strategy for accelerating its deployment as a critical technology for combating climate change.

Indeed, it is not possible to achieve EU or global CO_2 reduction targets *without* CCS – providing 20% of the cuts required in the EU by 2030 and 20% of the global cuts required by 2050, according to the International Energy Agency (IEA)[1].

Phase I: creating a Vision and strategy, 2005-2009

While the SDD therefore outlined a strategy for accelerating the market to achieve zero emissions power capability by 2020, the SRA[2] described a collaborative programme of technology development for reducing the costs and risks. The conclusion: an integrated network of CCS demonstration projects should be implemented urgently across Europe as the next vital step.

This holistic approach was endorsed by both the European Commission and European Council, and by 2009, two key objectives had already been met – to establish funding for an EU CCS demonstration programme and a regulatory framework for CO_2 storage[3].

Phase II: accelerating implementation and deployment, 2010+

ZEP has therefore now moved from Phase I objectives – creating a Vision and strategy – to Phase II: accelerating implementation and deployment of CCS. This incorporates three main goals:

1. Achieve the objectives of the EU CCS demonstration programme and enable CCS as a key technology for combating climate change
2. Maximise the learnings of CCS demonstration projects and accelerate R&D into next-generation CCS technology
3. Make CCS commercially available by 2020 to enable rapid and wide deployment.

This corresponds with the launch of the European Industrial Initiative (EII) on CCS in June 2010 – a unique collaboration between industry, Member States, the European Commission, research institutes, the European Energy Research Alliance (EERA) and environmental NGOs[4] (see page 16). It will also build on the Commission's European CCS Demonstration Project Network – the collaborative vehicle for all EU-funded CCS demonstration projects (see page 15).

[1] World Energy Outlook (WEO), 2009
[2] For updated research priorities, see pages 21-22 and ZEP's long-term R&D plan, "Recommendations for research to support the deployment of CCS beyond 2020", published in March 2010: www.zeroemissionsplatform.eu/zep-long-tem-r-d-ccs
[3] Directive 2009/31/EC on Geological Storage of Carbon Dioxide
[4] Non-governmental organisations

However, while the EU CCS demonstration programme is making good progress, its success is far from assured. Indeed, urgent action is still required – not only to ensure that demonstration projects are up and running by 2015, but that CCS is deployed rapidly post-2020.

This document therefore outlines critical short- and long-term challenges that need to be addressed – by the European Commission, Member State governments and CCS stakeholder community alike.

Why CCS is more vital than ever

Climate change is not a vision, it is a reality: in the 20th century, average global temperature increased by 0.74°C[5], while sea levels rose by 17 cm as a result of thermal expansion of the ocean and melting of ice across the globe. This has already resulted in a dramatic increase in the frequency, intensity and duration of floods, droughts and heatwaves: precipitation has increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia, while it has declined in the Sahel, the Mediterranean, Southern Africa and parts of south Asia[6].

In September 2009, EU and G8[7] leaders therefore agreed that CO_2 emissions must be cut by 80% by 2050 if atmospheric CO_2 is to stabilise at 450 parts per million (ppm) and global warming stay below 2°C – the global target agreed in Copenhagen in December 2009. 'Business as usual', on the other hand, will lead to CO_2 concentrations of 1,000+ ppm, a temperature increase of up to 6°C[1] – and irreparable damage to the planet. CO_2 concentrations have already reached 386 ppm[8] and are increasing by 2-3 ppm every year.

But with world energy demand expected to increase by 40% over the next 20 years alone[1], only a *portfolio* of solutions can achieve this goal. This includes greater energy efficiency, a vast increase in renewable energy – and CCS.

CCS is the only technology that can capture *at least 90%* of CO_2 emissions from power plants and other carbon-intensive industries; transport it by pipeline or ship; and store it deep underground – between 700 m and 5,000 m – using natural mechanisms that have already "stored" CO_2, oil and gas underground for millions of years.

As a safe and efficient method of capturing and storing billions of tonnes of CO_2 underground indefinitely, 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.

[5] Compared to pre-industrial levels
[6] Intergovernmental Panel on Climate Change (IPCC)
[7] The Group of Eight industrial powers – the United States, Canada, the UK, France, Italy, Germany, Russia and Japan
[8] Globally averaged marine surface annual mean data from the US National Oceanic & Atmospheric Administration: www.esrl.noaa.gov/gmd/ccgg/trends/index.html#global

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Executive summary

CO_2 Capture and Storage (CCS) is recognised as a critical technology for combating climate change – within a portfolio of technologies, including greater energy efficiency and renewable energy.

Indeed, the International Energy Agency (IEA)[9] confirms that it is not possible to achieve EU or global CO_2 reduction targets *without* CCS, providing 20% of the cuts required in the EU by 2030 and 20% of the global cuts required by 2050.

The European Union (EU) has responded swiftly, establishing a legal framework for CO_2 storage and EU funding for up to 12 CCS demonstration projects – supported by the launch of the European CCS Demonstration Project Network and European Industrial Initiative on CCS. However, urgent action is still required, not only to ensure demonstration projects are operational by 2015 – as mandated by the European Council – but rapid deployment post-2020.

Achieving the objectives of the EU CCS demonstration programme

A fully integrated project can take 6.5-10 years before it becomes operational, but final investment decision can only be made once construction and operation permits have been awarded across the entire CCS value chain. National regulatory frameworks must therefore be implemented as a matter of urgency – including the transposition of the Directive on Geological Storage of CO_2 ("CCS Directive").

Establish national regulatory frameworks as a matter of urgency

In order for CCS to become commercially viable, industry needs both a strong regulatory framework and a manageable risk exposure. A flexible and pragmatic approach is therefore essential. However, while financial security and liability requirements should remain an incentive to develop the best and safest storage sites, current provisions in the European Commission's Guidance Documents to the CCS Directive impose unbearable uncertainties and risks on the storage operator and are likely to represent a show-stopper for CCS in the EU.

ZEP recommends that the Directive presents options – not mandatory actions – that an operator can use to demonstrate safe storage, with a focus on demonstrating non-leakage and only then trying to quantify plume volume etc; monitoring, reporting and verification (MRV) guidelines should be site-specific. A site-specific, criteria-based – rather than time-based – approach should be also used to determine when operators hand over their liabilities to the Competent Authority. Finally, regulation should limit the risk to operators of storage failures that result from events outside their control – significantly reducing costs and risks, and facilitating commercial financing.

Operators' liability for purchasing emission unit allowances (EUAs) is also likely to block deployment unless governments limit the CO_2 price risk. By sharing or capping liability, Member States may take on the residual liability, with the premium paid by the operator assessed on a case-by-case basis.

Finally, an effective European CO_2 market will only develop if standards and specifications are aligned

[9] IEA World Energy Outlook (WEO), 2009

EU-wide such that free flow of CO_2 to the best storage opportunities can take place. The EU should therefore support the removal of all barriers to achieving this.

Close the funding gap for EU CCS demonstration projects

While current EU funding streams from the EU Energy Programme for Recovery and "NER 300" fund (see page 10) provide a good foundation for closing the funding gap for CCS demonstration projects, together they will only cover up to 50% of the incremental costs of CCS. While industry will contribute significantly to closing the remaining gap, additional government support – whether through state aid or EU structural and cohesion funds – is essential and must be in place by the end of 2011 at the latest. As importantly, the second tranche of the NER 300 should be allocated such that the entire portfolio of CCS technology options is demonstrated. This means prioritising projects with characteristics that are not represented in already funded CCS demonstration projects, e.g. retrofits, gas-fired power plants, biomass co-firing, CO_2 transport by ship and the complete range of storage options.

Prioritise CCS R&D to maximise the learnings of EU demonstration projects

Learnings from EU CCS demonstration projects will be significantly improved by complementary R&D activities, which should be prioritised in the EU's Seventh Framework Programme (FP7).

Maximise knowledge sharing among EU and international CCS projects

ZEP advocates an ambitious level of knowledge sharing between CCS demonstration projects – both within the EU and internationally – as key to the success of the European CCS Demonstration Project Network.

Facilitating the wide-scale deployment of CCS

100 commercial-scale CCS projects must be operational worldwide by 2020[10] to ensure global warming stays below 2°C, as agreed in the Copenhagen Accord. This rises sharply to 3,400 worldwide by 2050, including 320 in Europe. Yet even the minimal target of 14 in Europe by 2020 is unlikely to be met by current levels of deployment. Early action on a range of issues is therefore vital, maintaining the significant momentum created by the EU CCS demonstration programme.

Apply CCS across all carbon-intensive industrial sectors

The application of CCS to heavy industry and fuel transformation could abate ~15%[11] of all global man-made CO_2 emissions by 2050. Indeed, in steel and cement production, it is the only means of achieving deep emission cuts. Large-scale public funding should therefore be made available for demonstration projects in industrial sectors, in addition to those in power generation. Indeed, if different CO_2 sources – power, industry and fuel transformation – are located in close proximity, they can share CO_2 transport and storage infrastructure, saving both time and money. Industrial applications and the development of trans-sector CCS clusters should therefore be included in all National CCS Master Plans.

Move closer towards a carbon-negative energy system

Co-firing power plants with biomass offers great abatement potential and will increase public support for CCS. However, biomass fuels of the necessary quality are costly and clarification or adjustment of the EU Emissions Trading Scheme (ETS) Directive is required to ensure proper credits for CO_2 abated from biomass. Policy measures are also needed to ensure sustainable land management, biomass production and supply.

Establish a long-term infrastructure plan for CCS in Europe

A business model for CO_2 transport and storage must be established to ensure EU CCS demonstration projects do not result in isolated, point-to-point solutions, without scope to grow. The EU's forthcoming Energy Infrastructure

[10] 2009 IEA CCS Technology Roadmap: www.iea.org/papers/2009/CCS_Roadmap.pdf
[11] IEA, Energy Technology Perspectives 2010, Scenarios and Strategies

Package must therefore explicitly address the development of new CO_2 pipeline infrastructure *in addition* to existing gas and electricity transportation networks. EU policy should also support the development of National CCS Master Plans in which key clusters are identified and a long-term CO_2 pipeline infrastructure plan established. This will necessitate complementary studies and could require financial incentives/ support for "over-sizing" infrastructure. Finally, the preferred regulatory regime and business model for CO_2 pipeline infrastructure should be clarified, including transparent and non-discriminatory rules and tariffs for third party access.

CO_2 storage is the most critical element of a CCS project and more technical and comprehensive characterisation of potential sites is also urgently needed, EU-wide.

Create a secure environment for long-term investment in Europe

The most effective incentive for the EU-wide deployment of CCS is the price of Emission Unit Allowances under the EU ETS. However, this must be significantly higher and more predictable than at present to make CCS cost-competitive by 2020. While ZEP does not recommend any specific non-ETS incentive schemes, they should be revenue-neutral for treasuries, predictable for investors and effective for project developers. Nor should they tilt the level playing field between low-carbon generation technologies or abruptly distort the functioning of the electricity market. Given the long lead-times for CCS projects, they should be adopted sooner rather than later, using a harmonised EU approach.

Recognise CCS in international financing mechanisms

Out of the 100 commercial-scale CCS projects required worldwide by 2020, 50 are in developing countries. ZEP therefore advocates the large-scale international public financing of demonstration projects and the recognition of CO_2 storage credits via flexibility mechanisms recognised in their own cap-and-trade schemes, e.g. the Clean Development Mechanism (CDM) under the Kyoto Protocol.

Accelerate R&D into next-generation CCS technologies

In addition to the EU CCS demonstration programme, further R&D into next-generation technologies must be initiated immediately to enable rapid and wide deployment post-2020. Experts within ZEP have therefore identified key areas for improvement, together with the main strands for R&D to 2030 and beyond. To ensure maximum effectiveness, this should be coordinated at a national and EU level, and include key learnings from the EU demonstration programme. Coordination is also needed at national and European level for concrete R &D activities with a clear European added value in order to realise the commercial availability of new technologies/concepts by 2020-2025. This should be addressed via larger pilot installations, known as "lighthouse projects".

Realise the full potential of CCS

CCS also allows the production of large volumes of *CO_2-free Hydrogen* which can then be used for electricity or as a fuel. With fuel cell electric vehicles (FCEVs) now comprehensively tested in a customer environment, the focus has shifted from demonstration to planning commercial deployment so that they may benefit from the economies of scale. This was clearly signalled by the Memorandum of Understanding issued by leading car manufacturers in September 2009, in which they stated their goal to commercialise FCEVs by 2015, with hundreds of thousands of vehicles being rolled out worldwide shortly thereafter – if sufficient Hydrogen infrastructure is in place. This will also facilitate the introduction of stationary fuel cells for residential and small commercial applications, which will play a key role in distributed Combined Heat and Power (CHP) generation.

Where appropriate, opportunities for *geothermal heat production* with CCS should be investigated in order to provide cheap district heating for the local population, while increasing CO_2 storage capacity. While the *use of CO_2 in industrial processes and products* is currently limited (0.5% of CO_2 emissions worldwide), research should also continue to explore new applications.

Maximise international cooperation

In order to maximise synergies and accelerate deployment, international cooperation is crucial, not only among CCS projects, but international and regional bodies. International standards to qualify CO_2 streams for CCS are also important for developing an integrated, global CCS industry.

Establish an overarching 2050 energy decarbonisation scenario

ZEP looks forward to the launch of the European Commission's roadmap towards a low-carbon energy system by 2050, as the base reference document indicating the lowest cost pathway to decarbonise EU power. This should be realistic enough to ensure current reliability is maintained without compromising energy security and precise costing is essential. There is also a need for a regionalised bottom-up approach and forward analysis in order to identify nearer-term and verifiable milestones, which could form the structure of a true decarbonisation roadmap, within the 2050 overarching scenario.

Building support for CCS: the critical role of effective communications

A disconnect exists between governments engaged in vital CCS demonstration programmes and a public that is almost totally unaware of CCS and why it is urgently needed. Belief in climate change is also on the decline. Support for a CCS project is more likely to occur when the following factors are in place: trust in industrial actors; regional/national government support; local (economic) benefits; low population density; sufficient public engagement; and credible NGO/third-party support. It is therefore essential that communications start as early as possible in the process.

- Place CCS within the **context of climate change** and the challenge posed by the continued use of fossil fuels and industrial processes for decades to come. The potential for carbon-negative approaches, such as biomass co-firing in power plants, should also be communicated
- Demonstrate why only a **portfolio of solutions** can achieve the massive CO_2 reductions required, with CCS a bridging technology towards a low-carbon society
- Address the **unique benefits of CCS** and **key concerns over CO_2 storage**, highlighting the decades of relevant experience that already exists within the industry and the use of natural mechanisms that have already "stored" CO_2, oil and gas underground for millions of years.
- Engage in an **open dialogue** that includes all CCS stakeholders (industry, government, environmental NGOs, local communities, science and academia)
- Coordinate and leverage the diverse CCS stakeholder community to provide appropriate and credible input, using **the right messenger for the right issue and audience**
- Achieve the highest possible levels of **transparency, factuality and responsiveness**
- Make CCS a reality through opportunities to **"touch, feel and see"** it in operation.

The Zero Emissions Platform (ZEP)

Founded in 2005 on the initiative of the European Commission, ZEP represents a unique coalition of stakeholders united in their support for CCS as a critical solution for combating climate change. Members include European utilities, oil and gas companies, equipment suppliers, national geological surveys, academic institutions and environmental NGOs. The goal: to make CCS commercially available by 2020 and accelerate wide-scale deployment.

Over 200 people from 19 countries actively contribute to ZEP's activities in its role as:

- *CCS Advisor and Facilitator* – providing expert advice on all technical, policy, commercial and other CCS-related issues
- *CCS Technology Contributor* – providing input on all technology issues, including recommendations for next-generation technologies, taking into account experience gained from the EU CCS demonstration programme
- *Respected Communicator* – acting as an educator and authoritative source of information, while engaging internationally on CCS.

Achieving the objectives of the EU CCS demonstration programme

Background

CCS capitalises on a series of technologies[12] that have already been used in the oil and gas industry for decades:

- *CO_2 capture* technologies are already used extensively in other industrial applications (e.g. natural gas processing) and their components now require scale-up, full process optimisation and integration in the specific context of power generation. There are various capture technologies under development, the three main options being post-combustion, pre-combustion and oxy-fuel.
- *CO_2 transportation* has been taking place since the 1970s with onshore pipelines carrying CO_2 from industrial or natural sources to oil/gas fields in order to increase production via Enhanced Oil/Gas Recovery (EOR/EGR). Today, over 5,000 km of CO_2 pipelines are in operation in the US alone.
- *CO_2 storage* technology combined with EOR/EGR is very advanced, providing ample data for storage in depleted oil and gas fields, while pure storage has been successfully demonstrated for over a decade[13] in a limited range of deep saline aquifers[14]. Valuable offshore experience has also been gained through the operation of a 150 km offshore pipeline transporting CO_2 from the Snøhvit LNG plant for sub-sea injection in the Barents Sea.

The next step is therefore to scale up the technology, with demonstration projects of a size large enough to allow subsequent projects to be at commercial scale.

CCS has made significant progress since ZEP's first Strategic Deployment Document

CCS has made significant progress since the launch of ZEP's first Strategic Deployment Document in 2006: 18 pilot projects have already started[15], enabling industry to progress with the validation of components and processes in the real-life industrial conditions of an operating power plant.

A significant pipeline of large-scale demonstration projects are also coming online (>100 MW). According to the Global CCS Institute (GCCSI)[16], as of April 2010, 238 projects involving CO_2 capture, transport and/or storage are either active or planned worldwide. Of these, 80 are large-scale, integrated projects (>1 million tonnes of CO_2/year for coal; >500,000 tonnes of CO_2/year for gas), where the entire CO_2 capture-transport-storage chain is demonstrated: nine (mainly storage-oriented projects) are already operational, two are under construction and 69 are at planning stages:

- 21 projects are performing feasibility studies and preliminary engineering design (most mature)
- 24 projects are conducting pre-feasibility studies and initial cost estimates (moderately mature)
- 24 projects are undertaking scoping studies (least mature).

Out of these 80 projects, 44 are in the power sector and 25 in Europe.

[12] For an overview of how CCS works, see the animations on ZEP's website, "The Hard Facts, Inside CCS and Safe Storage": www.zeroemissionsplatform.eu
[13] For example, 1 million tonnes of CO_2 from the Sleipner gas field have been stored every year in the Utsira deep saline aquifer under the North Sea since 1996; 1 million tonnes of CO_2 every year in a producing gas field at In Salah in Algeria since 2004; ~37,000 tonnes of CO_2 in a deep saline aquifer at Ketzin in Germany between 2008 and 2010
[14] Deep saline aquifers are porous rocks filled with very salty water which makes them unsuitable for drinking water or agriculture
[15] Hazelwood, Loy Yang and Munmorah in Australia; Schwarze Pumpe, Staudinger and Niederaussem in Germany; Gaobeidian and Shidongkou in China; CEDF Alliance and Mountaineer in the US; Maasvlakte in the Netherlands, Karlshamn in Sweden; Renfrew in the UK; Matsushima and Mikawa in Japan; Lacq in France; CIUDEN and Elcogas-Puertollano in Spain
[16] The Status of CCS Projects – Interim Report 2010: www.globalccsinstitute.com/general_information/reports_papers_documents.html

In 2008, experts within ZEP and the wider CCS community identified the functional, operational and technical specifications for all the technologies that require validation and integration within the CCS value chain (excluding emerging technologies). Known as Technology Blocks[17], very few were found not to be validated at all, while many were either partially validated or already at pilot stage.

It was a key turning point, as it not only demonstrated the advanced stage of CCS technologies, but that industry was prepared and eager to deploy them – if the immediate cost gap could be met. While industry is willing to cover a major portion of the costs and risks of implementing an EU CCS demonstration programme, McKinsey & Company estimated that 10-12 projects would require €7-12 billion[18] in public funding in order to close the funding gap.

In the same year, ZEP carried out an in-depth study into how an EU CCS demonstration programme could work in practice, as the next vital step. Such a programme is essential in order to ensure the implementation of complete CCS value chains, accelerate technology development, build public confidence – and make CCS commercially available by 2020. The resulting report, "EU Demonstration Programme for CO_2 Capture and Storage – ZEP's Proposal"[18] therefore described what the programme should cover, how it could be funded and what steps must be taken to ensure it is up and running by 2015.

In response, the EU agreed to set aside 300 million emission unit allowances (EUAs) from the New Entrance Reserve ("NER 300") to demonstrate CCS and innovative renewable energy technologies – including funding for up to 12 large-scale CCS demonstration projects. This is currently valued by the European Commission at €4-5 billion[19] for CCS demonstration. The EU also launched an EU Energy Programme for Recovery (EEPR) in which €1 billion[20] was set aside for CCS demonstration projects in Poland, Germany, the Netherlands, Spain, Italy and the UK.

But if EU CCS demonstration projects are to be up and running by 2015[21] – as mandated by the European Council – the following issues must be addressed as a matter of urgency.

Establish national regulatory frameworks as a matter of urgency

Building a CCS project is a lengthy process: a fully integrated project can take 6.5-10 years from inception before it becomes operational. However, final investment decision (FID) by a company's board can only be made once construction and operation 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, thus setting the critical path (Exhibit 1).

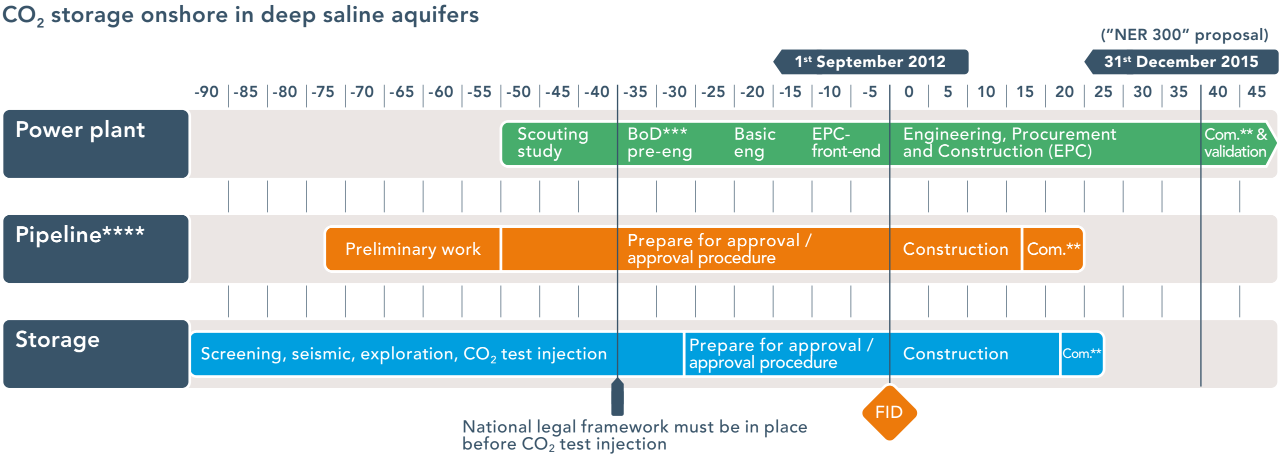
Permitting itself is dependent on the evaluation of risk – including a comprehensive risk mitigation strategy – for which storage liability must be clarified and a level playing field established for all project developers (see following page).

However, no CCS project can go ahead without the support of the public and a comprehensive communications strategy should be initiated as early as possible in the process (see pages 25-27).

[17] www.zeroemissionsplatform.eu/library.html/publication/47-techmatrix
[18] www.zeroemissionsplatform.eu/information.html/publication/2-eu-demonstration-programme-co2-capture-storage
[19] The actual financial value of the NER 300 will depend on the value of the CO_2 allowance at the time of monetisation by the European Investment Bank
[20] €50 million was also assigned to a steel plant project demonstrating CCS in France
[21] The first tranche of "NER 300" CCS demonstration projects

Exhibit 1: A typical timeline* for a CCS project – if EU demonstration projects are to be operational by 2015, national regulatory frameworks must be implemented as a matter of urgency

CO_2 transport by pipeline
CO_2 storage onshore in deep saline aquifers



Assumptions at FID

- Permits for power plant, pipeline and storage site have been granted
- Funding scheme secured two months before decision – at the latest
- No major investments have been made

Before FID: Timeline is determined by **pipeline** and **storage**
After FID: Timeline is determined by **power plant (capture)**

* Given timescales may vary depending on project-specific conditions
** Com. = Commissioning
*** Basis of Design (BoD) pre-engineering study
**** Preparation of approval can only start if storage site has been located

Implement the CCS Directive in Member States

As a national CCS legal framework is the basis for the approval of permit applications, Member States with projects due to operate from 2015 need to implement the Directive on Geological Storage of CO_2 ("CCS Directive") – or at least provide legal certainty for CO_2 storage – well before the deadline in June 2011. The European Commission is therefore in the process of establishing Guidance Documents on the transposition of the Directive, to which ZEP has submitted a detailed response[22].

In general, its implementation must reflect the spirit of the Directive, while not exceeding its requirements: as CCS is a key technology for mitigating climate change, the Directive must be regarded as a tool for its safe, wide and accelerated deployment. **A flexible and pragmatic approach in the pre-commercial, demonstration phase of CCS is therefore essential.** ZEP also recommends that the Guidance Documents be periodically reviewed on the basis of lessons learned from the demonstration projects.

ZEP supports the principle that financial security and liability provisions should remain an incentive to act as a prudent and reasonable operator, and develop the best and safest storage sites. However, the long lifetime of CCS projects – and even longer periods for which financial security will need to be provided by the operator – means that the detailed rules (e.g. type of security, timing of build-up of the security, discount rates and presumption of risk of leakage) will have a huge impact on their financial viability.

Indeed, some of the current provisions – in particular, for Article 19 on Financial Security and Article 20 on Financial Contribution – impose unbearable uncertainties and risks on the storage operator and, if implemented, are likely to represent a show-stopper to the development of

[22] www.zeroemissionsplatform.eu/extranet-library.html/publication/123-zepresponseguidancedocs

CCS within the EU. In order for CCS to become commercially viable, industry needs both a strong framework and a manageable risk exposure.

Without justification, the guidance seems to perceive CCS as a high-risk activity. The result is that some Financial Security obligations impose unnecessary and disproportionate costs on the storage operator. It is unclear why the level of Financial Security needs to be so high, as CO_2 storage does not present the same risk profile or immediate impact on health, safety or the environment as many other industrial activities. Indeed, applicable precedents already exist in the oil and gas industry – in particular, experience of sub-surface modelling, CO_2 injection, site closure and monitoring. Existing industry best practice should therefore be utilised in managing risk and uncertainty.

ZEP therefore believes that while site characterisation and monitoring should follow a risk-based approach, the Directive should present options (not mandatory actions) that an operator can use to demonstrate safe storage. Monitoring should focus on demonstrating non-leakage and only then trying to quantify plume volume and types of trapping mechanisms etc.

A key prerequisite for CCS activities is the possibility for operators to hand over their liabilities at some stage to the Competent Authority, as commercial companies cannot operate over an indefinite horizon. A project-specific, criteria-based – rather than a time-based – approach should therefore be used to determine when hand-over can take place. Only a criteria-based approach can provide the required certainty for the Competent Authority.

Quantify the CO_2 price risk for operators

Beyond financial security, operators' liability for purchasing EUAs, in case of major leakages, is likely to block the development of CCS unless governments can offer them a way to limit, through a contractual arrangement, the CO_2 price risk for such events.

Indeed, unlimited exposure – in particular to an increase in EUA prices – will discourage operators from undertaking CCS projects and be counter-productive from a climate risk mitigation point of view. By sharing or capping liability, Member States may take on the residual liability, i.e. act as an insurer. The premium paid for such service by the operator should therefore be tailored on a case-by-case basis.

These issues require clarification beyond the Guidance Documents – and at least before FID for CCS projects are made. Competent Authorities should do this on a site-specific basis, drawing on relevant experience from oil and gas extraction, and waste deposits.

Develop flexible standards for CO_2 quality

CCS pilot and demonstration projects will provide key data for characterising the environmental impact of CCS and related costs, and a clear definition of the quality of the CO_2 stream produced with different technologies which could be included in the BREF[23] Document for Large Combustion Plants under the IPPC[24] Directive.

The required CO_2 quality for transport and storage should be flexible to enable the most economic option to be chosen, e.g. the concentration of the CO_2 in the stream produced, transported and stored should be able to vary depending on the project-specific requirements. Different standards should therefore be developed for the different standard set-ups.

If CO_2 is taken out of the flue gas stream the overall volume of the flue gas released to the atmosphere is reduced; however, metrics for emission still link limit values for classic pollutants (notably NO_X, SO_X and dust) to flue gas volumes and therefore need to be reconsidered. Other metrics, such as pollutants per unit energy produced, may therefore be more appropriate in the future.

Sooner rather than later, CO_2 transport will cross borders, either by pipeline or by ship and an effective European CO_2 market will only develop if standards and specifications are aligned EU-

[23] BAT (Best Available Techniques) Reference Documents
[24] Integrated Pollution Prevention and Control

wide, such that free flow of CO_2 to the best storage opportunities can take place. This is a complicated issue and the EU should support the removal of all barriers to achieving this, including:

- Supporting common standards for material usage, basic design rules and shipping, set by industry and scientific institutes.
- Recognising that satisfying specific transport or storage requirements will come at a cost to the capture facility and thus the entire CCS value chain. The solution should therefore be cost-efficient and avoid unnecessarily high purities of CO_2 that will increase the cost of CO_2 capture. This may necessitate multiple standards, depending on the storage option, e.g. industrial-grade CO_2, CO_2 for deep saline aquifers, CO_2 for EOR, CO_2 for depleted gas fields and for other industrial uses.
- Ensuring no waste is added to the CO_2 stream for the purposes of disposal and that agreed CO_2 quality standards should not impact on the effectiveness of transportation networks or the integrity of storage. There must also be a strong distinction between adding contaminants to a CO_2 stream vs. permitting the injection of contaminants already found within the CO_2 stream.

The OSPAR Convention[25] has already been amended to permit the storage of CO_2 in sub-seabed geological formations and the London Protocol[26] has recently been amended to permit the cross-border transfer of CO_2. However, the latter will not enter into force until two-thirds of Parties have ratified the amendment and ZEP urges all Parties to do so at the earliest opportunity.

Provide regulatory flexibility to reduce the costs and risks

Operational flexibility that is not excessively constrained by regulation is key to early commercial deployment of CCS – significantly reducing costs and risks for plant owners and operators, and providing a more secure generation capacity. Specific consideration should also be given to "no-harm/no-foul" provisions for potential negative outcomes where good-faith efforts and state-of-the-art technology have been deployed for storage site characterisation.

Regulation should also recognise the potential for temporary reductions or cessation of CO_2 storage or EOR operations. Experience will reduce the probability of such events, but not provide absolute certainty that they cannot occur. As the technology becomes more widely deployed, CCS clusters (see page 19) will significantly reduce this risk, but will not be available for early projects.

Combining no-harm/no-foul provisions with inherent design flexibility for the entire system to be able to operate with or without CCS will therefore significantly improve the risk profile for the purpose of commercial financing. It will also increase grid robustness to be able to respond in those instances when reserve capacity is not sufficient to deal with demand excursions.

Establish monitoring, reporting and verification (MRV) regulations for CO_2 storage

Despite the fact that the processes used for CO_2 storage and transportation are almost identical to those used by the oil and gas industry for decades, public concerns centre on their perceived novelty. The assurance that Competent Authorities will safeguard transportation and storage over the long term is therefore essential.

This means the urgent establishment of **site-specific** monitoring, reporting and verification (MRV) guidelines by the European Commission and Member States as part of the implementation of the CCS Directive and the European CCS Demonstration Project Network. Commission Decision 2010/345/EU of 8 June 2010 has already included capture, transport and storage of CO_2 into the EU ETS Monitoring and Reporting Guidelines.

It is therefore crucial that Competent Authorities in the Member States engage in a process of knowledge-sharing for this purpose, building on industry's experience of transporting and

[25] OSPAR was set up in 1992 to prevent and eliminate pollution in the marine environment of the North-East Atlantic. Its members include Denmark, France, Germany, the Netherlands, Norway, Spain, UK and the EU, represented by the European Commission

[26] The London Protocol sets out rules to prevent marine pollution by the dumping of waste worldwide and has over 77 member countries

storing other liquids and gases. This will ensure a common understanding across Member States of the main aims of MRV plans, including:

- Monitoring for early warning signs of any significant irregularities or actual seepage emissions, e.g. loss of wellbore integrity; and, if necessary, activating recovery measures to bring the potential seepage hazard under control.
- Verifying and validating dynamic earth models in the short term in order to estimate the long-term behaviour of the CO_2 plume, inform the frequency and duration of the monitoring plan and confirm secure containment.

Close the funding gap for EU CCS demonstration projects

While the price of EUAs is expected to make CCS economically viable in the longer term, like most climate change mitigation technologies, it is not cost-competitive at the current stage of industrial-scale demonstration. Unlike other climate change mitigation technologies, however, most Member States have been reluctant to fund a technology that has only one direct benefit – CO_2 emission reduction. Hence the need for EU funding for an EU CCS demonstration programme via the EEPR and “NER 300” fund.

While these funding streams provide a good foundation for closing the funding gap, further action is nevertheless required in order to ensure a complete portfolio of CCS technologies is demonstrated:

- Together, these EU instruments will only cover up to 50% of the incremental costs of CCS, net of avoided EUA expenditure. While industry will contribute significantly to closing the remaining gap, **additional government support – whether through state aid or EU structural and cohesion funds – is therefore essential**. Co-financing of CCS demonstration projects by Member States must be in place by the end of 2011 at the latest.
- It is essential that the second tranche of the NER 300 is allocated in a manner that secures **the entire portfolio of CCS technology options**, as described in “EU Demonstration Programme for CO_2 Capture and Storage: ZEP’s Proposal”[18]. This involves prioritising projects with characteristics that are not represented in already funded CCS demonstration projects, e.g. retrofits, gas-fired power plants, biomass co-firing, CO_2 transport by ship and the complete range of storage options.
- Conditions for participating in EU funding should be sufficiently flexible to recognise the effects of the current economic crisis.

Prioritise CCS R&D to maximise the learnings of EU demonstration projects

Every year since 2006, ZEP has provided detailed recommendations for R&D within European Commission and Member State programmes in support of CCS. The result is that the EU is now leading the world in the implementation of an ambitious demonstration programme for CCS as a critical technology for combating climate change.

In autumn 2009, ZEP addressed the following R&D topics still to be prioritised for the EU Seventh Framework Programme (FP7):

CO_2 capture
- *Post-combustion* – integration and optimisation with power plant; improve solvents
- *Pre-combustion* – improved gasification of solid fuels; full process integration and optimisation for power, competitive availability and load-following characteristics
- *Oxy-fuel* – create a firm basis for design for boilers and CO_2 capture, compression and conditioning processes

CO_2 storage and transport
- Develop procedures for safe operation of CO_2 storage in deep saline aquifers

- Develop and demonstrate long-term modelling of CO_2 storage in deep saline aquifers
- Investigate impact of the quality of CO_2 on transport and storage behaviour
- Further develop methods to assess and improve wellbore integrity
- Adapt and develop safety assessments and standards for large-scale transport through densely populated areas and harbours (shipping)
- Mitigation and remediation – develop a portfolio of various measures that can be used to remediate significant irregularities and leakages at different timescales, during both injection and post-injection.

Maximise knowledge sharing among EU and international CCS projects

A world first, the European CCS Demonstration Project Network[27] is the collaborative vehicle for all EU-funded CCS demonstration projects to share knowledge[28] and identify best practices. (It is also open to other CCS projects willing to share knowledge on a reciprocal basis.) On an operational level, ZEP has therefore strongly supported its development – in particular, by providing recommendations for the implementation of "NER 300" funding[29] and knowledge sharing[30].

As the key to the success of the Network, ZEP advocates an ambitious level of knowledge sharing, whose principles may be summarised as follows:

- Maximise sharing – without compromising innovation
- Share significantly beyond the minimum legal requirement, e.g. to obtain permits
- Provide full transparency, while ensuring that stakeholders only receive the information they need
- Distinguish between stakeholders: *Contributors to the demonstration programme, Non-contributors, Research Institutes, Government/EU and Public/NGOs*
- Distinguish between categories of knowledge *(Technical Set-up and Performance, Cost Levels, Project Management, Environmental Impact, Health and Safety)* and levels of detail *(Detailed, Medium and Aggregated)*
- Share knowledge on a reciprocal basis with EU and developed countries; and on a reciprocal or asymmetric basis with developing countries.

While not prescriptive, ZEP's proposal offers a clear and transparent framework for knowledge sharing that goes significantly beyond normal business practice. In fact, in the range and depth of knowledge recommended to be shared, it has no precedent. While central to the EU CCS demonstration programme, it can therefore also be used as a model for other programmes.

Covering the full CCS value chain, it provides specific recommendations on what should be shared, with whom and how. This includes practical solutions for sharing knowledge which is either subject to Intellectual Property Rights or competitive constraints (classed as "know-how").

The role of ZEP

Network projects will play a crucial role in identifying solutions to key issues, such as financing and regulation, which will accelerate the wide-scale deployment of CCS. A clear dialogue between the Network's Steering Committee and its Advisory Forum – on which ZEP is represented – is therefore vital to ensure these solutions are optimal from an EU perspective and "future-proof".

ZEP can maximise knowledge sharing by incorporating insights and verifying solutions swiftly through its four Taskforces – Demonstration and Implementation, Policy and Regulation, Technology and Public Communication – in which both industry and non-industry stakeholders are broadly represented. As importantly, it can facilitate engagement with non-Network projects, both in the EU and internationally.

[27] www.ccsnetwork.eu
[28] All EU-funded demonstration projects are legally required to share knowledge under Article 10a(8) of the revised EU ETS, 2009/29/EC
[29] www.zeroemissionsplatform.eu/information.html/publication/1-new-entrant-funding
[30] Published in May 2009: www.zeroemissionsplatform.eu/information.html/publication/55-zep-ccs-knowledge-sharing

The European Industrial Initiative on CCS

In November 2007, the European Commission's Strategic Energy Technology (SET) Plan announced the development of six European Industrial Initiatives (EIIs) – public-private partnerships to support the development and large-scale deployment of low-carbon technologies, including CCS. One of the first EIIs to be launched in June 2010, the CCS EII has two strategic objectives[31]:

1. To enable the commercial deployment of CCS in coal-fired power plants by 2020
2. To further develop CCS technologies to allow application in all carbon-intensive industrial sectors.

The SET Plan recognises that these objectives are best achieved through a coherent effort by industry, the Commission and Member States – driving and accelerating changes required in policy, technology and financing, at all levels of governance.

Activities for the achievement of these objectives are already in motion, including: identification of priority actions; synchronisation of agendas; identification of synergies between activities and possible interdependencies on risks; and monitoring and reporting of progress to stakeholders. Although industry-driven, the CCS EII will build on the comparative strengths of each of the partners:

- *Industry:* to manage technology and market risk, and deliver on technology and cost objectives
- *Member States:* to ensure regulatory compliance through provision of a clear regulatory framework at national level; provide financial support as needed, taking into account favourable State Aid rules for CCS; and reflect agreed CCS EII RD&D priorities in their national RD&D Programmes
- *European Commission:* to provide guidance, as necessary, in relation to the regulatory framework; provide clarity over applicable EU law and policy and their impact on business decisions; coordinate CCS demonstration at EU level via the European CCS Project Network; and provide funding support via the EEPR and "NER 300" etc.
- *Research organisations and EERA:* to undertake necessary research activities which complement those of industry and therefore deliver required breakthrough research at least cost and on time.
- *NGOs:* to promote understanding and raise awareness of the benefits of CCS in civil society and advise on actions, as appropriate.

An effective organisational structure will be decided jointly by all partners and reviewed periodically.

The role of ZEP

As the key stakeholder of the EU CCS demonstration programme, ZEP will continue to track and advise on all key issues – including technology, funding, policy and regulation, knowledge sharing and public communication – as the vehicle for both industry and non-industry stakeholders.

[31] "CCS EII Implementation Plan, 2010-12": www.zeroemissionsplatform.eu/eu-ccs-industrial-initiative-launched

Facilitating the wide-scale deployment of CCS

In order to ensure global warming stays below 2°C – as agreed in the Copenhagen Accord – the 2009 IEA CCS Technology Roadmap[32] concludes that at least 100 commercial-scale CCS projects must be operational worldwide by 2020, including 14 in Europe.

This rises sharply to 3,400 worldwide by 2050, including 320 in Europe. It represents an enormous challenge, which can only be achieved through forward planning and a dedicated, coherent effort. Yet even the minimal target of 14 in Europe by 2020 (50 for all OECD countries) is unlikely to be met by current levels of deployment.

Early action on a wide range of issues is therefore essential if CCS projects are to be implemented at the rate and scale required – maintaining the significant momentum created by the EU CCS demonstration programme.

Apply CCS across all carbon-intensive industrial sectors

ZEP has always emphasised the key role CCS can also play in dramatically reducing CO_2 emissions from non-power sectors and represents a key strategic objective of the CCS EII (see page 16). Indeed, in steel and cement production, CCS is the only means of achieving deep emission cuts.

In four sectors alone – iron and steel, chemicals, cement and fuel transformation – the IEA[33] estimates CCS could abate more than four billion tonnes of CO_2 a year in 2050. This is equivalent to two-thirds of 2007 CO_2 emissions from industry and fuel transformation and ~15% of all man-made CO_2 emissions worldwide.

Yet although CO_2 capture technologies for power generation can be easily applied to industrial applications – especially on flue gases and/or from captive CHP plants – few such CCS demonstration projects are currently being planned (with important exceptions, e.g. the ULCOS iron and steel initiative[34]). ZEP therefore urges OECD countries to make large-scale public funding available for demonstration projects in industrial sectors in addition to, and not at the expense of, those in power generation.

Indeed, if all these different CO_2 sources – power, industry and fuel transformation – are located in close proximity (e.g. in ports), with detailed planning they can share CO_2 transport and storage infrastructure, saving both time and money, e.g. the Humber cluster in the UK; the Rotterdam cluster in the Netherlands. Industrial applications and the development of trans-sector CCS clusters should therefore be included in all National CCS Master Plans (see page 19).

N.B. All actions for accelerating the deployment of CCS in power generation may also apply to industrial applications, including incentive schemes and the challenges of international competition.

[32] www.iea.org/papers/2009/CCS_Roadmap.pdf
[33] IEA, Energy Technology Perspectives 2010, Scenarios and Strategies
[34] www.ulcos.org

Move closer towards a carbon-negative energy system

By co-firing power plants with biomass – or using 100% biomass combustion – CCS can also be used to generate power with net *negative* CO_2 emissions, because biomass also absorbs CO_2 from the atmosphere while it is growing. When combined with sustainably produced biomass, this offers great abatement potential, which will be addressed in the IPCC's Fifth Assessment Report to be published in 2014. It will also increase public support for CCS.

Today, modern coal-fired power plants (hard coal or lignite) can achieve up to 20% co-firing with biomass with no significant impact on efficiency[35], although for cost reasons it is unlikely CCS would be applied to plants smaller than ~300MW. Biomass feedstock can also be used in technical processes, such as in the cement industry, and combined with CCS.

However, biomass fuels of the necessary quality are costly and clarification or adjustment of the EU ETS Directive is required to ensure proper credits for CO_2 abated from biomass. Replacing a large proportion of fossil fuels with biomass in power plants could also prove challenging for the biomass supply chain. Care should be taken that biomass production does not compete with food and feed production, and that indirect CO_2 emissions – especially those coming from the biomass supply chain (e.g. processing, transportation) – do not degrade the global CO_2 profile of this solution.

Policy measures are therefore required to ensure that sustainable land management and biomass production and supply are employed to minimise any negative effects. New ways also need to be found to generate sustainable biomass feedstock – not only for power production, but also for production processes which produce biofuels and bioproducts, known as biorefineries.

ZEP has established a Joint Taskforce on biomass and CCS with the European Biofuels Technology Platform (EBTP) with a view to advancing this vital technology and recommends that the EU CCS demonstration programme includes at least one project in the power sector with biomass co-firing.

Establish a long-term infrastructure plan for CCS in Europe

In order to ensure that the EU CCS demonstration programme leads to rapid deployment post-2020, a business model for CO_2 transport and storage must be established that includes the demonstration projects within a long-term infrastructure plan for Europe.

Indeed, with only a small number of demonstration projects spread over various Member States – and great pressure on cost containment – there is a risk that projects will result in isolated, point-to-point solutions, without scope to grow. The EU's policy of developing networks in order to achieve energy and climate objectives should therefore be extended explicitly to include the development of new CO_2 pipeline infrastructure[36], as well as existing gas and electricity transportation networks.

The manner in which CO_2 pipeline infrastructure projects are developed in the near term will have a significant impact on how (or whether) the European CCS infrastructure develops in the medium to long term. Clearly, there is a need for new and early CO_2 pipeline infrastructure and its complexity and lead-time should not be underestimated. The definition of the optimum CO_2 infrastructure in terms of transport systems, volume and all other technical aspects will necessitate complementary studies which should be supported by planned EU policy.

The European Commission's Directorate-General for Energy is planning to publish a first study on European CO_2 infrastructure in autumn 2010. The Commission will then issue an Energy Infrastructure Package in November 2010, mapping out what is required to develop Europe's energy networks by 2020. An efficient CO_2 infrastructure is crucial to reducing the costs of CCS, given the potential for clusters which will facilitate the transition to early market deployment. It is therefore vital that

[35] Modifications are mainly to fuel handling and pre-treatment equipment

[36] CO_2 transport by ship may also be economically advantageous in the start-up phase of projects and where CO_2 volumes are limited and/or storage sites are remote

the Energy Infrastructure Package also maps out clearly what is needed to support its development.

Identify CCS clusters in order to maximise synergies and reduce costs

Financing, potential local opposition and lengthy permitting procedures may represent important obstacles for CO_2 pipeline infrastructure development. From the outset, EU policy should support the development of appropriate CCS clusters underpinned by regional CO_2 pipeline networks – given these are likely to form the first building blocks for European CO_2 pipeline networks.

This process has already begun, with the development of regional public-private partnerships, such as the Rotterdam Climate Initiative, which aspires to become the CO_2 hub for Northwest Europe and the Yorkshire and Humberside network, which has been designated the UK's first Low Carbon Economic Area for CCS.

EU policy should also encourage Member States to develop National CCS Master Plans in which key clusters are identified and a long-term CO_2 pipeline infrastructure plan developed to address optimal network routing, sizing, prioritisation and phasing of CO_2 transport and storage. Given CO_2 sources are spread throughout Europe, with potential storage sites not usually situated in their vicinity, the EU will need a trans-boundary CO_2 pipeline infrastructure – together with the Master Plans – to address this.

The Dutch National CO_2 Infrastructure Master Plan

Through its state bodies, EBN and Gasunie, and following extensive interviews with stakeholders, the Netherlands Government developed a national CO_2 Transport and Storage strategy over the course of 12 months, setting out the framework for future government and industry efforts. The document details:

- A set of scenarios for CO_2 transport and storage requirements in the Netherlands
- The most likely regional infrastructure solutions, differentiating between an offshore network in Western Netherlands and an offshore network in North Netherlands
- The preferred market models for CO_2 transport and storage
- The role of government and state bodies
- The required legislative changes to allow a smooth emergence of CO_2 storage activities.

Collaborative models like the CCS EII offer the opportunity to accelerate the required political and regulatory agreement and ensure a joint Member State commitment on CO_2 infrastructure. The CCS Project Network will also contribute to the creation of an effective CO_2 infrastructure, thanks to shared learnings among EU CCS demonstration projects.

There is compelling evidence that an integrated future capacity planning approach to pipeline infrastructure development offers the lowest average cost per tonne solution (i.e. best value for consumers), provided sufficient capacity utilisation is achieved relatively early in the pipeline life. Furthermore, the early provision of the CO_2 pipeline infrastructure removes barriers to entry for follow-on CCS projects – accelerating the transition from demonstration to deployment.

Economies of scale will reduce the costs of wide deployment, but current market forces alone – with the EU ETS as sole incentive – will not deliver CO_2 pipeline infrastructure at the scale and pace required, especially in the initial phase. EU policy should therefore support this "least regrets" approach to CO_2 pipeline infrastructure development – potentially providing financial incentives/support for "over-sizing" infrastructure. Transparent and non-discriminatory rules and tariffs for third party access to CO_2 pipeline infrastructure will also be necessary.

Regulatory regimes for gas infrastructure projects vary widely across the EU. In most Member States, it remains unclear who will build, own and operate a future CO_2 pipeline infrastructure and under which conditions. Within some Member States, (semi-) state companies may assume a role in CCS pipeline infrastructure.

This uncertainty fuels the 'wait-and-see' approach being adopted by many potential players, which in turn negatively impacts the speed of deployment.

EU policy should clarify, either directly or through the National CCS Master Plans, the preferred regulatory regime and business model for CO_2 pipeline infrastructure. Due to their different risk and liability structure, ZEP recommends differentiating between CO_2 transportation and storage, which should be reflected in any policies.

Accelerate the characterisation of potential storage sites

There is an urgent need for more technical and comprehensive characterisation of potential CO_2 storage sites – especially deep saline aquifers – EU-wide. If storage is not sufficiently proven then investors, including state-owned entities, will not have the confidence to commit to an initial pipeline infrastructure and the possibility of a rapid transition from demonstration to wide-scale deployment will be compromised. Indeed, potential storage sites should be identified as early as possible as the most critical element of a CCS project in order to avoid any time lost.

The study underway by Arup and the Scottish Centre for Carbon Storage / University of Edinburgh, on behalf of the European Commission, is a useful start. However, a step increase in support of storage characterisation at the pre-investment stage is urgently needed. This includes regional storage maps of relevant geological stages, e.g. Jurassic and Triassic for the North European Basin.

Create a secure environment for long-term investment in Europe

Like all major new technologies, the costs of early CCS projects will be high, but experience, technology development and economies of scale should drive these down.

It is estimated that CCS will require global investment of over $2.5-3 trillion[32] from 2010 to 2050 in order to provide 20% of the global emission cuts required by 2050. Without CCS, however, abatement costs would be far higher – $1.3 trillion[37] per year – a stark 71% more. The earlier Europe starts investing in CCS, the greater the benefit it can therefore derive from these investments. A CCS competitiveness analysis, based on experience gained from the EU CCS demonstration programme, will prevent exaggerated subsidies and perverse incentives.

The best and most readily available incentive for EU-wide deployment of CCS is the price of emission unit allowances (EUAs) under the EU ETS. However, this needs to – and can reasonably be expected to – be significantly higher and more predictable than at present to make CCS cost-competitive. Continued support for CCS is therefore required in the intermediate period – after the technology is commercially proven, but before the carbon market has matured sufficiently to allow full commercial and competitive operation. This does not mean that under long-term, stable conditions market rules should be bent to favour a specific technology, but that greater regulatory certainty is needed.

Substantive state aid has been pledged to demonstration projects in the UK, Norway and the Netherlands, but not in the most coal-dependent countries in Europe where new coal-fired power plants are most likely to be built. Increasing public deficits across the EU have also made it even more unlikely that state aid alone will close the funding gap. Some Member States may prioritise CCS in their operating programmes for EU structural and cohesion funds under the new EU financial framework starting in 2014, but this remains highly uncertain.

ZEP does not have a preference for specific non-ETS incentive schemes. However, at this stage we believe there is a particular need to investigate how they can be revenue-neutral for treasuries, predictable for investors and effective for project developers. In general, they should not tilt the level playing field between low-carbon generation technologies; or abruptly distort or have unwanted impacts on the electricity market and subsequent security of supply.

The long lead-times for building large-scale thermal power plants mean that incentive schemes to make CCS cost-competitive from 2020 need to be adopted sooner rather than later, using a harmonised EU

[37] IEA, "CO_2 Capture and Storage – a Key Carbon Abatement Option"

approach. Progress is being made by some Member States in the design of incentive schemes and ZEP recommends a common approach.

In summary, incentive schemes for CCS deployment should:

- Make CCS competitive with unabated fossil fuel alternatives, while avoiding abrupt market distortions
- Be established in advance for a well-specified period, taking into account the market price of CO_2
- Use competitive markets as widely as possible
- Safeguard against CO_2 leakage through non-discriminatory measures consistent with internal market law, e.g. guarantee of origin requirements
- Be reduced over time, with experience gained from EU CCS demonstration projects, the development of next-generation technologies and the evolution of the CO_2 emission price.

Options for CCS deployment incentives include a carbon levy on electricity: in the UK and the Netherlands, schemes have been proposed to produce long-term predictability for a high price on CO_2 emissions in the power sector, using those revenues to fund CCS projects.

In its Energy Act 2010, the UK introduced a new CCS Levy to be charged on electricity supplies to finance CCS demonstration projects. The electoral programme of the Conservatives suggested it vary with the EUA price in order to create a stable carbon price floor for the power sector. The contribution of each electricity supplier will be based on its market share, whilst the CCS incentive payments will be linked to the CO_2 abated by the project.

The "bonus-malus" system recommended by the Dutch CCS Task Force to the Dutch government consists of a similar mechanism, although it would not necessarily be channelled via the Treasury. It is based on setting a CO_2 emission "norm" (grams per kilowatt-hour). Power plants emitting above the norm would pay a penalty per kilowatt-hour, equivalent to the average CO_2 abatement cost for CCS on coal-fired power plants in the Netherlands. The penalty would be channelled to plants emitting below the norm, which would then gain the equivalent "bonus".

Other types of incentives may be also be reviewed, e.g. the use of Forward Capacity Markets (FCM) specifically for CCS.

Recognise CCS in international financing mechanisms

CCS has a vital role to play in dramatically reducing greenhouse gas emissions in all countries dependent on fossil fuels – in both the power and industrial sectors. Indeed, of the 100[32] commercial-scale CCS projects required to be operational worldwide by 2020 in order to achieve the 2°C target, 50 are in developing countries.

CCS is also currently not recognised under international mechanisms to support the development of low-carbon technologies in developing countries. The result: most developing countries are missing out on a crucial technology, while developed countries are already pursuing rapid programmes of development and deployment.

ZEP therefore advocates the large-scale international public financing of demonstration projects and the recognition by the EU and other OECD countries of CO_2 storage credits via flexibility mechanisms recognised in their own cap-and-trade schemes, e.g. the Clean Development Mechanism under the Kyoto Protocol.

Accelerate R&D into next-generation CCS technologies

While individual components of the CCS value chain are already proven – ready for scale-up and integration – further R&D into next-generation technologies must also be initiated immediately to enable rapid and wide deployment post-2020.

Implement ZEP's long-term R&D plan

To this end, experts within ZEP have identified key areas for improvement, together with the main strands for R&D to 2030 and beyond. To ensure maximum effectiveness, this should be coordinated at a national and EU level and *include key learnings from the EU demonstration programme*. Technologies still at an early stage should also be included since sudden technology breakthroughs cannot be foreseen, but are the outcome of dedicated R&D.

The resulting report, "Recommendations for research to support the deployment of CCS in Europe beyond 2020", was published in spring 2010[38].

Key conclusions
Second-generation CCS technologies (2020-2030): technologies brought to commercialisation within this period are likely to be based on improvements and refinements of first-generation technologies employed pre-2020. Some new technologies, currently in the R&D phase (e.g. chemical looping combustion or carbonate looping) should reach the demonstration or even commercial phase.

Third-generation CCS technologies (post-2030): technologies brought to commercialisation within this period are likely to be based on optimised and refined first- and second-generation technologies. In particular, demonstration phase, second-generation technologies should become commercialised. New technologies, which today could be in R&D infancy (e.g. membrane separation) should reach the demonstration phase and then become commercially available.

CO_2 capture
R&D activities for CO_2 capture should focus on improving and developing new and competitive capture technologies in order to reduce cost and energy consumption, including:

- Undertaking further R&D on the current portfolio of capture technologies – post-combustion, pre-combustion and oxy-fuel – and identify improvements in those closest to commercial maturity.
- Investigating novel technologies and the novel use of known technologies
- For all technologies, identifying additional areas of improvement in reliability, availability, maintainability and flexibility (e.g. in terms of fuel or operation).

CO_2 transportation and storage
R&D activities for CO_2 transportation and storage should focus on enhancing technologies and methodologies expected to facilitate wide-scale deployment, including:

- Developing a complete transportation infrastructure, including industrial sources of CO_2
- Improving methodologies for assessing storage options and their capacities
- Optimising storage capacity and efficiency.

Deploy EU CCS "lighthouse projects"
Coordination is needed on a national and European level for R&D activities with a clear European added value on different aspects of CCS. The aim: to realise the commercial availability of new technologies/concepts by 2020-2025. While some funding has already been allocated to the development of CO_2 infrastructure and cooperation with emerging economies, the following concrete R&D areas need to be addressed, where possible through larger pilot installations, known as "lighthouse projects".

In April 2010, the European Commission therefore asked ZEP to assist with the identification of 3-5 R&D projects with a high impact and strong industrial involvement, each with a budget of ~€30-80 million, to be initiated by 2012. ZEP launched an expression of interest among its members and presented the results to the Commission, which is expected to fund projects through an open framework programme call for proposals, together with co-financing from Member States.

ZEP estimated that lighthouse projects for the period 2012-2016 would require a budget of €950 million. For a similar budget, we expect that further improvement in the performance of CCS can be achieved in the period 2016-2020, bringing the total required budget for CCS-related R&D to ~€1,900 million.

N.B. Lighthouse projects relate to prioritised R&D – ZEP's long-term R&D plan goes significantly beyond this and will require additional funding.

[38] www.zeroemissionsplatform.eu/library.html/publication/95-zep-report-on-long-term-ccs-rad

Realise the full potential of CCS

Use the production of CO_2-free Hydrogen for electricity or fuel

In pre-combustion CO_2 capture technology, systems process the primary fuel (natural gas or synthetic gas from coal) in a shift reaction to produce streams of CO_2 and hydrogen which can be separated. The large volumes of CO_2-free Hydrogen produced can then be used for either electricity or as a fuel.

With hundreds of passenger cars now having covered millions of kilometres and undergone thousands of refuellings, fuel cell electric vehicles (FCEVs) are considered to have been comprehensively tested in a customer environment. The result: the focus has now shifted from demonstration to commercial deployment so that FCEVs, like all technologies, may benefit from mass production and the economies of scale.

This was clearly signalled by the establishment of the Fuel Cells and Hydrogen Joint Undertaking[39] in 2008 – a joint public-private partnership supporting research, technological development and demonstration (RTD) activities in fuel cell and Hydrogen energy technologies in Europe.

It was also reinforced by a Memorandum of Understanding issued by leading car manufacturers[40] in September 2009, in which they stated their goal to commercialise FCEVs by 2015, with hundreds of thousands of vehicles being rolled out worldwide shortly thereafter, if sufficient Hydrogen refuelling infrastructure is available. A public-private partnership called H_2 Mobility was then established to develop a detailed business plan for building a Hydrogen refuelling infrastructure in a single Member State as an essential first step towards a full EU roll-out.

An existing Hydrogen infrastructure will also facilitate the introduction of stationary fuel cells for residential and small commercial applications, which will play a key role in providing distributed CHP generation.

Explore geothermal heat production with CCS

When storing large amounts of CO_2 in deep saline aquifers, the fluid pressure of the storage system may increase to levels where production of salt water is desirable – as in the case of the Gorgon[41] project in Western Australia. This can then be reinjected at other locations, or disposed of in marine waters.

With temperatures ranging from 45°C to 90°C, production water may be used for geothermal heat production – where appropriate – providing cheap district heating for the population in the vicinity of the storage site. In short, water production may result in increased storage capacity and benefits for local residents. This concept for synergy is quite novel and opportunities for deployment should be pursued in future CCS demonstration projects.

Utilise CO_2 in industrial processes and products

While limited in volume, industrial uses of CO_2 can be an attractive option to reduce the costs of the CCS value chain by providing a value to the captured CO_2. In 2008, 150 Mt CO_2 were used in industrial processes, representing 0.5% of CO_2 emissions worldwide. This included EOR/EGR, industrial applications and other uses, e.g. as a refrigerant, solvent, in fire extinguishers etc.

Research is ongoing and must focus on finding new processes/applications that ensure CO_2 usage with a real net reduction of emissions over the lifecycle. This also includes using CO_2 in biological processes (e.g. as fertiliser in greenhouses or to produce biomass, such as algae, which can then be used for energy production) and applications whereby the CO_2 is kept out of the atmosphere in CO_2-bearing products, assuming it is not emitted after a period of time.

Maximise international cooperation

CCS is a fast-growing industry, with work ongoing on mapping knowledge gaps and developing roadmaps for CCS R&D and deployment – including the work of ZEP. For example, the Carbon Sequestration Leadership Forum (CSLF) delivered a technology roadmap in 2009, while the IEA followed up on

[39] www.ec.europa.eu/research/fch/index_en.cfm
[40] Daimler AG, Ford Motor Company, General Motors Corporation/Opel, Honda Motor Co., Ltd., Hyundai Motor Company, Kia Motors Corporation, the alliance Renault SA and Nissan Motor Co., Ltd. and Toyota Motor Corporation: www.bmvbs.de/Anlage/original_1096793/Memorandum-of-Understanding-mehr-Informationen.pdf
[41] www.chevronaustralia.com/ourbusinesses/gorgon.aspx

the G8 call to have 20 operational projects by 2020 with its own global CCS technology roadmap in the same year.

ZEP welcomes the growth in regional and international CCS bodies which should continue to work closely together on all aspects of CCS. Indeed, in order to maximise synergies and accelerate deployment, international cooperation is crucial. International standards to qualify CO_2 streams for CCS are also important for developing an integrated, global CCS industry – a task for the International Standardisation Organisation.

ZEP therefore advocates knowledge sharing on an international scale, following the principles outlined in its proposal, "Maximising the benefits of knowledge sharing" (see page 15).

Establish an overarching 2050 energy decarbonisation scenario

The companies, scientists, academics and environmental NGOs that together make up ZEP are united in their support for decarbonising electrical power generation using a *portfolio* of technologies – including CCS and renewable energy. ZEP therefore looks forward to the launch by the European Commission of its roadmap towards a low-carbon energy system by 2050, as the base reference document indicating the lowest cost pathway to decarbonise EU power. It should also be realistic enough to ensure current reliability is maintained without compromising energy security.

The precise costing of the 2050 scenario will be an essential parameter of its credibility and usefulness. It must therefore be able to integrate:

- The sensitivity analysis of both fossil fuels costs, including certificate prices of overall emissions and cost of capital
- The modellisation of fuel prices versus fuel consumption on a world market basis
- A detailed cost assessment and modellisation of increased grid, storage and capacity back-up extension needed to accompany the increased use of renewable energy
- The inclusion of up-to-date data on technology costs and learning curves, along with their relative operation and maintenance costs, including distribution network operation
- A modellisation of electricity pricing mechanisms, which would strongly impact on actual prices paid for energy and influence demand
- The inclusion of specific differences in the regional/ national grids and energy markets, taking energy security into account.

The potential for energy efficiency savings must also be costed and barriers considered from a variety of perspectives, including that of the investor.

As much as a strong, top-down framework is needed to give general directions and key milestones, there is also a need for a regionalised bottom-up approach and forward analysis in order to identify nearer-term[42] and verifiable milestones, which could form the structure of a true decarbonisation roadmap within the boundaries defined by the 2050 overarching scenario.

A sound regional analysis would include:

- A preliminary energy decarbonisation SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of the main European regions
- Regionally tailored technology implementation and deployment propositions which would result in the lowest cost decarbonisation pathway for Europe
- Resulting proposals for specific EU Member State decarbonisation roadmap priorities.

Finally, as technology and markets move forward, a regular[43] revision of the overarching 2050 scenario and corresponding regional roadmaps will be required to monitor progress and adapt EU policy recommendations to both market and technology evolution. Such a regular revision cycle also offers an excellent public communication opportunity to communicate progress on key technologies, the effective use of public funding, and energy regulations and policies.

[42] A typical "roadmap" horizon for energy infrastructure is 10 years
[43] For example, every two years

Building support for CCS: the critical role of effective communications

Public funds and support are essential to kick-start a large number of currently uneconomic technologies to enable the shift towards a low-carbon society.

This in turn will enhance energy security, create new jobs and boost European industry and technology leadership. The debate over which technology is deserving of such support ignores the realities and time constraints imposed by climate change: only a *portfolio* of technologies can cut CO_2 emissions at the rate and scale required.

Yet despite increasing recognition of CCS as a key part of this technology portfolio, a disconnect exists between the actions of supportive governments engaged in vital CCS demonstration projects and programmes[44] and a public that is effectively uninformed as to how CCS works, its significant benefits and why it is urgently needed.

CCS also continues to be associated solely with coal, reinforcing the belief that it is merely a means for the continued use of fossil fuels. Yet it is key for natural gas power generation as well. There is also great potential to combine CCS with biomass, leading to carbon-negative production (see page 18). CCS can also reduce CO_2 emissions from industrial processes, such as steel, cement, fuels transformation and gas processing (see page 17).

The next decade will be critical in launching CCS on the path towards wide deployment, which cannot be achieved without the explicit and implicit support of the public. Concerns over the largely unknown activity of using and storing CO_2 in the subsurface and the economic benefits of CCS must therefore be given the highest priority – especially at local level. Addressing this information vacuum requires a series of actions by a broad set of credible stakeholders.

Polls and surveys[45]

- A 2010 poll by Infratest/Der Spiegel revealed that only 42% of Germans now believe in climate change, down from 62% in 2006.
- A BBC/Populus poll from February 2010 also revealed that the percentage of respondents who believe climate change is happening and established as largely man-made has fallen dramatically from 41% in November 2009 to 26%.
- A 2009 survey by Germany's CCS industry association, IZ Klima, revealed that out of 1,000 participants, only 1% knew about CCS.
- However, a 2009-2010 study on CCS communications undertaken under the FENCO-ERA NET programme found that ~40% of respondents in the six countries covered had heard a little, or quite a bit, about CCS.
- A TNS Gallup survey in Norway (2010) showed that three out of four know of CCS, while a report made for WWF (2010) found that two out of three Norwegians think people and nature in poor countries will be negatively affected by climate change and 50% worry about the consequences of global warming in Norway.

[44] EU, USA, Canada, Australia, China, South Africa and Norway
[45] Types/numbers of respondents and methodologies vary making it inappropriate to compare poll results directly

Steps to raise awareness and understanding of CCS through effective communication activities must address the following key issues:

1. **The belief in climate change is on the decline**
   The causes of climate change and actions required to address it must be continuously and strenuously communicated, serving as the cornerstone for any communication on low- and zero-carbon energy technologies.
2. **The awareness and understanding of CCS is low to non-existent**
   As part of the portfolio of necessary solutions to combat climate change, CCS requires significant profiling to address the knowledge gap.
3. **Safely storing CO_2 and the benefits of CCS are the key concerns**
   It is paramount to communicate the benefits of the technology and the existing expertise behind all stages of the CCS value chain – especially CO_2 storage, while emphasising the use of natural mechanisms that have already "stored" CO_2, oil and gas underground for millions of years.

Highlight the key role of CCS in combating climate change

Early analysis has shown that support for a CCS project is more likely to occur when the following factors are in place: trust in industrial actors; regional/national government support; local (economic) benefits; low population density; sufficient public engagement; and NGO/credible third-party involvement and support.

Any public-facing CCS communications strategy should therefore:

- Place CCS within the context of climate change and the challenge posed by the continued use of fossil fuels and industrial processes for decades to come. The potential for carbon-negative approaches, such as biomass co-firing in power plants, should also be communicated
- Demonstrate why only a portfolio of solutions can achieve the massive CO_2 reductions required, with CCS a bridging technology towards a low-carbon society
- Explain what elements of the technology are proven and what remains to be validated for the entire CCS value chain, addressing the benefits of CCS and key concerns over the safety of CO_2 storage
- Engage in an open dialogue that includes all CCS stakeholders (industry, government, NGOs, local communities, science and academia) and addresses the rational and emotional aspects of CCS, equitably and factually
- Leverage the diverse CCS stakeholder community to provide appropriate and credible input
- Achieve the highest possible levels of transparency, factuality and responsiveness so the public can make informed decisions
- Make CCS a reality to those directly impacted by CCS projects, through opportunities to "touch, feel and see" it in operation.

Leverage the expertise and diversity of the CCS stakeholder community

The great strength of the CCS community is its diversity and expertise, and the credibility this can carry when applied to public engagement – using the right messenger for the right issue and audience. There is a significant opportunity for CCS bodies to relate to one another in a more coordinated and consistent manner:

International
International bodies vary from intergovernmental initiatives, such as the Carbon Sequestration Leadership Forum (CSLF), to global environmental NGOs and companies. While their individual roles differ, they can provide much-needed global perspectives, analysis, direction and knowledge-sharing that constitute the "bigger picture" surrounding the need for, and role of, CCS.

Pan-regional
Pan-regional bodies, such as ZEP, provide the platform for outlining pan-regional needs and challenges, with a particular emphasis

on the key issues relating to deployment – technology, regulation, safety and financing.

National
The diverse CCS stakeholder community exists within some EU Member States with differing levels of expertise. Certain countries have well-developed collaborative models, while others are in the process of establishing them. National CCS stakeholder communities should focus on how, why and where CCS fits into national climate change scenarios (including security of energy supply), with an emphasis on appropriate regulation, safety and benefits of the technology.

Local
At the closest point of contact to CCS projects are the bodies that directly represent the local inhabitants concerned, as well as the inhabitants themselves. They play a direct and primary role in deciding whether CCS demonstration projects will go ahead. Open and transparent lines of dialogue must therefore be created and maintained in order to address key issues – primarily around safety and the economic benefits of CCS. Since a CCS project may include several locations for capture, transportation and storage, a coordinated communication across the different local communities is also important. In addition, local authorities will play a key role in the granting of permit applications etc.

Key communications activities

The resources required for an effective communication and stakeholder strategy should not be underestimated. CCS demonstration projects have also shown that communication cannot start early enough in the process – well before final locations are selected for capture, transport and storage. A variety of stakeholders will have to be engaged, educated and often convinced of the necessity for CCS.

Any structured CCS communications plan must incorporate a variety of communications activities, including, but not limited to:

Media relations
While a certain level of interest exists within the media, more needs to be done to provide the facts and realities surrounding CCS, its workings and the move toward deployment. Organisations should leverage the expertise and perspectives of their members to engage with media at all levels, whether international, national, regional or local.

Events
CCS organisations and their members must break out of their comfort zone and share their expertise within the larger climate change and energy technology debate, serving as CCS ambassadors.

Online presence
The most direct means of interacting with the public – and ensuring genuine responsiveness – CCS websites must be designed to provide clear and compelling information, via the right tools, to the right audience. The CCS community should also be active in the many national online fora addressing climate change and energy technologies.

Printed collateral
Inspiring and involving design, with content and messaging in layman's terms, are key to avoid the technical and non-emotional packaging that has too often enveloped CCS.

Cooperation with CCS stakeholders
As indicated, the universe of diverse CCS bodies and partners should be appropriately leveraged – including geologists, academia and supportive NGOs.

Engagement in public debates
CCS experts should ensure that misunderstandings and misrepresentations in both printed and electronic media are swiftly countered by credible, authoritative and understandable rebuttals.

Glossary

CO_2	Carbon dioxide
CCS	CO_2 Capture and Storage
CCS Directive	EU Directive on Geological Storage of CO_2
CHP	Combined Heat and Power
EERA	European Energy Research Alliance
EEPR	Energy Programme for Recovery
EGR	Enhanced Gas Recovery
EOR	Enhanced Oil Recovery
EPC	Engineering, Procurement and Construction
EII	European Industrial Initiative
ETS	Emissions Trading Scheme
EU	European Union
EUA	Emission unit allowance
FCEV	Fuel cell electric vehicle
FID	Financial investment decision
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquefied natural gas
MRV	Monitoring, reporting and verification
NER 300	The 300 million EUAs set aside from the New Entrance Reserve under the EU ETS for the demonstration of CCS and innovative renewable energy technologies
NGO	Non-governmental organisation
NO_x	Nitrogen oxide
OECD	Organisation for Economic Cooperation and Development
R&D	Research and development
RD&D	Research, development and deployment
SDD	Strategic Deployment Document
SO_x	Sulphur oxide
SET Plan	Strategic Energy Technology Plan
SRA	Strategic Research Agenda
ZEP	European Technology Platform for Zero Emission Fossil Fuel Power Plants – or Zero Emissions Platform

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