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COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

on the Future of Carbon Capture and Storage in Europe

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Consultative Communication on

The Future of Carbon Capture and Storage in Europe

Content

1. Introduction

Currently, more than 80% of global primary energy use is fossil based. Over the last decade 85% of the increase in global use of energy was fossil based. Estimates of future energy consumption based on current policies and developments indicate a continuation of this fossil fuel dependence[1]. These trends are not consistent with the necessary mitigation of climate change. They could lead to an average increase in global temperatures of 3.6 or 4 degrees Celsius according to the International Energy Agency (IEA) and a report commissioned by the World Bank respectively[2]. In the transition to a fully low-carbon economy, the Carbon Capture and Storage (CCS) technology is one of the key ways to reconcile the rising demand for fossil fuels, with the need to reduce greenhouse gas emissions. Globally CCS is likely to be a necessity in order to keep the average global temperature rise below 2 degrees[3]. CCS is also vital for meeting the Union's greenhouse gas reduction targets and it offers potential for a low-carbon re-industrialisation of Europe's declining industries. However, this depends on whether CCS can be used as a large scale technology that can be commercially viable to allow for large scale deployment[4].

The assessments made in the context of the EU's Roadmap for moving to a competitive low carbon economy in 2050 and the Energy Roadmap 2050 see CCS, if commercialised, as an important technology contributing to low carbon transition in the EU, with 7% to 32% of power generation using CCS by 2050, depending on the scenario considered. Furthermore, in these assessments, by 2035 CCS starts to contribute on a broader scale to reducing CO_2 emissions from industrial processes in the EU.

The EU is committed to supporting CCS both financially and with regulatory steps. Following the European Council's decision back in 2007 to support up to 12 large-scale demonstration projects by 2015, the Commission took a number of steps to establish a common regulatory and demonstration support framework.

The **CCS Directive** was adopted to provide a legal framework for CO_2 capture, transport and storage, with transposition deadline set at June 2011[5]. The CO_2 transport network was included in Europe's **Energy Infrastructure Priorities (EIP)** tabled in November 2010 and in the Commission's proposal for a regulation on "Guidelines for Trans European Infrastructure". CCS has also become an integral part of the EU R&D initiatives - the

[1] IEA estimates in their World Energy Outlook 2012, that 59% of the demand increase is met by fossil fuels, resulting in a share of 75% of the energy mix in 2035.

[2] IEA "World Energy Outlook 2012" page 23, and "Turn down the heat", a report commissioned by the World Bank, available here: http://www.worldbank.org/en/news/2012/11/18/new-report-examines-risks-of-degree-hotter-world-by-end-of-century

[3] The Commission estimated that in 2030 in the "Appropriate global action scenario" 18% of fossil fuel power generation is with CCS, which illustrate how crucial this technology will be in the future to achieve a sustainable carbon emission path at global level, and that large scale demonstration has to commence without delay. Estimate is taken from: Towards a comprehensive climate change agreement in Copenhagen. Extensive background information and analysis - PART 1 - available here: http://ec.europa.eu/clima/policies/international/negotiations/future/docs/sec_2009_101_part1_en.pdf

[4] Low carbon transition can obviously also be reached with more energy efficiency, renewable energy and carbon free energy sources, but in the case of continued or increasing use of fossil fuels, CCS is crucial as it is the only option available. Around 60% of global primary energy at present comes from stationary use of fossil fuels. Other decarbonisation options of the energy system are increased energy efficiency, demand side management and other low carbon energy sources such as renewable and nuclear energy.

[5] A detailed report on the transposition of the directive will be published in the course of 2013.

European Industrial Initiative (EII) on CCS has been established as part of the Strategic Energy Technology (SET) Plan.

Moreover two funding instruments have been set up: the **European Energy Programme for Recovery (EEPR) and the NER300[6] programme** funded by ETS allowances to channel substantial EU funding to large scale demonstration projects[7].

Despite these efforts, CCS has not yet taken off in Europe for a variety reasons as briefly set out in this Communication. While it is clear that "no action" is not an option and further steps need to be taken, time is running out, especially for those demonstration projects that have managed to secure part of the necessary financing but have not yet taken their final investment decision. This Communication therefore summarises where we are today taking into account the global context and discusses the available options to encourage CCS demonstration and deployment, in order to support its long term business case as an integral part of the EU's strategy for low carbon transition.

2. Fossil fuels in the energy mix and in industrial processes

Since the European Council's decision on developing CCS back in 2007, the relevance and importance of CCS has further increased, at European as well as at global level, as the global addiction to fossil fuels has intensified. Meanwhile, the time available to mitigate climate change has shortened, making it all the more urgent to deploy CCS.

2.1. The role of fossil fuels in global energy mix

In 2009, fossil fuels met 81% of global primary energy demand, with two-thirds of the world’s power generation coming from fossil fuels. In the past ten years, coal, oil and gas have jointly accounted for 85% of the increase in global energy demand, where coal alone represents 45% of the increase in primary energy consumption, as can be seen in figure 1 below. These developments have largely been driven by increased demand in developing countries. Consequently, since 1990, coal production worldwide has almost doubled and has reached nearly 8,000 million tonnes in 2011.

[6] No CCS projects were selected by the first call of the NER300.

[7] However, the projections of a carbon price of 20 to 30 € per ton did not materialise, which lowered the funds available substantially, and also significantly worsened the economics of CCS projects

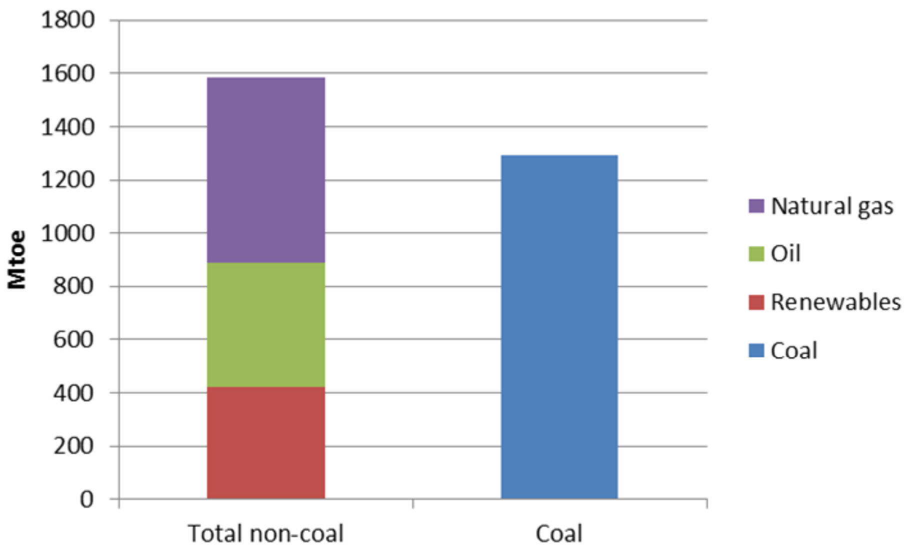

Figure 1: Incremental world primary energy demand by fuel, 2001-2011 (Source: IEA World Energy Outlook 2012)

The historical developments seen in the figure above are reflected in the forecasts provided in the "New Policies Scenario" in the World Energy Outlook 2012 of the International Energy Agency (IEA), shown in figure 2, which show that coal will have an increasing importance in power generation investments in the coming decades in developing countries if current policies are continued, whereas in developed countries the coal capacity starts to decrease.

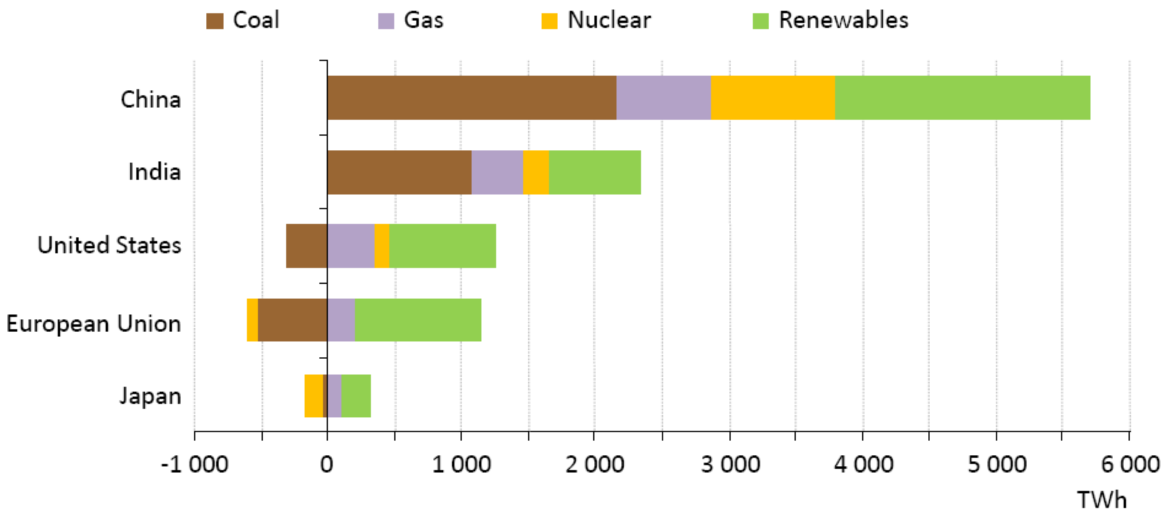

Figure 2: Change in power generation for selected parts of the world, 2010 – 2035. (Source: IEA, World Energy Outlook 2012)

2.2. The role of fossil fuels in Europe's energy mix

In the EU, the share of gas in primary energy consumption has grown over the last ten years to a level of 25% in 2010[8], most of which is imported since only about 35% of EU's gas

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[8] Source: EU energy in figures, 2012 Pocketbook, European Commission

supply is produced domestically[9]. Approximately 30% of gas is used for electricity generation.

While our gas imports have doubled over the last two decades, the opposite has happened in the US, where significant discoveries and developments of shale gas have both reduced the price of gas and made the US less dependent on energy imports. The rapid developments in and forecasts for the use of shale gas in the US are shown in figure 3 below.

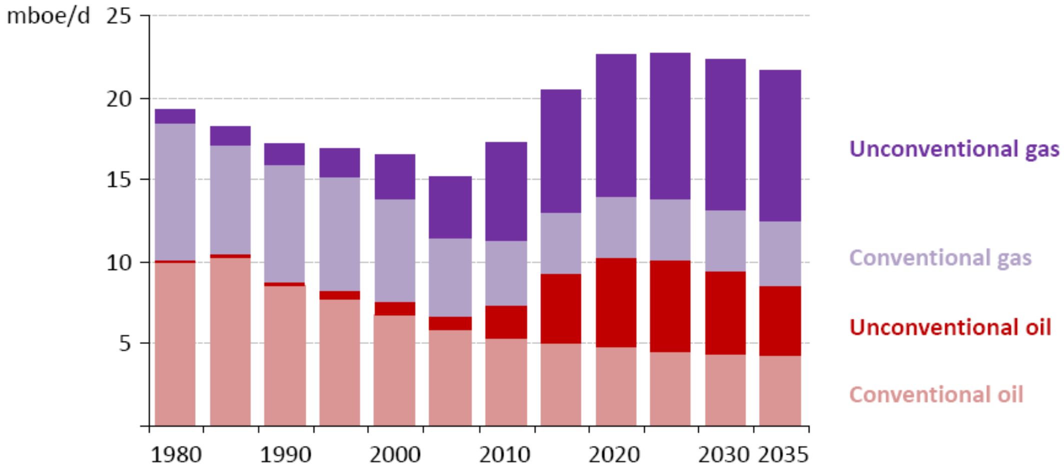

Figure 3: Historic and forecasted US oil and gas production (Source: IEA, World Energy Outlook 2012)

This in turn has put a downward competitive pressure on American coal (as can be seen in figure 4 below) leading to the American coal industry seeking new outlets through increased exports of coal that would normally have been consumed within the US. The current indications are that this trend will continue and may be further aggravated.

Figure 4: Coal prices over 12 months (Source: Platts)

The EU has been the recipient of much of these exports leading to increased coal consumption. Figure 5 below shows the overall developments within the coal sector in the EU over the last 20 years (data includes up to and including May 2012). The recent increase

[9] The three largest producers are UK with 51.5 Mtoe, The Netherlands with 63.5 Mtoe and Germany with 9.7 Mtoe of natural gas production in 2010. Russia and Norway (22% and 19% of EU's gas supply) are the biggest two gas exporters to the EU.

in coal consumption[10] has therefore potentially halted, and to some extent reversed a two decade long trend of decreasing coal consumption.

The reasons are multiple, but in particular the lower than expected prices of coal and carbon are considered as major contributors.

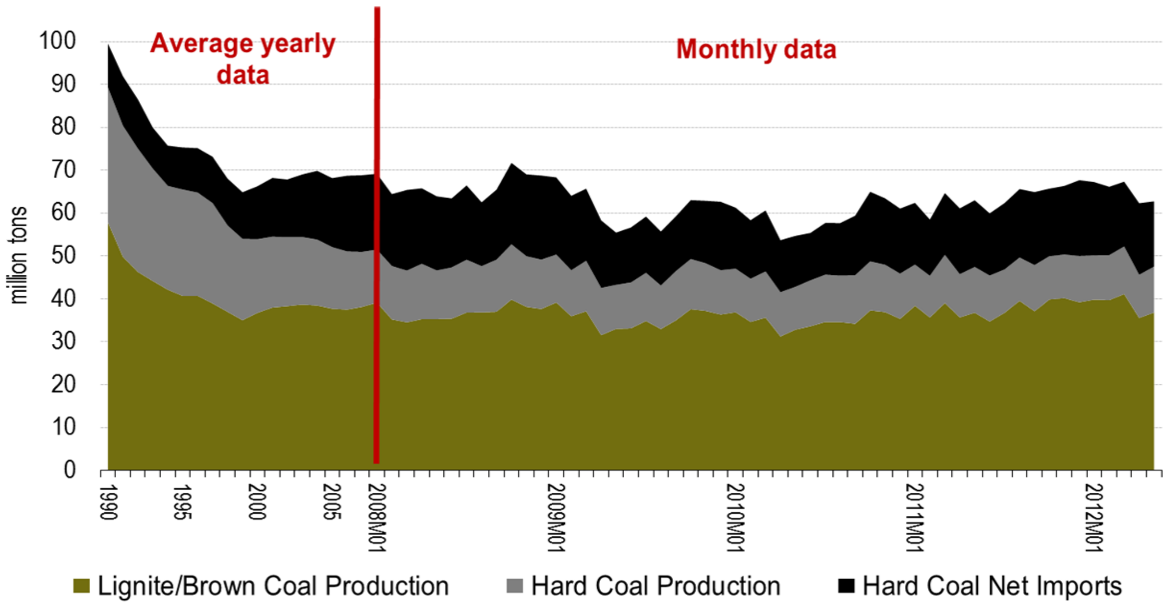

Figure 5: Coal consumption developments in the EU over the last 20 years (including May 2012) (Source: Eurostat) Note that to the left of the bar are yearly data back to 1990, while monthly data are shown for the period after 1/01/2008 to the right.)

At this low price, together with relatively high gas prices compared to coal, coal has become a new and economically interesting input for power production in the EU. The lifetime of power plants that were expected to close is now being extended and as such the risk related to carbon lock in for new fossil fuel developments increases.

Over the last few years, the impact of the economic crisis has seen GHG emissions decrease significantly, resulting by early 2012 in a surplus of 955 million unused ETS allowances. Overall the structural surplus is rapidly growing and for most of phase 3 could result in around 2 billion of unused allowances[11], resulting in carbon prices rapidly decreasing towards €5 and below per ton of CO_2.

This renewed attractiveness of coal in the short run certainly has negative impacts on the transition to a low carbon economy.

2.2.1. Coal in Europe's electricity generation

The coal sector significantly contributes to Europe's security of energy supply given that coal is largely produced within the EU - more than 73% of coal used in the EU is produced domestically, as shown in figure 6 below.

[10] Analysing the same data-set and comparing hard coal consumption in the first 5 months of 2010 with the same period in 2011 and 2012, one observes a 7% increase from 2010 to 2011 and a further 6% increase from 2011 to 2012. Brown coal (lignite) in the same period increased with 8% and 3% respectively.

[11] Source: Report from the Commission: The state of the European carbon market in 2012

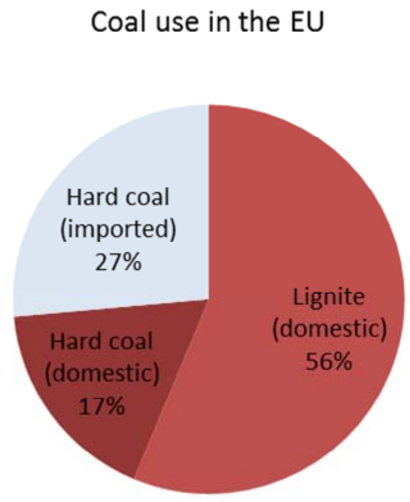

Figure 6: Coal use in the EU in 2010 (Source: Eurostat)

The coal consumed in Europe is mainly used for electricity production. Overall, the use of brown and hard coal in the EU increased from 712.8 Mt in 2010 to 753.2 Mt in 2011, representing around 16% of total energy consumption. Whilst the contribution of coal to EU's electricity generation had been slowly decreasing up to 2010 (when it represented around 25% of the electricity produced in the EU[12]), since then it has increased again, as discussed above. The main consumers of coal in the EU are shown in the table below.

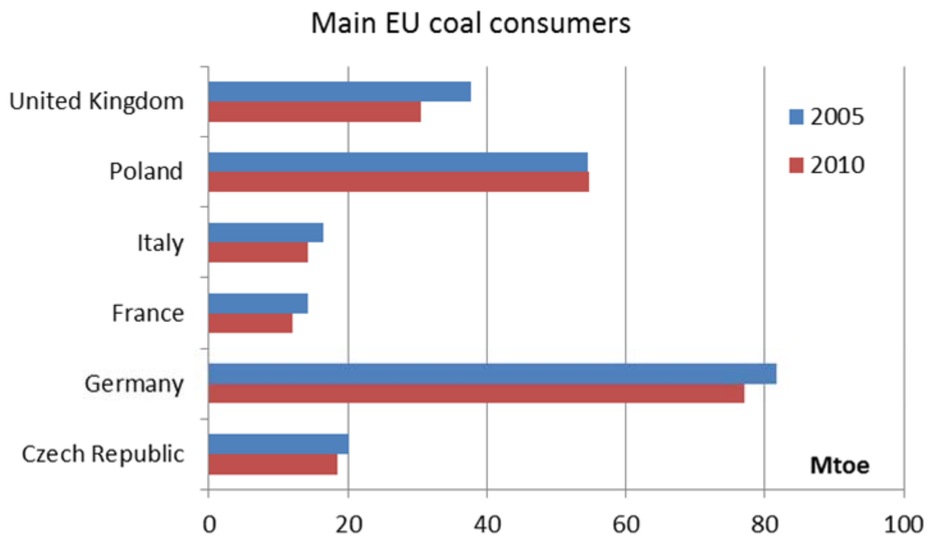

Figure 7: Main consumers of coal in the EU for 2010. (Source: Eurostat)

[12] However, there are significant regional differences across Europe. While the share of coal in some Member State's electricity mix (e.g. in Sweden, France, Spain, and Italy) is well below 20%, some Member States such as Poland (88%), Greece (56%), Czech Republic (56%), Denmark (49%) Bulgaria (49%), Germany (42%) and UK (28%) rely heavily on coal. With the exception of Denmark, those are also the Member States with a relevant domestic mining industry.

Data submitted by Member States indicate that around 10 GW of additional coal capacity is being constructed or is planned (in Germany, Netherlands, Greece and Romania). However, the figures submitted by Member States are considerably lower than those reported by Platts, which estimate that as much as 50 GW of coal fired power plants are proposed, being developed or under construction. In addition, a range of old coal power plants will need to be refurbished or closed down, as they are reaching their planned operational life.

2.2.2. Gas in Europe's electricity generation

The share of gas in Europe's electricity mix has been steadily increasing over the past 20 years from 9% in 1990 to 24% in 2010[13]. Moreover, power generation based on gas is expected by many Member States to increase significantly. Relative to coal, gas power plants have several benefits. The greenhouse gas emissions are half those of coal, gas power plants have low investments costs and they can be operated in a more flexible way, making them suitable to balance out the varying power production from wind and solar energy sources. In total 20 GW of capacity has been notified to the Commission as being under construction, which is about 2% of today's installed total capacity for electricity production (with a further 15 GW of additional capacity notified as in planning). The figure below shows the capacity of the 32 gas power plants notified to the Commission as under construction.

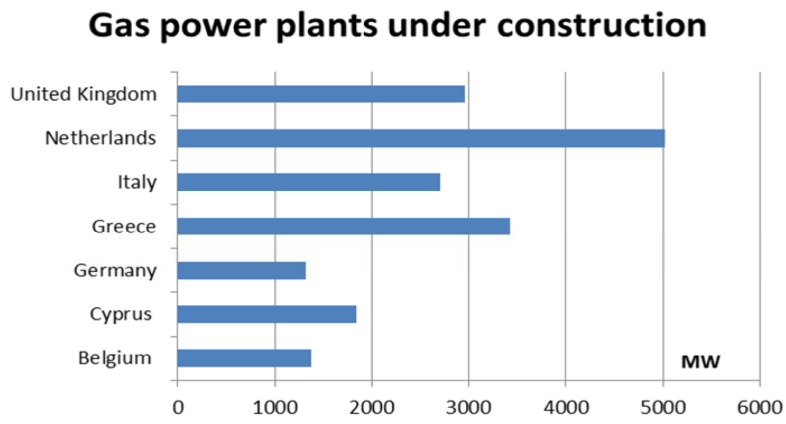

Figure 8: Main Member States where gas power plants are under construction (Source: Member States' notifications)

While new gas power plants will reduce emissions compared to using coal power plants, such new investments have a significant lifetime, and it is not necessarily cost-effective to retrofit gas power plants with CCS. This is particularly the case if the gas power plant is not running as base load[14]. On the other hand, gas power plants have lower capital costs than coal plants, implying that the cost effectiveness of the investments is less dependent on a long lifetime.

2.2.3. Oil in Europe's electricity generation

Oil is used to a limited extent in electricity production, i.e. in niche applications, such as isolated power systems - 2.6% in the EU only, and somewhat more globally, but with a

[13] Similarly to coal, there are significant regional differences: in some Member States gas plays a dominant role in electricity generation, e.g. in Belgium (32%), Ireland (57%), Spain (36%), Italy (51%), Latvia (36%), Luxembourg (62%), NL (63%), UK (44%), while in many other Member States (Bulgaria, Czech Republic, Slovenia, Sweden, France, Cyprus and Malta) gas contributes to less than 5% of the electricity mix.

[14] Running as base load means that it runs most (80%) of the time while as balancing power it runs considerably less (10 – 20%) of the time

declining trend. Oil is mainly used for transport purposes in combustion engines, like airplanes, ships and vehicles. Given its limited role for industry and power production, and as it is impossible with today's technology to capture carbon efficiently from such small emitters, oil is not discussed further.

2.2.4. The composition and age structure of Europe's electricity generation

Investments in power generation capacity in Europe have changed over time, from mostly renewable energies (hydropower) in the early periods of electrification more than a hundred years ago, to mainly coal, nuclear and gas power plants in the 1950s and onwards, and back to renewables (wind and solar) during the last decade. This development is shown in figure 8 below.

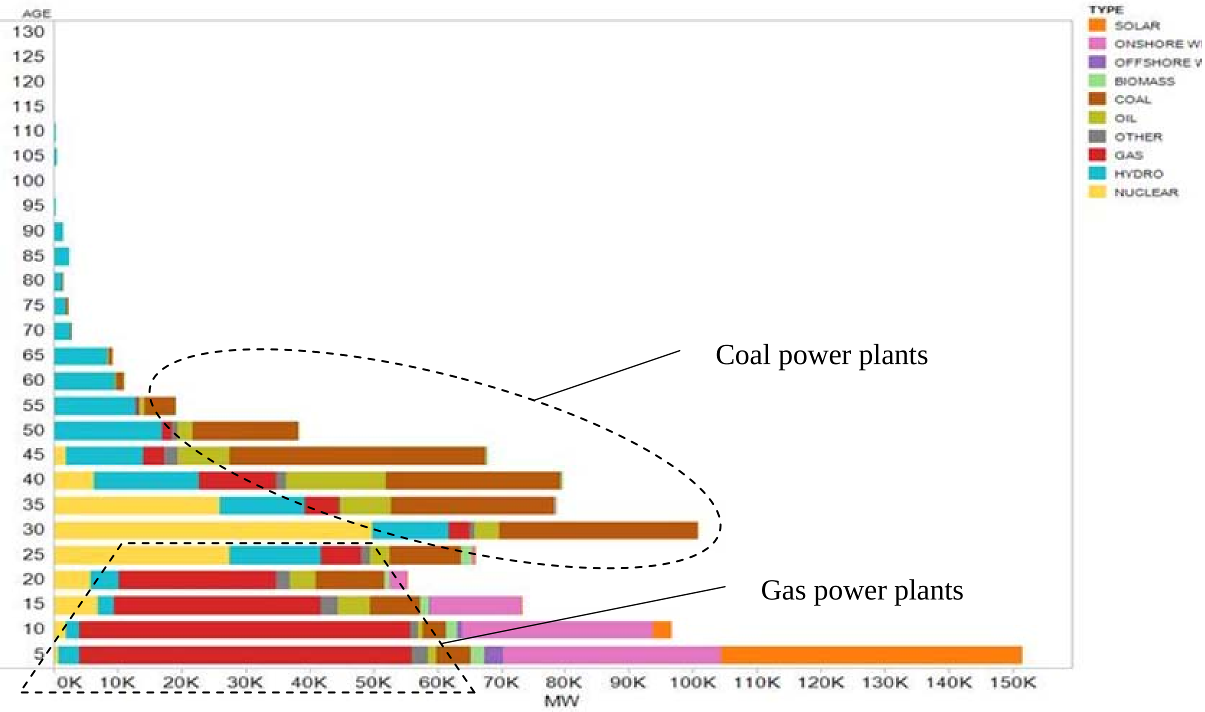

Figure 9: Age structure of Europe's electricity generation (source: Platts)

Investments made 55 to 30 years ago in coal power plants, as seen in the figure above, imply that Europe has a large fleet of old coal power plants that are now reaching the end of their lifetime (for gas power plants the situation is the opposite, as most investments were made during the last 20 years). This leads to an increasing number of power plants (on average 3-5 GW per year – equal to around 10 coal power plants) reaching an age where it can be cheaper for investors to decommission the asset rather than spend resources on refurbishing it[15], providing an opportunity to replace them with low carbon alternatives but also increasing the risk for renewed carbon lock in if relative energy and carbon prices stay where they are today.

[15]Under EU environmental law (the currently existing Large Combustion Directive replaced by the Industrial Emissions Directive from 2013 onwards in case of new plants, and from 2016 onwards in case of existing ones), power plants needs to close down if they do not meet the required minimum standards. These directives lay down minimum standards in terms of emissions (emission limit values), requiring at the same time that the best available techniques (BAT) be used as the reference when setting such limit values and other operating conditions in permits. The Commission regularly adopts BAT conclusions in the form of implementing decisions for the activities covered by the scope of the IED. Capture of CO_2 is also covered, therefore BAT conclusions will be adopted in the future for that activity.

2.2.5. The use of fossil fuels in other industrial processes

CO_2 capture from several industrial processes is significantly easier than in the power sector due to the relatively high concentration of CO_2 produced. The application of CCS in certain industries therefore represents an interesting option for the early deployment of the technology. The assessment of the Roadmap 2050 for moving to a competitive low carbon economy in 2050 indicates that CO_2 emissions from the industrial sector need to be reduced by 34% to 40% by 2030, and by 83% to 87% by 2050 compared to 1990.

Recent studies by the JRC focusing on the application of CCS in the iron and steel and cement sectors have shown that the CCS technology can become competitive in the medium-term, thus contributing to the cost effective emissions reduction from these industrial sectors[16]. Taking the steel sector as an example, the potential application of CCS to the industry could result in a dramatic reduction of direct emissions. Although the energy efficiency of steel production has improved dramatically over the last 50 years, the production process of crude steel remains an energy intensive process. Between 80-90% of the CO2 emissions from the steel sector are generated by the coke ovens, blast furnaces and basic oxygen furnaces of integrated steel plants. EU accounts for approximately 15% of global steel production, with nearly 180 million tonnes of crude steel produced within the EU27 in 2011[17].

In its 2012 Industrial Policy Communication Update, the EU set an ambitious target of boosting the weight of industry in Europe from its current level of around 16 % of GDP to 20 % by 2020. The application of CCS to industrial processes would enable the Union to reconcile this goal with its long-term climate objectives. Nevertheless, the significance of technical barriers still to be explored and the scale of R&D efforts still needed, as well as the economic aspects linked to the international markets for these commodities, should not be overlooked.

The deployment of CCS in industrial processes may also help to increase public understanding and acceptance of the technology given the very visible link between jobs in local communities and continued industrial production.

2.2.6. Potential of CCS in Europe and globally

The EU is committed to an overall greenhouse gas emissions reduction of at least 80% by 2050. Nonetheless, fossil fuels are likely to continue to be used in Europe's power generation as well as in industrial processes for decades to come. Therefore, the 2050 target can only be achieved if the emissions from fossil fuel combustion are eliminated from the system, and here CCS may have an essential role to play, as a technology that is able to significantly reduce CO_2 emissions from the use of fossil fuels in both the power and industrial sectors. CCS can also be applied in conjunction with the production of transport fuels, particularly for the production of alternative fuels[18] like hydrogen from fossil sources.

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[16] Prospective scenarios on energy efficiency and CO2 emissions in the EU iron & steel industry, EUR 25543 EN, 2012; Moya & Pardo, Potential for improvements in energy efficiency and CO2 emission in the EU27 iron & steel industry, Journal of cleaner production, 2013; Energy efficiency and CO2 emissions in the cement industry, EUR 24592 EN, 2010; Vatopoulos & Tzimas, CCS in cement manufacturing process, Journal of Cleaner energy production, 32 (2012)251.

[17] See the World Steel Association publications at http://www.worldsteel.org

[18] Proposal for a Directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, COM(2013)18 final; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Clean Power for Transport: A European alternative fuels strategy, COM(2013)17 final

CCS is normally considered in conjunction with fossil fuel combustion, but it can also be used to capture biogenic carbon from the use of biomass (Bio-CCS). Bio-CCS application can range from capturing CO_2 from biomass co-firing and biomass-fired power plants to biofuel production processes. However, the technical feasibility of biomass-CCS value chain has still to be demonstrated on a large scale.

IEA analysis suggests that without CCS, capital costs – in the power sector - to reach the greenhouse gas targets required for a maximum 2 degree rise in global temperatures might increase by as much as 40%[19]. The role of CCS in cost efficient climate mitigation has been illustrated in the 2050 Energy Roadmap in which all of the scenarios imply the use of CCS. In 3 of the 5 decarbonisation scenarios that were elaborated, CCS was applied to more than 20% of Europe's electricity mix by 2050, as shown in figure 10 below.

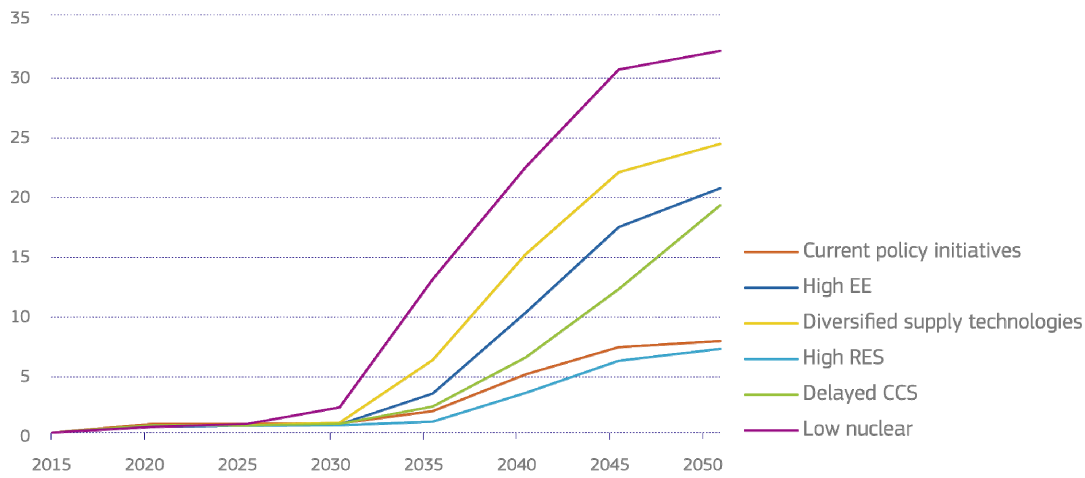

Figure 10: Share of CCS (%) in power generation towards 2050 in the Energy Roadmap (Source: 2050 Energy Roadmap)

The "diversified supply technology scenario" of the 2050 Energy Roadmap shows that by 2035 a total of 32 GW of CCS could be installed, rising to around 190 GW by 2050. This is potentially a significant opportunity for European industry within the field of capture and storage technologies but is, nonetheless, a daunting prospect when viewed from the level at which the EU currently stands. Any delay in CCS development in Europe will ultimately also affect negatively those business prospects.

Projections show that under current policies, while fossil fuel use in the EU continues to decrease, it remains the largest share of the EU energy mix in the decades to come. Even if policies are upscaled in order to shift our energy mix further towards lower carbon intensity, fossil fuels would still represent more than 50% of the EU energy mix in 2030.

[19] IEA Energy Technology Perspectives 2012

		Reference/CPI		Decarbonisation scenarios	
	2005	2030	2050	2030	2050
RES	6,8%	18,4%-19,3%	19,9% - 23,3%	21,9% - 25,6%	40,8% - 59,6%
Nuclear	14,1%	12.1% - 14,3%	13,5% - 16,7%	8.4% - 13,2%	2,6% - 17,5%
Gas	24,4%	22,2% - 22,7%	20,4% - 21,9%	23,4% - 25,2%	18,6% - 25,9%
Oil	37,1%	32,8% - 34,1%	31,8% - 32,0%	33,4% - 34,4%	14,1% - 15,5%
Solid fuels	17,5%	12,0% -12,4%	9,4% - 11,4%	7,2% - 9,1%	2,1% - 10,2%

Table 1: Energy mix projections, reference scenario representing current policies (Source: European Commission, Impact Assessment Energy Roadmap 2050)

In the 2050 Energy Roadmap assessments, large scale deployment starts from around 2030, with the carbon price generated in the Emission Trading System (ETS) being the main driving force. The development of a 2030 climate and energy framework, with its overall aim of setting the EU on track towards its 2050 GHG emissions reduction objective in order to keep global temperature increase to below 2 degrees, will influence the deployment of CCS.

2.3. Potential of industrial use of CO_2

CO_2 is a chemical compound that can be used for the production of synthetic fuels, as a working fluid (for example in geothermal plants), feedstock in chemical processes and biotechnological applications or for the manufacture of a wide range of other products. Insofar, CO_2 has been successfully utilised for the production of urea, refrigerants, beverages, welding systems, fire extinguishers, water treatment processes, horticulture, precipitated calcium carbonate for the paper industry, as an inert agent for food packaging and many other smaller-scale applications[20]. In addition, a number of emerging CO_2 utilisation options has sprung out recently, involving various pathways for the production of chemicals (e.g. polymers, organic acids, alcohols, sugars), or for fuel production (e.g. methanol, biofuels from algae, synthetic natural gas). However, most of these technologies are still in the R&D phase. Furthermore, there are no clear conclusions regarding their CO_2 abatement effects, due to their specific mechanism for temporary or permanent CO_2 storage, and they might not present the sufficient volumes of CO_2 needed. Irrespective of their potential to reduce CO_2 emissions, CO_2 utilisation paths represent a direct near-term potential to produce revenues. Hence, CO_2 would not be regarded anymore as a waste product but as a commodity, which could also help addressing public acceptance issues of CCS.

Enhanced oil (and in some cases gas) gas recovery is on the other hand able to store significant amounts of CO_2, while at the same time increasing oil production by on average 13%[21], which has a significant economic value. Moreover, oil and gas reservoirs are prime candidates for CO_2 storage for several reasons. First, the oil and gas that originally accumulated in traps did not escape, demonstrating the safety and reliability of such storage sites, provided that their structural integrity was not compromised as a result of exploration and extraction processes. Second, the geological structure and physical properties of most oil and gas fields have been extensively studied and characterized. Third, existing fields' geology

[20] Source: Chapter 7.3 of Carbon Dioxide Capture and Storage - IPCC, 2005 - Bert Metz, Ogunlade Davidson, Heleen de Coninck, Manuela Loos and Leo Meyer (Eds.)

[21] Source: Chapter 5.3.2 of Carbon Dioxide Capture and Storage - IPCC, 2005 - Bert Metz, Ogunlade Davidson, Heleen de Coninck, Manuela Loos and Leo Meyer (Eds.)

and characteristics are well known to the oil and gas industry to predict the movement, displacement behaviour and trapping of gases and liquids. Nevertheless, the precautionary principle needs to be applied, as recently highlighted by the European Environmental Agency in its report on "Late lessons from early warnings" (2013)[22]. Furthermore, the potential of EOR in Europe is limited[23].

2.4. Cost competitiveness of CCS

Globally, more than 20 demonstration scale CCS projects are successfully operating, of which 2 are in Europe (Norway)[24]. Most of them are industrial applications, such as oil and gas processing or chemical production, which capture CO_2 for commercial reasons. Eight of the projects have the full CCS chain (capture, transport and storage), five of which are made economically feasible through enhanced oil recovery, where the carbon is used to increase the extraction of crude oil (more details about the projects are set out in Annex 1).

According to the Commission's 2050 Energy Roadmap and the IEA's assessment[25], CCS is expected to become a competitive low carbon transition technology. Cost estimates of CCS vary, depending on the fuel, technology and storage type, but most calculations for current costs fall in the range of €30 to €100/tCO_2 stored. According to *Cost and Performance of Carbon Dioxide Capture from Power Generation* by the IEA (see footnote 29 for full reference), which is based on existing technical engineering studies, the current cost of CCS is in the order of 40 €/ton CO_2 avoided[26] for coal power plants and 80 €/ton CO_2 avoided for natural gas power plants. In addition the costs of transport and storage must be taken into account. However, costs are expected to decrease in the future.

According to assessments done by the JRC[27], the first generation CCS coal or natural gas power plants are expected to be significantly more expensive than similar conventional plants without CCS. Once CCS power plants start being deployed, costs will decrease benefiting from R&D activities and the building of economies of scale.

Given persistently high oil prices, CCS may in some cases be cost competitive for the oil and gas extraction industry, where economic margins are considerable higher than in power production and other sectors involved in consumption or supply of fossil fuels. This is exemplified by the only two full scale CCS projects in operation in Europe today. These are located in Norway, where the oil and gas producers face a tax of around 25 €/ton of CO_2

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[22] http://www.eea.europa.eu/publications/late-lessons-2/late-lessons-2-full-report

[23] A JRC study that assessed the CO2-EOR potential in the North Sea concluded that although the process can increase considerably the European oil production and hence improve the security of energy supply, the impact on reducing CO2 emissions will be limited to CO2 sources in the vicinity of oil fields. The main barrier to implementation in Europe is the high cost of the associated offshore operations, including the necessary modifications to the existing infrastructure and the unfavourable geology

[24] Source: ZEROs CCS project database; keeping track on the development and deployment of CCS globally. http://www.zeroco2.no/projects and GSSCI, The Global Status of CCS: 2012 An overview of large-scale integrated CCS projects: http://www.globalccsinstitute.com/publications/global-status-ccs-2012/online/47981

[25] World Energy Outlook 2012, IEA 2012 and; *Cost and Performance of Carbon Dioxide Capture from Power Generation* IEA working paper Edition: 2011, available here: http://www.iea.org/publications/freepublications/publication/costperf_ccs_powergen-1.pdf, and; *A policy strategy for carbon capture and storage* Information paper IEA 2012

[26] This assumes a pulverized coal plant operating as base load. The cost in USD is 55. Assumed currency exchange rate of 1$ being equivalent to 1.298 €. The 55 USD/ton estimate is in line with estimates by the European Technology Platform for Zero Emission Fossil Fuel Power Plants, which estimated a range of 30-€40/tCO_2 avoided cost. Natural gas CCS would need a carbon price of around 90€/ tCO2.

[27] Source: The Joint Research Centre (JRC) The cost of CCS, EUR 24125 EN, 2009

emitted[28]. This tax, which is specific for gas and oil producers on the continental shelf, has led to the commercial development of CCS at Snøhvit and Sleipner (see Annex I for more details).

2.5. Cost competitiveness of CCS being retrofitted on to existing power plants

If the global expansion of fossil fuel power plants is not reversed, CCS retrofit will be a necessity for limiting global warming to below 2°C. However, the International Panel on Climate Change (IPCC)[29] states that "*Retrofitting existing plants with CO_2 capture is expected to lead to higher costs and significantly reduced overall efficiencies than for newly built power plants with capture. The cost disadvantages of retrofitting may be reduced in the case of some relatively new and highly efficient existing plants or where a plant is substantially upgraded or rebuilt"*. Most subsequent studies agree with the findings of the IPCC. The main reasons for the higher costs are:

- **Higher investments** cost as the existing plant configuration and space constraints could make adaptation to CCS more difficult than for a new build.
- **Shorter lifespan**, as the power plant is already operating. This implies that the CCS retrofit investment would need to be repaid over a shorter timespan than the CCS of a new built.
- **Efficiency penalty**, as a retrofit is difficult to optimally integrate to maximise the energy efficiency of the capturing process, leading to lower output.
- **Stand still cost**, as the existing installation that is being retrofitted would need to be taken out of production while the building works takes place.

In order to minimise site specific constraints, and thereby the costs, it has been suggested to require new installations to be "CCS ready"[30], which could avoid further "locking in" of CO_2 emissions from new installations[31].

Under Art. 33 of the CCS Directive, Member States have to ensure that operators of all combustion plants with a rated electrical output of 300 MW or more have assessed whether the conditions of 1) availability of suitable storage sites; 2) economic and technical feasibility of transport facilities and of 3) retrofit for CO2 capture are met[32]. If so, the competent authorities shall ensure that suitable space on the installation site for the equipment necessary to capture and compress CO2 is set aside. The number of plants that have been already designed "CCS ready" is, however, very low.

An assessment of the measures which have been taken by Member States to ensure that Art.33 of the CCS Directive is implemented will be provided in the upcoming analysis of the CCS Directive transposition and implementation in the Member States.

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[28] The tax is 0.47 NOK per litre of oil and per Sm^3 of gas

[29] IPCC, 2005 - Bert Metz, Ogunlade Davidson, Heleen de Coninck, Manuela Loos and Leo Meyer (Eds.) - Cambridge University Press, UK, p 431. Available here:
http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

[30] CCS ready means that the plant can be retrofitted with CCS at a later stage

[31] The "Clean Air Act" in the US effectively forces new coal power plants to be "CCS ready" (see also text box 1) as the emissions performance standard is allowed to be met over a 30 year period. The proposed rule is available here: http://www.gpo.gov/fdsys/pkg/FR-2012-04-13/pdf/2012-7820.pdf

[32] By this provision, the Large Combustion Plant Directive has been amended and it currently appears as Article 36 of Industrial Emission Directive

3. The state of play of CCS demonstration in Europe and gap analysis

The role of CCS is recognised in a future low carbon energy mix. This is *inter alia* the result of the European Union's commitment to take the vital step of advancing CCS from pilot scale research projects to commercial scale demonstration projects[33] that can reduce costs, demonstrate the safe geological storage of carbon dioxide (CO_2), generate transferrable knowledge about the potential of CCS, and de-risk the technologies for investors.

Despite considerable efforts to take the lead on CCS development in the EU, out of eight operating full size[34] demonstration projects with complete CCS (capture, transport and storage – see details in Annex I), none of them are located in the EU, and even the most promising EU projects are facing major delays due to a number of reasons outlined below.

3.1. Lack of business case

At current ETS prices well below €40/tCO_2, and without any other legal constraint or incentive, there is no rationale for economic operators to invest in CCS. When the Commission proposed the Climate and Energy Package in 2008, carbon prices were temporarily as high as €30. Expectations were that, when the targets under the climate change and energy package were implemented, such price levels would be reached for 2020, and would continue to increase afterward. It was recognised that this might still not be sufficient to allow even demonstration plants to be commissioned. In addition to the establishment of the legal framework (the CCS Directive), the NER300 funding programme was introduced to finance CCS commercial scale demonstration, together with innovative renewables energy projects, alongside the European Energy Programme for Recovery (EEPR) focusing on 6 CCS demo projects. At carbon prices of €30, total support could have been as high € 9 billion. Together, the carbon price incentive and additional financial support through the NER300 and the EEPR were seen as adequate to ensure construction of a number of CCS demonstration plants in the EU.

Today, with carbon prices closer to €5, and revenues from the NER300 significantly below initial expectations, it is clear that no rationale exists for economic operators to invest in demonstration CCS, as the additional investment and operational costs are not covered by the revenue accrued from the reduced emissions, through having to buy considerably fewer ETS allowances.

The completed Front End Engineering Studies (FEED) for the CCS projects show that the initial cost assumptions for the capital costs for CCS were realistic. However, the business case significantly worsened as of 2009 because of the economic crisis resulting in a low ETS carbon price. Most of the projects based their calculations on a carbon price of at least €20/ton CO_2. Assuming a 10 year operational period (as requested under NER300) with 1 million ton CO_2 stored per annum, a price difference of €10/ton CO_2 would effectively lead to additional operating costs of approximately €100 million. Compared to the €30 price expectation when the climate and energy package was proposed, the additional cost to cover is up to €200 million.

These additional costs would at present need to be covered either by industry or by public funds. Enhanced Oil Recovery (EOR) may help some projects, but unlike in the US and China, EOR has not been a driver for CCS deployment in Europe. While industry declared in

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[33] the integrated full chain of CO_2 capture, transport and storage at scales of over 250 MWe – or at least 500 ktCO_2/year for industrial applications

[34] All 8 are as large or larger than an equivalent 250 MW gas power CCS project, while 3 are larger than an equivalent 250 MW coal power CCS project

2008 that it was willing to invest more than €12bn in CCS, the actual financial commitments made so far are not in line with this commitment. In fact, for most projects, industry is now limiting its funding to approx. 10% of the additional costs for CCS. Also, at Member State level, the financial and political circumstances which prevailed in 2008 are presently very different.

In the current economic situation, and even with additional funding through the European Economic Recovery Programme which allocated around € 1 billion to CCS demonstration[35], the structural surplus in the ETS of around 2 billion allowances and subsequent prolonged low carbon prices and lower than anticipated funding through the NER300, industry simply does not have the incentives to make CCS demonstration viable, affecting negatively the potential for large scale deployment. In the absence of a policy strategy that makes CCS commercially viable or made mandatory, industry is likely to not to engage in large scale CCS.

This was underlined recently in the Award Decision of the first call of the NER300 programme[36]. The original goal was to fund 8 CCS demonstration projects of commercial size together with 34 innovative renewable energy projects. 13 CCS projects were submitted to the NER300 call, 2 of which were CCS projects in industrial applications and 11 in the power generation sector, covering 7 Member States. 3 projects were withdrawn during the competition. By July 2012, the Commission had identified 8 top-ranked CCS projects and 2 reserve projects still running in the competition[37]. In the end no CCS projects were awarded funds as, at the last stage of reconfirmation of the projects, Member States were unable to confirm their CCS projects. The reasons for non-confirmation include: funding gaps in the national and/or private funding contribution[38], but also delays with the permitting procedures or, in one case, an on-going national funding competition, which did not allow the Member State concerned to confirm according to the requirements of the NER300 Decision.

The majority of CCS projects sought NER300 funding well in excess of €337 million (the level at which the funding cap was set in light of the revenues raised from the monetisation of NER allowances). In fact, as much as half of all CCS projects sought total NER300 contribution in excess of €500 million. The lower than expected funding cap therefore placed additional pressure on Member States and private operators to cover the shortfall. Even for those projects whose funding requests from NER300 were only slightly higher than the funding cap, funding gaps remained a key challenge and a determining factor in their non-confirmation.

Another important point is that private operators putting forward applications in NER300 appeared little willing to contribute to the costs themselves. Instead, a majority of CCS operators put forward applications that relied almost entirely on public funding, while the rest of the applicants proposed to contribute with a relatively small share. One could draw a conclusion that, as long as the expected carbon price will be low, the private sector will expect the CCS development to be co-financed on a large co-share by public funds, which is a proof of the ongoing challenges in the sector,

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[35] For details regarding the status of the 6 demonstration projects funded under the EU EEPR, programme, Annex II provides details.

[36] Available here: http://ec.europa.eu/clima/news/docs/draft_award_decision_ner300_first_call_en.pdf

[37] Commission Staff Working Document 'NER300 - Moving towards a low carbon economy and boosting innovation, growth and employment across the EU'

[38] The NER300 programme offers to cover 50% of the additional cost associated with investment and operation of CCS plants. The rest should be covered by contributions of either the private sector or through public funding.

Both utilities that use fossil fuel as an input in their production and fossil fuel providers should have a strong interest in successful development of CCS for their future economic prospects. Without CCS they face an uncertain future.

3.2. Public awareness and acceptance

Some projects that envisage onshore storage face strong public opposition. This is especially true for projects in Poland and Germany. In Germany, lack of public acceptance was the main reason for the delayed transposition of the CCS directive. The EEPR-supported project in Spain – after a dedicated information and engagement campaign – successfully overcame the public opposition. The projects that aim at offshore storage in the UK, NL and Italy have equally found public acceptance. A recent Eurobarometer survey[39] shows that the European population is unaware of CCS and its potential contribution to mitigating climate change. However, those who are informed are more likely to support the technology. This shows clearly that more needs to be done to introduce CCS into the debate on Europe's and Member States efforts to combat climate change, that potential health and environmental risks (associated with leakage of stored CO_2) need to be further explored, and that public acceptance should not be assumed without prior assessment.

3.3. Legal framework

The CCS directive provides a comprehensive legal framework for capturing, transporting and storing CCS. By the transposition deadline in June 2011 only a few Member States reported full or partial transposition. The situation has substantially improved in the meanwhile and currently only one Member State has not notified any transposition measures of the Directive to the Commission. While the majority of Member States with proposed CCS demonstration projects have completed the transposition of the Directive, several Member States are banning or restricting storage of CO_2 on their territories.

The full analysis of the CCS Directive transposition and implementation in the Member States will also look at this in detail.

3.4. CO_2 Storage and Infrastructure

According to the EU GeoCapacity project[40], the estimated overall availability of permanent geological storage capacity in Europe is equivalent to over 300 Giga tonnes (Gt) of CO_2, whereas the conservative storage capacity is estimated at 117 Gt CO_2. Total CO_2 emissions from EU power generation and industry are around 2.2 GtCO_2 annually and hence would allow for storage of all the CO_2 captured in the EU for decades to come, even if taking into account the conservative estimates. Storage capacity in the North Sea alone has been estimated at over 200 GtCO_2. A coherent approach to using this capacity should be further explored.

While sufficient storage capacity exists in Europe not all capacity is accessible or located close to CO_2 emitters. Hence a cross border transport infrastructure is necessary to efficiently connect CO_2 sources to sinks. This is reflected in the Commission's proposal to include CO_2 transport infrastructure in its proposal for a regulation on "Guidelines for Trans European Infrastructure". Under this regulation, CO_2 transport infrastructure projects can qualify to become projects of European Common Interest and can eventually be eligible for funding. Nevertheless, initially CCS projects will most often explore CO_2 storage sinks in the vicinity of capture points, hence infrastructure will first have to be developed at national level. Such

[39] Available here: http://ec.europa.eu/public_opinion/archives/ebs/ebs_364_en.pdf

[40] More information available here: http://www.geology.cz/geocapacity

national infrastructure needs will have to be properly addressed by Member States, in order to then advance to cross-border networks.

3.5. International Cooperation

Climate change will only be successfully tackled if addressed globally. Leading action by the EU can drive the necessary international cooperation, but there is additionally a clear policy rationale for promoting the use of mitigation technologies in countries that will need them to reorient their expanding economies to a low carbon pathway. This undoubtedly includes CCS, for which the non-EU market is likely to be much bigger than the internal market.

For example Chinese coal consumption grew by 10% in 2010 and now represents 48% of global coal use. A significant part of the 300GW of coal-fired power plants currently under construction or planned in China are likely to still be operational in 2050. Unless new plants in China and around the world can be equipped with CCS and existing plants retrofitted, a large proportion of the world's emissions between 2030 and 2050 are already 'locked-in'. The European Commission therefore engages actively with third countries, including emerging economies, and industry. It aims at further internationalising knowledge sharing activities among CCS projects in the context of the European CCS Demonstration Project Network, as well as through its membership in the Carbon Sequestration Leadership Forum (CSLF) and as a collaborating participant in the Global CCS Institute (GCCSI).

4. Moving forward

The second call of the NER300, which will be launched in April 2013, is a second chance for European industry and Member States to improve the current prospects for CCS. But considering the clear delays in the CCS demonstration programme, it is time to re-assess the objectives set by the European Council and re-orient our policy goals and instruments.

The need for large scale demonstration and deployment of CCS, in view of its commercialisation, has not receded and has only become more urgent. It is in our longer term competitive interest that our energy and industrial sectors gain experience in progressing CCS to commercial scale roll-out[41] that can reduce costs, demonstrate the safe geological storage of CO_2, generate transferrable knowledge about the potential of CCS, and de-risk the technologies for investors.

CCS will always incur higher costs than unabated fossil fuel combustion, and would thus require a corresponding compensation, as combustion of fuels without capture requires less investment and less energy. The compensation can be made through various policy interventions. Today we already have the ETS, which gives direct incentives for CCS by pricing carbon, although at a much too low level. In addition, the use of some of the revenues from the auctioning of carbon allowances (the NER300 programme) provides potential funding for CCS, as well as renewable energy projects.

The current price expectation for CO_2 allowances is well below the 2008 assessment for the Climate and Energy Package, which projected 2020 prices in the order of €30 (2005 prices)[42]. Today's price signal in the EU ETS does not incentivise fuel switching from coal to gas and increases financing costs for low carbon investments as these increase with the perceived risks associated with the low carbon investment. A survey of 363 EU ETS operators confirms

[41] the integrated full chain of CO_2 capture, transport and storage at scales of over 250 MWe – or at least 500 $ktCO_2$/year for industrial applications

[42] See also section 4.3 of the Staff Working Document on the functioning of the carbon market.

that the price of European carbon allowances has recently become less important for investment decisions[43].

A structural ETS reform may provide increasing prices and can confirm to the market that also over the long term the ETS will be providing a sufficiently strong carbon price signal to drive the deployment of CCS. Accordingly, the Commission has launched a Carbon Market Report, together with a public consultation, that looks at a number of possible options to do so. For driving CCS deployment without any other incentives, significant ETS price increases (or expectations thereof), of 40 € or more, would be necessary[44].

The IEA highlights that a CCS strategy needs to take into account the shifting needs of the technology as it matures, from more specific measures in the early stages to more neutral measures to ensure CCS becomes competitive with other abatement opportunities as it approaches commercialization[45]. Following this and regardless of the final outcome of the discussions of a structural reform of the ETS, it is important that CCS deployment is adequately prepared by a robust demonstration process. Policy options therefore need to be taken into consideration in order to enable as soon as possible large scale demonstration with a view on further deployment and roll-out.

Under the climate change and energy package it was recognised demonstration would probably not only come through the carbon price signal. Additional incentives were foreseen through the NER300 and the EEPR financial package, as well as through the CCS legal framework. The current ETS foresees, through the second call of NER300, that CCS and innovative renewable energy projects could be supported. Expanding this type of financing could be considered also for the period towards 2030. Such financing could address some of the objectives of the SET plan, and could also explicitly focus on innovation in energy intensive industries as CCS is a key technology that is applicable to both the energy and industrial sectors. Furthermore by using the format of a competition, it allows a level playing field across all EU business, ensuring smart use of limited funds.

In addition, taking into consideration developments that have been explored and/or implemented in a number of countries, several policy options that go beyond the existing measures could be taken into consideration. Such options are briefly presented below.

It is evident that, while carbon price is not at a sufficient level, there is still a need to develop CCS infrastructure, skills and knowledge through the deployment of a limited amount of CCS projects. Any measures to promote demonstration could be limited in scope, containing costs to the overall economy while at the same time providing the necessary investor certainty, allowing for the benefits of early deployment to be reaped. The demonstration process would also provide clearer perspectives for the future need for CCS, especially in a situation in the short to mid-term where the carbon price is not at a sufficiently high level to provide for investments in CCS.

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[43] Long term carbon prices remain for 38% of respondents the decisive factor and for a further 55% of respondents an influencing factor. However, for the first time since 2009, the share of those actually not taking carbon prices at all into account has almost doubled to reach 7% in the 2012 survey. Thomson Reuters Point Carbon, Carbon 2012, 21 March 2012, http://www.pointcarbon.com/news/1.1804940

[44] It is not expected that such levels of the carbon price will be reached any time soon, and it is therefore not likely that industry will commit the appropriate investments to CCS projects on the basis of the carbon price alone. This is further reinforced in a context of lack of clear policy framework and incentives at national level, compounded by public resistance, unless actions are undertaken at European and Member State level to change the negative prospects.

[45] IEA (2012), 'A Policy Strategy for Carbon Capture and Storage'.

A mandatory CCS certificate system could require carbon emitters (above a certain size) or suppliers of fossil fuels to buy CCS certificates equivalent to certain amount of their emissions or embedded emissions (in case the commitment is placed on the fossil fuel suppliers). Certificates could be given to the oil and gas industry, ensuring that the knowledge already contained in these sectors regarding geology and field expertise is contributing to identifying the best suited storage sites, including the possibility for enhanced oil and gas recovery, in so far as this ensures permanent CO2 storage.

Box 1: CCS obligation currently in operation

Starting in 2015, electric power utilities in the state of Illinois in the USA are required to source 5% of their electricity from a clean coal power source, with a target of 25% by 2025. Plants operating before 2016 qualify as clean coal as long as at least 50% of CO_2 emissions are captured and sequestered. This requirement rises to 70% for coal power plants expected to commence operating in 2016 or 2017, and to 90% thereafter.

Such a system could work with the ETS, provided the volume of CCS certificates that would be required would have its equivalent in ETS allowances, which would have to be permanently withdrawn from the market (the quantity of carbon reductions through CCS certificates is known, so that a swift integration with the ETS system would be possible by reducing the amounts of ETS allowances with the same number). Such a system could define how much CCS needs to be developed and delivered. If targeted in scope, the impact on the functioning of the ETS could be limited whilst still allowing the flexibility to business to meet the cap.

Emission performance standards could be a targeted solution which could consist of creating mandatory emissions performance standards either on new investments only or on all emitters in a sector, by limiting firms or installations to no more than a fixed amount of emissions per unit of production.

Box 2: Emissions performance standards currently in operation

An emissions performance standard (EPS), as a long term support policy, is currently in place in California, where a non-tradable emissions performance standard of 500g CO_2/kWh on new electricity generating plants has been instigated[1]. The US is also considering on the federal level an emissions performance standard through the Clean Air Act implemented by the EPA, which effectively forces new investments in coal power to be "CCS ready" and retrofitted at a later stage. This is ensured by allowing the emissions performance standard to be met on average over a 30 years period. Another example is Norway, where no gas power plant can be built without CCS.

Emission performance standards raise a number of methodological questions. They give no guarantee that plants would be built with CCS, and could rather shift investments simply to energy sources with a lower carbon content as determined by the EPS. Furthermore, if rigorously implemented, the scheme would de facto replace the carbon price signal from the ETS as an incentive to decarbonise, without allowing the sectors concerned the flexibility as foreseen under the ETS. Therefore any Emission Performance standard would need further consideration on how it would impact the ETS and the sectors concerned[46].

[46] See for instance http://ec.europa.eu/clima/policies/lowcarbon/ccs/docs/impacts_en.pdf

Furthermore national governments also have a role to play in demonstration. Member States could for instance set up systems that ensure a minimum return on any CCS investment made, similar to feed-in tariffs often employed to ensure demonstration and penetration of renewable technologies. If designed in a flexible manner, to avoid windfall profits, and if limited to demonstration only, such schemes could prove effective, and have no undue negative impact on the functioning of the ETS or the internal market.

5. Conclusions

The Energy Roadmap 2050 as well as global developments and reports[47] make it evident that fossil fuels will stay in the global and European energy mix and will continue to be used in many industrial processes. CCS is at present one of the key available technologies that can help to reduce CO_2 emissions in the power generation sector. In order to realise its potential CCS needs to become a cost-competitive technology, so that it could start to be commercially deployed and thus contribute to the low-carbon transition of the European economy.

But CCS is now at a crossroads.

All aspects of CCS have already been demonstrated outside the EU, where its application for gas processing is commercial and around 20 full scale industrial projects are expected to be in operation by 2020. Despite much effort and significant EU support, CCS commercial scale demonstration projects in the EU are delayed and available funding is not sufficient. In fact, efforts need to be increased to realise at least those few projects that have been awarded EU funding. Delays of CCS on coal and gas-fired power will likely lead to greater costs for decarbonising the electricity sector in the longer term, especially for those Member States that rely heavily on fossil fuels.

An urgent policy response to the prime challenge of stimulating investment in CCS demonstration is required to test whether the subsequent deployment and construction of CO2 infrastructure is feasible. The first step on this path is therefore to ensure a successful commercial-scale demonstration of CCS in Europe that would confirm CCS's technical and economic viability as a cost effective measure to mitigate GHG in the power and industrial sector.

CCS is also on the longer term necessary to be able to reduce emissions in industries with process emissions that cannot be avoided. Further delays may ultimately result in the need of the European industry to purchase CCS technology from non EU countries in the future.

Given the complexities explained above, and in the light of the work started on the 2030 energy and climate framework and the need for an informed debate, including the issue of the determining factors for successful CCS deployment, the Commission invites contributions on the role of CCS in Europe, particularly:

1) Should Member States that currently have a high share of coal and gas in their energy mix as well as in industrial processes, and that have not yet done so, be required to:
    a. develop a clear roadmap on how to restructure their electricity generation sector towards non-carbon emitting fuels (nuclear or renewables) by 2050,
    b. develop a national strategy to prepare for the deployment of CCS technology.

[47] IEA – World Energy Outlook 2012 estimates that fossil fuels represent 80% of global energy use today, while it will represent 75% in 2035 in the "new policies" scenario.

2) How should the ETS be re-structured, so that it could also provide meaningful incentives for CCS deployment? Should this be complemented by using instruments based on auctioning revenues, similar to NER300?

3) Should the Commission propose other means of support or consider other policy measures to pave the road towards early deployment, by:

    a. support through auctioning recycling or other funding approaches[48]

    b. an Emission Performance Standard

    c. a CCS certificate system

    d. another type of policy measure

4) Should energy utilities henceforth be required to install CCS-ready equipment for all new investments (coal and potentially also gas) in order to facilitate the necessary CCS retrofit?

5) Should fossil fuel providers contribute to CCS demonstration and deployment through specific measures that ensure additional financing?

6) What are the main obstacles to ensuring sufficient demonstration of CCS in the EU?

7) How can public acceptance for CCS be increased?

Based on the responses to this consultation and the full analysis of the CCS Directive transposition and implementation in the Member States, the Commission will consider the need to prepare proposals, if appropriate, in the context of its work on the 2030 Energy and Climate Framework.

[48] Taking into account complementarity with the European Structural and Investment Funds (ESI), as set out in the Common Strategic Framework annexed to the Commission proposal for a Common provisions regulation of the ESI Funds

Annex I – Full scale CCS projects

CCS projects currently under operation[49]. The projects marked with a * are projects with complete CCS (capture, transport and storage). More details on the business case are provided below the table.

Project name	Country	Project type	Industry	Scale	Status	Year of operation	Size [ton CO_2/yr]
*Shute Creek	USA	Capture Storage	Oil and gas processing	Large	Operative	1986	7,000,000
*Century Plant	USA	Capture Storage	Oil and gas processing	Large	Operative	2010	5,000,000
*Great Plains Synfuels Plant	USA	Capture	Coal to liquid	Large	Operative	1984 (plant) CO2 injections since 2000	3,000,000
*Val Verde natural gas plants	USA	Capture Storage	Oil and gas processing	Large	Operative	1972	1,300,000
*Sleipner West	Norway	Capture Storage	Oil and gas processing	Large	Operative	1996	1,000,000
*In Salah	Algeria	Capture Storage	Oil and gas processing	Large	Operative	2004	1,000,000
*Snøhvit	Norway	Capture Storage	Oil and gas processing	Large	Operative	2008	700,000
*Enid Fertiliser Plant	USA	Capture Storage	Chemical products	Medium	Operative	2003	680,000
Mt. Simon Sandstone	USA	Storage site	Biofuel	Medium	Operative	2011	330,000
Searles Valley Minerals	USA	Capture	Other	Medium	Operative	1976	270,000
Aonla urea plant	India	Capture	Chemical products	Large	Operative	2006	150,000
Phulpur urea plant	India	Capture	Chemical products	Large	Operative	2006	150,000
Husky Energy CO2 Capture and	Canada	Capture Storage	Ethanol production	Large	Operative	2012	100,000

[49] Source: ZEROs CCS project database; keeping track on the development and deployment of CCS globally. http://www.zeroco2.no/projects and;

GSSCI, The Global Status of CCS: 20122.1 An overview of large-scale integrated CCS projects: http://www.globalccsinstitute.com/publications/global-status-ccs-2012/online/47981

Liquefaction Project							
CO2 Recovery Plant to Urea production in Abu Dhabi	United Arab Emirates	Capture	Chemical products	Large	Operative	2009	100,000
Plant Barry CCS Demo	USA	Capture Storage	Coal Power Plant	Large	Operative	2011	100,000
Salt Creek EOR	USA	Capture Storage	Oil and gas processing	Large	Operative	2003	100,000
SECARB - Cranfield and Citronelle	USA	Storage		Large	Operative	2009 and 2012	100,000
Luzhou Natural Gas Chemicals	China	Capture	Chemical products	Large	Operative		50,000
Jagdishpur - India. Urea plant	India	Capture		Large	Operative	1988	50,000
Sumitomo Chemicals Plant - Chiba - Japan	Japan	Capture	Oil and gas processing	Large	Operative	1994	50,000

Details on the 8 commercial full scale projects:

Project	**Business case**
Shute Creek	EOR (enhanced oil recovery). ExxonMobil's Shute Creek gas processing plant near LaBarge, Wyoming, is currently capturing around 7 million tonnes per annum of CO_2 that is used for enhanced oil recovery.
Century Plant	EOR (enhanced oil recovery). Around 5 million tonnes per annum of CO_2 are currently being captured from the first train of the plant. This is expected to increase to around 8.5 million tonnes per annum when the second train, now under construction, becomes operational.
Great Plains Synfuels Plant	EOR (enhanced oil recovery). Sequestration began in 2000 and the project continues to inject around 3 million tonnes of CO_2 a year.
Val Verde natural gas plants	EOR (enhanced oil recovery). Five separate gas processing facilities in the Val Verde area of Texas, USA, capture around 1.3 million tonnes of CO_2 annually for use in enhanced oil recovery operations at the Sharon Ridge oilfield.
Sleipner West	The specification (quality) of the natural gas that is sold requires that the level of CO_2 content in the gas is lower than 2.5%. The capture of the CO_2 is commercially viable due to the CO_2 tax applied on the continental shelf of Norway.

In Salah	The specification (quality) of the natural gas that is sold requires that the level of CO_2 content in the gas is lower than 2.5%. The project applied for CDM credits.
Snøhvit	Same as for Sleipner West
Enid Fertiliser Plant	EOR (enhanced oil recovery). CO_2 needs to be removed in the production of fertilizer. Instead of venting the gas, the Enid Fertiliser Plant captures the gas and uses it for enhanced oil recovery at an oil field almost 200 km away.

Annex II – Status of European full-scale demonstration projects under the EEPR

The EEPR programme could finance 6 CCS demonstration plants with up to €180 million each. However, none of them have taken the final investment decision.

Main Achievements

The EEPR enabled a fast start of six projects (in Germany, the United Kingdom, Italy, the Netherlands, Poland and Spain). For one of these (ROAD in NL) the EEPR was instrumental in leveraging national funding. In the area of permitting, the EEPR has triggered a targeted dialogue and cooperation with authorities and local populations.

Some projects have also helped in structuring the actual implementation at Member State level of the CCS Directive. Furthermore, the detailed engineering studies performed so far have allowed utilities to gain insight know-how on the future operation of an integrated CCS facility. The characterisation work on specific geological storage locations has also led to the identification of suitable sites for the permanent and safe storage of CO_2.

The CCS sub-programme includes an obligation for projects to exchange experiences and best practices, which was made operational by the establishment of the CCS Project Network. It is the first such knowledge-sharing network worldwide and the 6 members are working together to inter alia produce common 'good practice' guides; this is unprecedented cooperation in a new energy technology area. The Network furthermore published reports of the lessons learned by projects on CO_2 storage, public engagement and permitting. It also aims at leading the development of a global knowledge sharing framework.

Critical issues

The CCS sub-programme as a whole is facing some major regulatory and economic uncertainties that risk undermining its successful implementation. The fact that none of the projects have yet adopted the final investment decision (FID) illustrates the on-going difficulties. This milestone has been delayed for a variety of reasons, including: permits have not yet been secured completely; characterisation of the storage sites has not been finalised; financial structure has yet to be completed. Furthermore, the low carbon price under the Emissions Trading System (ETS) renders the short and medium-term business cases for CCS unattractive. Finally, due to the current economic context, projects are facing increasing difficulties with access to financing.

In early 2012 the EEPR project in Germany, Jaenschwalde, was terminated. In addition to facing public opposition in the potential storage locations, the promoters concluded that the substantial delays in the German transposition of the CCS Directive would not allow the necessary CO_2 storage permits to be obtained within the project timeframe.

Outlook

The remaining 5 projects face different challenges, as briefly explained below:

- **ROAD (NL)**: The project has successfully completed all the preliminary technical and regulatory works. It is hence ready for the adoption of the final investment decision. Despite being ready for FID since mid-2012, the worsening of the business case for CCS, i.e. CO_2 price projections, opened a funding gap of €130m which has postponed the decision. The FID is subject to closing the financing gap. Discussions with additional investors are on-going. A decision is expected in Q2-Q3 2013. The integrated CCS demonstration project is scheduled to be operational in 2016.
- **Don Valley (UK)**: The recent decision of the UK not to support the project is a serious setback. After having consulted its key private partners and investors (including Samsung, BOC), the promoters (2Co, National Grid Carbon) are however committed to go ahead, but potentially with a smaller project and with focus on the planned "Contract for

Difference" (CfD) scheme which was on 29 November 2012 proposed by the UK government as part of the Energy Bill. The Commission is currently discussing a restructuring plan with the beneficiaries. If the plan is approved by the Commission, FID could take place in 2015.

- **Porto Tolle (IT)** faces severe delays due to the revocation of the environmental permit of the base power plant. In May 2013 the promoters will complete the Front End Engineering Studies. The way forward will be conditional on meeting a key milestone in Q2 2013: the capacity to mitigate significantly the permitting and financial risks.
- **Compostilla (ES)** will successfully complete the pilot phase within 2013 but lacks the necessary financing for the demonstration phase. The next phase would also require that Spain adopts legislation for planning and building the CO_2 transport corridor.
- **Belchatow (PL):** the project did not receive NER300 funding and has a significant financing gap. In addition Poland still has to transpose the CCS directive and adopt legislation for planning and building the CO_2 transport corridor. Against this background, the promoter decided to start termination of the project in March 2013.