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Physics Procedia 00 (2008) 000–000

Physics Procedia

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GHGT-9

Ramp-up of large-scale CCS infrastructure in Europe

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Elsevier use only: Received date here; revised date here; accepted date here

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Abstract

This paper investigates conditions for a rapid ramp-up of a large-scale CO2 transport and storage infrastructure within the power and heat sector in EU's Member States (MS). First, each MS is investigated individually with respect to the relevance of CCS in the power and heat sector. Second, the potential cost of CO2 transport and storage is evaluated and categorised into three levels for each MS with particular emphasis being put on power plant clusters, ownership concentration, source-sink distance and onshore storage potential. The chosen cost category for each member state is then used as input in a techno-economic modelling to evaluate the future electricity supply system in Europe as described elsewhere (Odenberger et al., 2008a). Finally, based on the modelling results, the study develops a detailed CO2 transportation and storage infrastructure for Germany and UK and discusses issues related to the ramp-up of such infrastructure.

The analysis shows that most MS have identified structures that may be suitable for subsurface storage of CO2. Fourteen MS have so far identified onshore reservoirs only. Several MS have clusters of large power plants along with considerable national or regional concentration of plant ownership, factors that may both facilitate the ramp-up of a bulk CCS infrastructure. Phasing in of CCS plants over time will obviously play a key role in building up large-scale transport infrastructure. CCS plants are likely to be located on existing sites and coal plants currently under construction may choose to retrofit the plant for CCS instead of building new plants. CO2 pipeline trajectories are likely to follow existing trajectories for natural gas pipelines, minimising interference with the surroundings and facilitate and speed up permitting processes. Timing, conflicts of interest and public acceptance, especially onshore, are other factors that may become an issue with regard to transport and storage of CO2. According to model results, some 5.2 Gt CO2 is transported and stored in Germany between 2020 and 2050 while the corresponding figure in the UK is 3.7 Gt. Based on assumed injectivity, total system costs up to 2050 range between € 18 and € 23 billion in Germany and between € 20 and € 30 billion in the UK while specific costs range between € 3.4 and € 4.4 per ton of CO2 in Germany and between € 5.4 and € 8.1 in the UK. Finally, the modelling results indicate a rapid switch from gas based to coal based power generation with CCS. It is, however, likely that the large fuel switch from gas to coal will be moderated considerably by market dynamics and issues related to the fuel supply chain.

Keywords: EU; Power Sector; CCS;Relevance; Infrastructure

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1. Introduction

Globally, around 60% of GHG emissions and almost 70% of CO2 emissions relate to energy supply and use. According to IPCC's (2007) Fourth Assessment Report (AR4), global CO2 emissions should peak no later than 2015 and be reduced by between 50 to 85% by 2050 relative to year 2000, in order to avoid a temperature increase of more than 2.0 to 2.4°C. The EU, characterising a temperature increase of more than 2.0°C as "dangerous climate change", has committed to reduce greenhouse gas (GHG) emissions by at least 20% by 2020 and possibly by 30% if other developed countries agree to reduce their emissions. Furthermore, the EU commission has suggested that by 2050 developed countries should reduce their emissions by 60 to 80% relative to year 1990. Total GHG emissions in EU-27 amounted to 5,143 Mt in 2006 not including LULUCF, down from 5,768 Mt in the base year, i.e. a reduction of 11% over the period meaning that much of EU's commitment to 2020 has already been achieved. However, this is mainly as a result of emission reductions achieved by the twelve new MS which entered the union in 2004 and 2007. EU-15 has in fact only reduced their emissions by 2.7% relative to the base year over the same period, or by 114 Mt not including LULUCF[2] (EEA 2008). Fossil fuels account for more than 50% of EU power generation and it is generally recognised that fossil fuels will remain vital as primary energy source for several more decades. Furthermore, although a switch from coal based power and heat generation to gas based generation will reduce emissions considerably, it will also increase the dependence on gas imports, in the long run particularly from Russia and Middle East, and this raises serious concerns for energy security. Introduction of large scale CCS will allow continued use of coal and lignite based power and heat generation and thereby enhance energy security through diversification of fuels, suppliers and transport routes. The European Commission (EC) has realised this and has targeted 12-15 large scale CCS demo plants up and running by 2015 and recently the EU Parliament suggested that CCS should be made mandatory for new coal plants after 2015. Furthermore, CCS is perhaps even more important as a global option to reduce emissions considering the rapid growth in energy consumption in countries like China and India which have little other choice than to utilise their vast coal resources in order to meet growing demand.

Some important work have been published matching sources and sinks of CO2 while at the same time developing cost curves for transport and storage of CO2, like IEA (2005), Gestco (2004), Pöyry (2007) and NOGEPA (2008). The ongoing GeoCapacity project continues the work made by the Gestco project expanding the geographical coverage to comprise several more MS. Additionally some MS have carried out their own investigations like Belgium (PSS-CCS 2008) and Ireland (SEI 2008) further increasing the knowledge base. As a result, it can now be concluded that most MS probably have suitable structures allowing for subsurface storage of CO2. Yet, there is a lack of work specifically focusing on CCS within the power sector in separate MS including source-sink matching, detailed investigation into parameters such as age and phasing out of existing plants, fuel distribution and ownership concentration and where the result for each MS is being used as input in a techno-economic modeling of the future power and heat generation system within Europe. There is also a lack of post-modeling analysis covering issues such as fuel market dynamics and fuel supply chains. The aim of this work is to provide detailed analysis of each EU MS, at a level which is appropriate to combine with energy systems modeling.

2. Methodology

The first part of the work comprised an evaluation of the relevance of CCS within the power and heat sector in each separate EU MS. Chalmers Energy Infrastructure database (CEI db) was applied extensively in a Geographical Information System (GIS) to derive parameters such as source and/or sink clusters, distance between plants and storage sites[3], ownership concentration, fuel distribution and phasing out/in of old/new plants respectively (for a detailed description of the CEI db, see Kjärstad et al, 2007). The data obtained in this investigation together with other parameters such as the share of CO2 emissions from the power and heat sector in total GHG emissions, CO2 storage potential and storage site location (onshore/offshore) were compiled and analyzed in order to classify the relevance of CCS within each MS as either poor, moderate or good (see Table 1). Storage potential is based on published figures as of October 2008 and since the potential currently is being investigated in a number of countries, present estimates may be reduced or raised in the future which in turn may lead to a re-evaluation of CCS relevance for some MS. The data

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[2] Another 90 Mt reduction has occurred as higher net CO2 removals from LULUCF over the period.

[3] Distance between power plants and storage sites have been measured based on a straight line in GIS. A "real life" CO2 pipeline will of course be longer.

on storage capacity used in this work has been taken mainly from Gestco (2004), GeoCapacity (2007) and, in the case of Ireland and Italy, SEI (2008) and Joule 2 (1996), respectively. However, the Carbon Sequestration Leadership Forum (CSLF 2008) has recently recommended methodologies to calculate storage capacity in aquifers, oil and gas fields and coal seams which deviate somewhat from the methods used in previous work by Joule 2 (1996) and Gestco (2004). However, application of the new methods will require detailed knowledge of each specific reservoir while most estimates quoted up to now are rough approximations on basin or regional scales. CSLF (2008) has also proposed to classify storage capacity into four different levels based on accuracy and/or availability of data, namely theoretical, effective, practical and matched storage capacity. It is not always clear what specific level the storage capacity quoted in Table 1 is referring to but generally, the storage capacity refers to the lowest value quoted by Gestco (2004) and GeoCapacity (2007).

The second part of the work involved classifying and assigning a cost level for transport and storage of CO2 within each MS applying three different cost levels; €5, 7.50 and 10 per ton of CO2. The different cost levels were thereafter used as input in the modelling work (Odenberger et al, 2008a). To decide the various cost levels particular emphasis was placed on plant clusters, ownership concentration, source-sink distance and site location (onshore or offshore) since these parameters to a large extent will determine transport and storage costs.

Finally, the last part of the work involves designing a large scale CO2 transport and storage infrastructure in Germany and UK. This part of the work refines a previous work by the authors (Odenberger et al., 2008b). Input, i.e. captured CO2 over time, was provided through modeling of the European electricity system up to 2050 based on strict CO2 emission reduction targets, or more specifically 30% reduction in 2020 and 85% reduction in 2050, in both cases relative to 1990 (Odenberger et al., 2008a). As a result of the assumptions and the modeling, CCS starts up in Germany in 2020 at a rate of 98 Mtpa increasing to between 190 and 205 Mtpa over the last decade with total cumulative captured and stored CO2 of 5.2 Gt up to 2051. In the UK, CCS starts up in 2023 at 8 Mtpa increasing rapidly to between 150 and 160 Mtpa over the last one and a half decade with a total cumulative amount of 3.7 Gt by 2051. Modeled CCS plants have been taken from the ENCAP project with block capacity of 600 MW (coal) and 1,000 MW (lignite). Each block is assumed to generate on base load with an efficiency of 37% increasing to around 43% at the end of the period. For the transport and storage infrastructure it has been assumed that CCS plants are being erected on existing sites following 1) the volume of captured CO2 over time as envisaged by the model results and 2) the phase-out of existing plants.

All transport of CO2 takes place by pipelines and the system has been designed already from start to accommodate the expected peak transport volume. This may not happen in practice since each utility may choose to phase in new plants according to its own requirements. Furthermore, it has been assumed that Collecting Pipelines (CPL) at nearby power plants transport the CO2 to large regional Bulk Pipelines (BPL). Around 30 km from the reservoir the bulk pipeline is divided into Reservoir Pipelines (RPL), each carrying 10 Mtpa to selected sites with a storage capacity of at least 400 Mt, thereby ensuring 40 years lifetime of all system components. Finally, 2 km from the reservoir, each RPL is divided into Injection Pipelines (IPL) based on an assumed injectivity of 0.5 and 1.0 Mtpa per well. The length of any segment of onshore pipelines is assumed to be 20% longer than a straight line measured in GIS between the same two segments. The corresponding increase in the length of offshore pipelines was set to 10%. The CO2 is assumed to leave the power plant with a pressure of around 110 bars being re-pressurised in booster stations each 200 km. Energy consumption for re-pressurising the CO2 was set to 1.9 kWh/ton CO2 per 200 km (IEA 2005), while the cost of electricity was set equivalent to the average marginal cost of electricity production according to the model results (€ 0.056/kWh). Sizing and cost of pipelines and cost of drilling are according to equations taken from IEA (2005). A terrain factor of 1.2 was applied on all onshore pipeline costs apart from IPL's to account for difficult terrain/population centres. All pipeline costs have thereafter been scaled up by a factor of 2 to account for the substantial increase in steel prices and other construction materials observed over the last three years[4]. Likewise site development costs, costs of booster stations, onshore surface facilities and monitoring have also been taken from IEA (2005). Costs for offshore platforms have been taken from BERR (2007) assuming a maximum of 20 injection wells per platform. Transport related investments have been assumed to materialise by equal annual amount over three years; the commissioning year and the two preceding years, while storage related investments have been allocated to the year of commissioning. Thereafter investments have been annuitized based on an economic lifetime of 20 years and 8% discount rate to derive annual capital costs. Annual costs include capital cost, 3% annual O&M (based on total

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[4] The scale factor was determined based on a comparison of costs applying IEA's equations on pipelines specified by (Pöyry, 2007) and by Vattenfall (2007).

investments) and cost of electricity. Finally, all annual costs between 2020 and 2050 have been summarised and divided by the amount of CO2 transported and stored over the same period to derive the cost per ton CO2 stored.

3. Results

CO2 emissions from the public power and heat sector accounted for 27% of total GHG emissions within EU-27 in 2006. The share varies, however, between MS, from 8% in France to more than 60% in Estonia and Malta, indicating that to what extent CCS will be in focus probably will vary between MS. Apart from the smallest MS Cyprus, Luxembourg and Malta, most MS have today identified structures that potentially may be used for subsurface storage of CO2. Estonia and Finland are the only MS completely without suitable reservoirs while Lithuania appears to have very limited storage potential apart from trapping through dissolution of CO2 in aquifer brine. All other MS have, as of October 2008, identified potentially suitable reservoirs and particularly Denmark, Germany, the Netherlands, Spain and UK are believed to have large storage capacity. However, the estimated storage potential in Germany and Spain are rough regional estimates referring to onshore sites only and the storage potential in the Netherlands is dominated by the Groningen field which will not be available for storage until after 2040. Public acceptance may represent a barrier to onshore storage of CO2 and only seven MS have so far identified offshore storage sites. Clusters of large plants ($\geq$ 500 MW) are found in most MS and perhaps more surprisingly, most countries also have a considerable concentration of plant ownership, either locally/regionally or nationally. In fact, only two countries have no particular plant clusters *and* a poor concentration of plant ownership; namely Slovenia and Sweden. Plant clusters and ownership concentration are two factors that are likely to facilitate a cost efficient build-up of a CO2 transport and storage system. Six countries have transport distances of less than 100 km between large sources and potential sinks but in general transport distances are likely to lie in the range 100 to 300 km. In summary, from our analysis we conclude that CCS is a relevant CO2 mitigation option in twenty one MS and the results are compiled and shown in Table 1.

As mentioned above the CO2 transport and storage system in Germany and UK transports and stores 5.2 and 3.7 Gt, respectively, between 2020 and 2050. There should be sufficient storage capacity both in Germany and UK to accommodate such volumes as shown in Table 1. Most of the German storage capacity is located in onshore aquifers in the North German Basin (NGB) while most of UK's storage capacity is located in aquifers, gas and oil fields in the North Sea.

Apart from public acceptance, German storage will require change of existing laws and the integrity of the hundreds of old gas and oil wells in the NGB may also pose a challenge. Storage in Germany has been modeled based on the approach used by Chadwick et al (2007) in the NGB. In an area[5] surrounding the Schweinrich structure some 26 structures were identified as potentially suitable storage sites of which 9 structures had an estimated storage potential of 400 Mt or more. It has been assumed that similar areas exist throughout the NGB, i.e. the basin has been divided into five Storage Areas (SA), each SA of the same areal extent and at the same latitudes as the area investigated in Chadwick (2007). Each SA has been assumed to contain 9-10 aquifers suitable for storage and with a storage capacity of 400 Mt or more. As mentioned above, CCS plants are assumed to be constructed on existing plant sites. In Germany 22 GW lignite based capacity with CCS comes on line between 2020 and 2024 provided suppliers are able to supply plant equipment and construct the plants in time. Also several of the existing lignite plants in Germany were commissioned between 1995 and 2002 and both RWE and Vattenfall are currently constructing new blocks in Neurath and Boxberg, respectively, indicating that some of these plants may be retrofitted for CCS instead of constructing new plants altogether.

The rapid build-up of lignite capacity together with the obvious ownership concentration of existing lignite plants with RWE owning all lignite plants in North-Rhine Westphalia (NRW) in the west and Vattenfall owning most of the lignite plants in the east indicates the build-up of three large-scale centralized transport and storage systems. Some 9 GW coal plants with CCS also come on line in Germany but considerably later, between 2035 and 2044, and it has therefore been assumed that these plants will need to build their own separate CO2 transport and storage systems[6]. Based entirely on the age of existing plants, coal based CCS plants will be located in NRW and Niedersachsen in the northwest and in Hessen and Baden-Württemberg in the southwest indicating build-up of two additional transport systems[7]. In addition, two coal plants are assumed to construct and operate their own transport system due to their

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[5] The investigated area comprises around 65x75 km and extends from 52°45' to 53°25'N and 11°55' to 12°55'E.

[6] It is possible that the system transporting CO2 from RWE's lignite plants in NRW may have sufficient excess capacity to add CO2 from RWE's coal plants in the same region like the Westfalen plant.

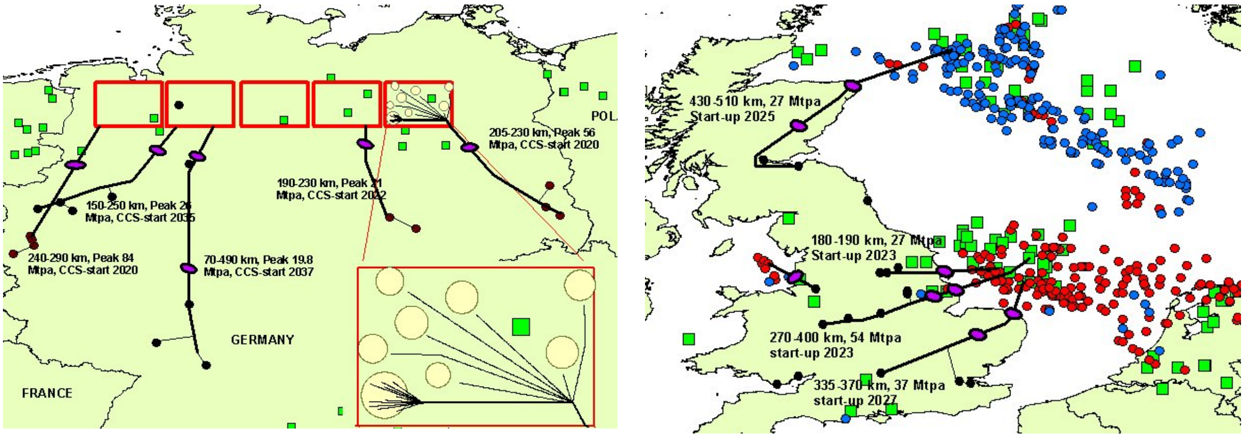
[7] The north-western system demonstrates some of the issues that probably will be a barrier against a centralized system; based on the age of the existing plants Walsum CCS plant will be commissioned in 2035 while Scholven CCS plant will be commissioned in 2044, nine years later.

location close to storage sites in the NGB. The system transporting CO2 from Hessen and Baden-Württemberg will be expensive relative to the other systems, as relatively small volumes of CO2 (16.5 Mtpa) will have to be transported for around 400 km or more. This fact may lead to that coal CCS plants instead are being constructed further north, closer to known storage sites. In total, between 3,300 and 3,700 km of pipelines are being laid, of which 2,200 km BPL's, 660 km RPL's and between 420 and 840 km IPL's. Total investment costs for the German transport and storage system range from € 6.1 billion to € 7.8 billion corresponding to injectivities of 1.0 and 0.5 Mtpa per well, respectively. Transport related costs account for between 76 and 84% of total investments. System costs between 2020 and 2050 were calculated to between € 17.9 and € 22.9 billion while specific cost was calculated to between € 3.4 and € 4.4 per ton CO2.

Apart from in Scotland, there is no ownership concentration of power plants in the UK and a large-scale centralized CCS infrastructure as developed in this work, may therefore be difficult to achieve in reality. Some forty-seven 600 MW coal based CCS blocks are being installed on existing sites between 2023 and 2044. Since in this work the replacement of ordinary coal blocks with CCS units is based entirely on age, the 3.6 GW Drax plant in North Yorkshire, the 1.5 GW Aberthaw plant and 400 MW Uskmouth plant in south Wales are assumed to be decommissioned.

Specific aquifers with sufficient storage potential for at least 40 years of storage have been chosen for storage from the CCS systems in Midland and Yorkshire and the southern parts of UK; namely the Bunter sandstones 1/48 and 5/43 for plants in Midland, the Bunter sandstone 2/83 for plants in Yorkshire and the Bunter sandstone 3/48 for the plants in south England. Based entirely on plant age, one single 600 MW CCS block should have been installed in Aberthaw in southern Wales but that would have required 200 km of pipeline to connect to the southern system starting up at the Didcot plant in Oxfordshire. Instead a fourth CCS unit was installed on the Kingsnorth site in Kent. The northern system comprising the Cockenzie and Longannet sites may be able to supply CO2 for EOR in oil fields in the northern parts of the North Sea while the western system comprising four coal blocks on the Fiddlers Ferry site in Warrington may choose to store CO2 in gas and oil fields in the Irish Sea. The CO2 is transported to existing natural gas terminals in St. Fergus, Easington, Theddlethorpe and Bacton where the CO2 is being pressurized up to around 200-250 bars before entering offshore pipelines. Since the UK has a large storage capacity within a relatively limited area, the UK system is designed differently from the German system.

Ten kilometers from the reservoir each BPL has been divided into Platform Pipelines (PPL), each carrying 10 or 20 Mtpa to a dedicated platform. From the platform the CO2 is transported to the injection well through 2 km long IPL's as in Germany. Since each platform is assumed to accommodate a maximum of 20 injection wells (BERR 2007), a 50% reduction in injectivity will double the number of required PPL's, IPL's and platforms raising overall costs considerably. In total between 2,200 and 2,600 km of pipelines will be laid of which 1,220 km onshore and 1,700 km BPL. Total investment costs for the transport and storage system range between € 6.7 and € 10.1 billion



a. **b.**

Figure 1. CCS infrastructure as obtained from the analysis of this work. a. Germany, b. UK.

However, Walsum is the coal plant farthest to the northwest in Figure 1a while the next plant in the transport system is the Scholven plant. Also, the two plants have different owner which may further complicate the picture.

corresponding to injectivities of 1.0 and 0.5 Mtpa per well respectively. Transport related costs account for between 70 and 76% of total costs in the high and low cost case respectively. System costs between 2020 and 2050 range between € 19.8 and € 29.7 billion while specific costs were calculated to between € 5.4 and € 8.1 per ton CO2.

The German and UK CCS systems are shown in Figure 1. Black and brown circles illustrate coal and lignite plants while red and blue circles illustrate gas and oil fields, respectively. Figure 1a (Germany) shows only coal plants with CCS while Figure 1b (UK) shows all large-scale (> 400 MW) coal plants in the present system including future CCS plants. Green squares illustrate aquifers. The red rectangles show the so-called SA's based upon the work in Chadwick (2007) while the purple ellipses illustrate booster stations and black lines illustrate pipelines. The legend shows average distance between source and sink including 20% added to the straight line distance, peak CO2 volume being transported through the system as well as start-up year of CO2 transport and storage. The enlarged picture in the bottom right corner of Figure 1a shows the SA farthest to the northeast indicating the BPL being divided into RPL's and further into IPL's some 2 km from the reservoir. Also shown are eight arbitrarily located aquifers plus the Schweinrich aquifer (green square).

The model results (Odenberger et al, 2008a) indicated a large build-up of gas based power generation up to 2020 followed by a rapid phase-out and switch to CCS based coal and lignite generation over the next fifteen years. Gas consumption in the electricity sector doubles between 2004 and 2019 and is thereafter essentially phased out over fifteen years while coal consumption initially drops by almost 45% up to 2019 and thereafter more than quadruples over thirteen years reaching a peak in 2037, almost 2.5 times the level in 2003. In volumetric terms consumption of steam coal increases from around 175 Mt in 2019 to 760 Mt in 2037, i.e. the increase is roughly equivalent to the entire global trade of steam coal in 2006 (IEA 2007). This will occur while at the same time EU's own coal production is expected to decline to less than 100 Mt (see for instance Kjärstad et al 2008 and EU 2007). The global coal market will probably not be able to supply such volumes and ports and hinterland in Europe will not be able to accommodate such volumes. Also, it should be recognized that the only abundant resource for base-load power that exist in Europe is lignite which could be mined at more competitive prices than imported coal, thereby enhancing overall supply security within Europe. Finally, market dynamics will probably also affect the relative competitiveness of gas versus coal moderating the results considerably.

4. Conclusions

An overall assessment of the prospects for CCS in the European power sector is presented together with a more detailed analysis of a CCS infrastructure in Germany and UK. CCS in the power sector will probably have various significance among EU's MSs given that CO2 emissions from the sector account for between 8 and 60% of total national GHG emissions. It is nevertheless clear that the prospects for CCS appear good with several MS having identified large suitable subsurface reservoirs located at reasonable distance from large point sources. Large clusters of emission sources along with considerable national or regional concentration of plant ownership have been found in many MS, factors that may both facilitate development of large scale centralized CO2 transport and storage systems. CCS plants are likely to be located on existing sites and CO2 pipeline trajectories will probably follow existing trajectories for natural gas pipelines since this should minimize interference with the surroundings and speed up permitting processes. A key issue will be the phasing out of existing plants versus phasing in of new CCS plants and plants recently commissioned or currently under construction may choose to retrofit existing units for CCS instead of building new plants altogether. According to the model results some 5.2 Gt CO2 is being captured and stored in Germany between 2020 and 2050 and 3.7 Gt in the UK. The CCS infrastructure will require investments between € 6.1 and € 7.8 billion in Germany and between € 6.7 and € 10.1 billion in the UK depending on reservoir injectivity while specific costs for transport and storage of CO2 have been calculated to range between € 3.4 and € 4.4 per ton CO2 in Germany and between € 5.4 and € 8.1 in the UK. Finally, the model results also indicate a fast build-up of gas based power generation up to 2020 followed by a rapid phase-out and fuel switch to coal based generation when CCS becomes available as mitigation option. Market dynamics and issues related to the fuel supply chain are however factors that probably will moderate model results considerably. Expanded utilization of lignite for power generation together with CCS could potentially improve energy security considerably within the union.

Acknowledgements

This work was co-funded by the AGS project “Pathways to Sustainable European Energy Systems” and the EU ENCAP project (SES6-CT-2004-502666, within the EU 6th Frame Work Programme).

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Table 1. CCS Relevance and Cost Classification for EU MS.

	GHG emissions Base Year	GHG Emissions 2006	CO2 Power & Heat[1]	Storage Capacity[2]	Identified Sites	Plant	Ownership	Approx distance[3]	Storage Cost	
	Mt CO2 eqv	Mt CO2 eqv	Share 2006, %	Mt CO2	Onshore/Offshore	Clusters	Concentration	Source-sink, km	Classification	CCS Relevance
Austria	79.0	91.1	13.2	500	Onshore	Yes	Fair	0-280	2	Moderate
Belgium	145.7	137.0	16.5	100	Onshore	Yes	Considerable	40-100	1	Moderate
Bulgaria	132.6	71.3	38.4	825	Onshore[4]	Yes	Considerable	0-170	1	Good
Cyprus	6.0	10.0	36.5	0	na	Yes	Considerable	na	3	Poor
Czech Rep	194.2	148.2	36.8	3 190	Onshore	Yes	Fair	10-60	1	Good
Denmark	69.3	70.5	38.1	18 007	Onshore & Offshore	Copenhagen	Considerable	0-120	1	Good
Estonia	42.6	18.9	60.6	0	na	Yes	Considerable	250-400 plus	3	Poor
Finland	71.0	80.3	36.6	0	na	Helsinki	Fair	370-1000	3	Poor
France	563.9	541.3	8.7	1 850	Onshore	Yes	Fair	0-240	2	Moderate
Germany	1 232.4	1 004.8	32.8	14 879-30 879	Onshore[4]	Yes	Considerable	20-450	1	Good
Greece	107.0	133.1	38.3	2 228	Onshore & Offshore	Yes	Considerable	30-240	1	Good
Hungary	115.4	78.6	22.2	5 648	Onshore	No	Poor	60-130	1	Good
Ireland	55.6	69.8	20.7	455	Offshore	Yes	Considerable	30-150	1	Good
Italy	516.9	567.9	21.4	2 417	Onshore & Offshore	Yes	Considerable	0-150	1	Good
Latvia	25.9	11.6	17.4	300	Onshore	No	Considerable	70-170	1	Good
Lithuania	49.4	23.2	16.1	18	Onshore	No	Considerable	250-530	3	Poor
Luxemb	13.2	13.3	11.0	0	na	No	Considerable	80 plus	2	Good
Malta	2.2	3.2	62.1	0	na	Yes	Considerable	na	3	Poor
Netherlands	213.0	207.5	23.8	11 255	Onshore & Offshore	Yes	Considerable	0-200	1	Good
Poland	563.4	400.5	44.0	4 794	Onshore	Yes	Fair	0-220	1	Good
Portugal	60.1	83.2	23.5	0	Onshore & Offshore	Lissabon	Considerable	0-100	2	Moderate
Romania	278.2	156.7	31.1	5 500	Onshore	Yes	Considerable	0-100	1	Good
Slovakia	72.1	48.9	16.8	1486	Onshore	No	Considerable	0-80	1	Good
Slovenia	20.4	20.6	30.8	149	Onshore	No	Poor	0-50	1	Moderate
Spain	289.8	433.3	23.4	43266	Onshore	Yes	Poor	0-300	2	Good
Sweden	72.2	65.7	12.4	1610	Offshore	No	Poor	25-310	3	Poor
UK	776.3	652.3	28.3	30352	Offshore[4]	Yes	Poor	60-480	2	Good
SUM EU	**5 767.8**	**5 142.8**	**26.8**	**148 829-164 829**	**Onshore & Offshore**					

[1] Power and Heat refers to Public Power and Heat generation corresponding to source category 1A1a as defimed by UNFCCC

[2] Storage potential refers to those figures that have been publicly announced as of October 2008 involving various degrees of accuracy. Also, investigations are ongoing within several MS to raise the accuracy and/or to identify new potential structures.

[3] Distance source-sink refers to straight line distance, a "real life" pipeline will necessarily be considerably longer

[4] Storage potential includes 4 Mt offshore potential in Bulgaria, 65 Mt offshore potential in Germany and 302 Mt onshore potential in UK