Kiel **Policy Brief**

How will Germany's CCS Policy Affect the Development of a European CO_2 Transport Infrastructure?

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1. CCS is already recognized in EU climate policy, but progress in enacting CCS legislation differs across member states

To react to the challenge of climate change, the European Union (EU) has set itself a target to reduce greenhouse gas (GHG) emissions by 20 % by 2020. As a result, the carbon dioxide (CO_2) price in Europe may increase significantly towards 2020. In fact, it could easily reach around € 50 per ton of carbon dioxide, as a recent comparison of integrated assessment models suggests (Böhringer et al., 2009). This price justifies the deployment of a variety of new mitigation options, including carbon dioxide capture and storage (CCS), which has recently been receiving increasing attention in policy debates because of its presumed large potential for reducing anthropogenic CO_2 emissions.

Against this background, the EU enacted Directive 2009/31/EC on the geological storage of carbon dioxide (the CCS Directive) as part of the EU Climate and Energy Package (EU, 2009a) in June 2009. The CCS Directive (EU, 2009b) mainly regulates the storage of CO_2 in geological formations to guarantee environmental safety, but it also regulates the capture and transport of CO_2. Individual member states (MSs) were requested to transpose the CCS Directive into national law by June 2011.

However, most of the MSs are still in the process of doing so (IEA, 2011). The United Kingdom (UK), for example, has passed the necessary legislation and initiated demonstration projects fairly smoothly. The UK Energy Act of 2008 already put into force regulations for offshore storage of CO_2. Additional regulations with regard to onshore storage were put into force in October 2010. Governmental funding for demonstration projects has been provided since the Energy Act of 2010 was passed. The British government has already received nine applications to fund CCS projects out of the EU's New Entrant Reserve (NER) scheme as of late April 2011 (DECC, 2011).[1]

In contrast, the process of passing the necessary legislation is not progressing so smoothly in Germany. After the German Parliament (*Bundestag*) failed to agree on a first draft of a CCS act[2] in June 2009, the Cabinet (*Bundesregierung*) agreed on a second draft[3] in April 2011 (Hohmuth and Kahle, 2010), but, this time, the draft failed to be passed by the German Federal Council (*Bundesrat*) in September 2011 (Bundesrat, 2011). The most prominent reason for this second failure was disagreement among decision-makers about a provision that allowed CO_2 storage to be prohibited in certain areas in Germany. The second draft, in contrast to the first, granted the German states (*Bundesländer*) the authority over CO_2 storage within their borders, including the authority to prohibit the use of potential storage sites.[4] Prior to the vote on the second draft, Schleswig-Holstein, a state with many potential CO_2 storage sites, had already

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[1] The NER scheme is a fund dedicated to supporting CCS and renewable energy projects across the EU.

[2] „Gesetz zur Regelung von Abscheidung, Transport und dauerhafter Speicherung von Kohlendioxid“ (BMWi, 2009).

[3] „Gesetz zur Demonstration und Anwendung von Technologien zur Abscheidung, zum Transport und zur dauerhaften Speicherung von Kohlendioxid“ (BMU, 2011).

[4] http://www.euractiv.de/energie-und-klimaschutz/artikel/bundesrat-stoppt-ccs-gesetz-005414.

decided to prohibit their use for storing CO_2, reflecting the opposition of the local public to the onshore storage of CO_2 (dradio, 2011). As a consequence of Schleswig Holstein's decision, RWE, a major energy company in Germany, abandoned its CCS demonstration plant in Hürth, near Cologne. Initially, RWE had planned to store the CO_2 captured in Hürth in Schleswig-Holstein.[5]

The second draft was also limited in its scope to demonstration projects, excluding the commercial use of CCS. The volume and duration of CO_2 storage were limited, and a comprehensive review of the act was not planned until after 2017 (BMU, 2011). On the one hand, this could have undermined firms' confidence in the long-term viability of CCS technology. On the other hand, at least CCS research and development would have been regulated. Currently, there are no legally valid CCS regulations in Germany, which has already induced companies in Germany to withdraw from research activities they had been planning.

The Netherlands is another example of a country where strong local opposition to CO_2 storage has significantly influenced the legislation process. Recently, the Baarendrecht CCS project was canceled due to local opposition; two other projects have been postponed. In response, the Ministry for Economic Affairs has decided to only consider offshore storage sites (Ministry for Economic Affairs, 2011). In addition, Dutch legislators are currently amending the current Mining Act, the so-called *Mijnbouwwet*, to comply with the CCS Directive.

This lack of policy coherence among MSs, exemplified by the difficulties related to the legislative processes mentioned above, poses a significant problem to the implementation of CCS. Large-scale implementation of CCS would require the establishment of sizable transport infrastructure for captured CO_2. This infrastructure, which would basically consist of a network of pipelines, would have to link multiple emission sources and storage sites to minimize total costs. This means that CCS operators in multiple countries would have to share the pipeline network. In other words, if a limited number of MSs (such as Germany) refuse to implement CCS or if subnational entities (such as Schleswig-Holstein) prohibit CO_2 storage, this could prevent the optimal pipeline network from being established. We argue that this is a particularly relevant issue as regards Germany, which is located at the heart of Europe and is a large CO_2 emitter as well as a large potential CO_2 sink. Below, we discuss the significance of this problem by summarizing the current estimates of CCS potentials and implementation in Europe.

[5] http://www.klimaretter.info/wirtschaft/hintergrund/8495-rwe-ensagt-kohlendioxidspeicherung.

2. Large-scale CO_2 transport infrastructure would be required because storage potentials and emission sources are located far apart throughout in Europe

The Intergovernmental Panel on Climate Change (IPCC, 2005) documents various estimates of the global and regional potential for CO_2 storage in such geological formations as oil and gas reservoirs, unmineable coal seams, and deep saline formations, which seem to provide the best options for CO_2 storage in the medium term (IEA, 2008). The GeoCapacity project (GeoCapacity, 2010) provides more recent estimates for the EU and Norway.[6] It estimates that at least 25 % of Europe's total storage capacity of 117 Gt CO_2 is located offshore along the Norwegian coast, mainly in deep saline aquifers. After Norway, the next largest storage capacities are found in Germany (17.1 GT), the United Kingdom (14.4 GT), Spain (14.2 GT), Rumania (9 GT), and France (8.7 GT). Together, these six countries comprise 64 % of the total potential CO_2 storage capacity in Europe (GeoCapapcity, 2010).

As CCS has so far mostly been considered in the context of combined use with coal-fired power generation systems, it might be particularly logical to deploy it in those EU MSs that produce a large proportion of their electricity using such systems, namely Estonia (93.7 %), Poland (91.4 %), the Czech Republic (61 %), Greece (54.6 %), Bulgaria (51.7 %), and Denmark (50.8 %) (EEA, 2010a). However, the greatest amount of CO_2 is emitted by power generation in other countries. The top six emitters of CO_2 in 2005 were Germany (325 Mt CO_2), UK (173 Mt CO_2), Poland (169 Mt CO_2), Italy (120 Mt CO_2), Spain (110 Mt CO_2), and the Czech Republic (62.4 Mt CO_2), altogether accounting for 70 % of all CO_2 emissions in the power generation sector in the EU 27 (EEA, 2010b).

In addition to the composition of the current emissions, the stringency of the European climate policy and the reduction requirements in EU MSs should also influence the outlook for the future deployment of CCS in Europe. The CO_2 emission sources, emission reduction targets, and potential storage sites in the MSs and Norway are shown in Table 1.

Total CO_2 emissions in 2005 exceeded the emission target for 2020 by 86.2 Mt CO_2. Given the large potential storage capacity, CCS could be one way to reach this emission target. However, regional heterogeneity with respect to storage capacities and electricity generation mixes implies that CO_2 is likely to be transported across borders, which may indeed improve the cost-effectiveness of CCS deployment in Europe. This also highlights the need to cooperate in Europe to establish the infrastructure necessary to effectively employ CCS in the future.

[6] GeoCapacity extends and updates the data provided by an earlier assessment, the GESTCO project (Christensen and Holloway, 2004). It widens the group of countries for which the storage potential is estimated and updates the GESTCO data for some countries (UK, Denmark, Germany, Netherlands, France, Greece). Some of the figures presented in the GeoCapacity report have not been updated but taken from the GESTCO project and adjusted to create conservative estimates (Norway and Belgium). Details can be found in the GeoCapacity reports.

Table 1:
Comparison of electricity generation mixes, CO_2 emissions, CO_2 emission reduction targets, and estimated storage capacities for the EU's 27 countries and Norway

Country	Share of coal and lignite in electricity mix (%)[a]	CO_2 emissions in 2005 (Mt CO_2)[b]	CO_2 emission reduction target for 2020 (%)[c]	CO_2 emission target for 2020 (Mt CO_2)[c]	Storage Capacity (Mt CO_2)[d]
Austria	9.9	12.7	–16	10.7	n.a.
Belgium	7.3	24.4	–15	20.7	199
Bulgaria	51.7	27.2	20	32.7	2,120
Cyprus	0.0	3.5	–5	3.3	n.a.
Czech Republic	61.0	62.4	9	68.0	853
Denmark	50.8	20.1	–20	16.1	2,756
Estonia	93.7	11.9	11	13.2	n.a.
Finland	26.3	18.7	–16	15.7	n.a.
France	4.3	50.1	–14	43.1	8,692
Germany	47.3	325.1	–14	279.6	17,080
Greece	54.6	54.2	–4	52.1	254
Hungary	18.5	17.1	10	18.9	616
Ireland	27.2	15.1	–20	12.1	n.a.
Italy	14.1	119.5	–13	104.0	6,550
Latvia	0.0	2.1	17	2.4	404
Lithuania	0.1	3.9	15	4.5	37
Luxembourg	0.0	1.5	–20	1.2	n.a.
Malta	0.0	2.0	5	2.1	n.a.
Netherlands	24.1	53.9	–16	45.3	2,340
Norway	0.0	0.4	–	–	29,188
Poland	91.4	169.0	14	192.6	2,940
Portugal	26.3	22.4	1	22.6	n.a.
Romania	40.7	46.3	19	55.1	9,000
Slovakia	17.1	8.8	13	9.9	1,716
Slovenia	36.5	6.3	4	6.5	94
Spain	24.1	110.1	–10	99.1	14,179
Sweden	0.4	7.7	–17	6.4	n.a.
UK	34.5	172.8	–16	145.1	14,400
Total	**–**	**1,369.2**	**–**	**1,283**	**113,418**

–: not applicable. — n.a.: not available. — [a]Source: EEA (2010a). — [b]CO_2 emissions from public electricity and heat production in 2005. Source: EEA (2010b). — [c]Source: EU (2009a). Note that the emission reduction targets in % refer to total GHG emissions from all sectors within a country. Here we assume that the same relative reduction target applies to CO_2 emissions caused by public electricity and heat production. — [d]Source: GeoCapacity (2010).

3. CCS deployment would require a cross-border pipeline transport system throughout Europe, in which Germany would occupy a central position

While transport is expected to be a relatively minor cost element in a European CCS system, building a CO_2 pipeline network would involve coordination problems at the regional and national level. A small number of studies have examined the scope and cost of building a CO_2 pipeline network (e.g., Odenberger et al. (2008, 2009), Kjärstad and Johnsson (2009), Middleton and Bielicki (2009a,b), Morbee et al. (2011) and Mendelevitch et al. (2010)).[7] Among these studies, only Morbee et al. (2011) and Mendelevitch et al. (2010) have specifically discussed building a CO_2 pipeline network in Europe.[8] They give us a basic idea of what it could cost to build a pan-European pipeline.

Morbee et al. (2011) conduct a simulation analysis about the evolution of a pan-European pipeline network by assuming a fixed set of CO_2 sources and sinks. They also assume that onshore storage sites would only be used by those countries that do not have easy access to offshore sites. They estimate that the pipeline network would be expanded steadily from 2015 to 2050.[9] Initially, 1,562 km of pipelines would have to be built, at an estimated overall cost of € 1.4 billion. They further estimate that by 2050, the end year of their analysis, 18,728 km of pipelines would have to be built, at an estimated overall cost of € 28.2 billion (see also Figure 1). At this time the pipeline network would serve 26 countries, and its backbone would be located in Germany, connecting emission sources in Eastern Europe and the Netherlands with sinks in the North Sea. This would require a high level of cooperation between the countries involved. This simulation, it should be pointed out, is based on conservative assumptions regarding climate policy. More stringent climate policy targets such as those currently aimed at by the EU would considerably increase total pipeline length and the related costs.

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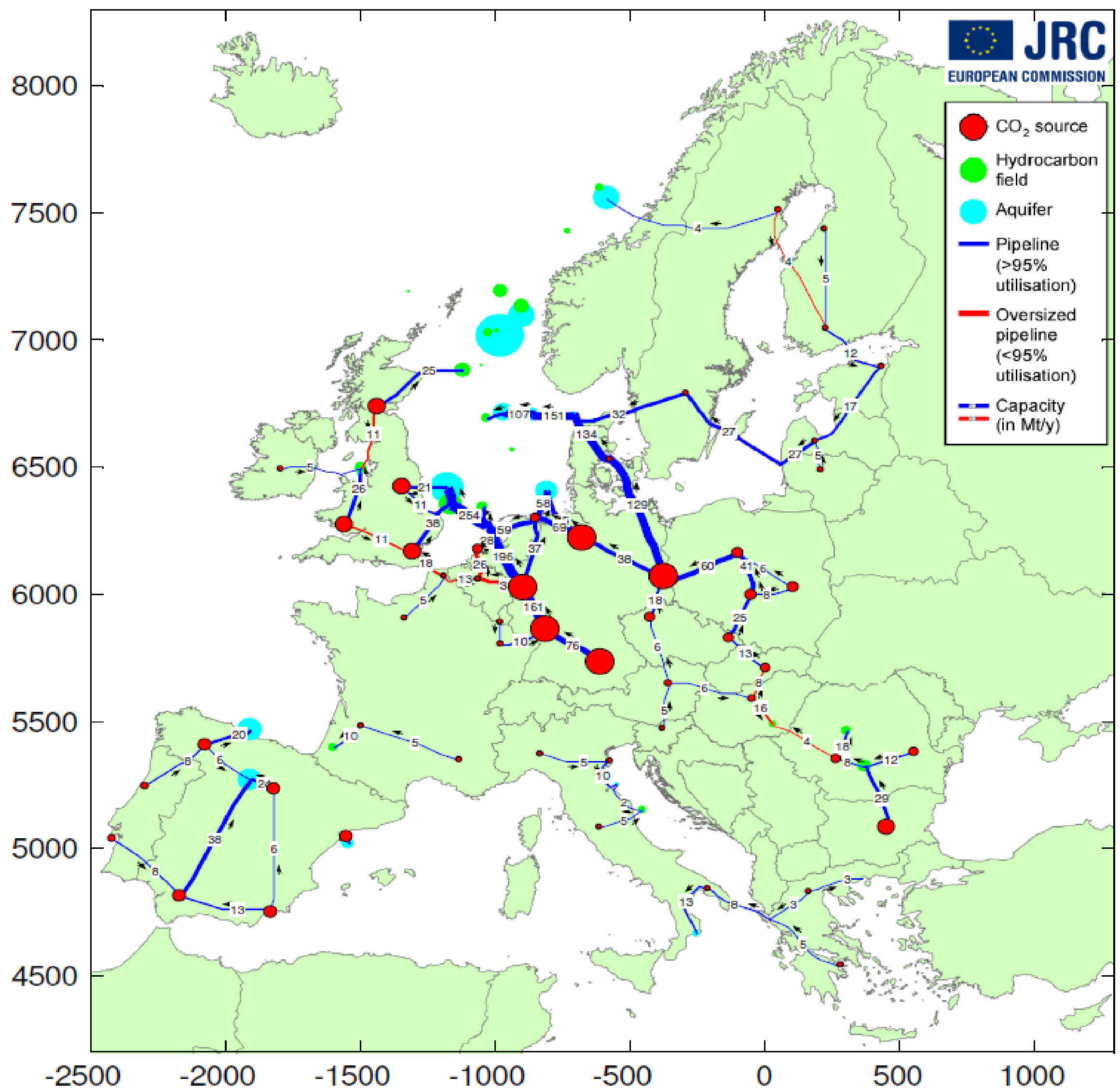
[7] Other studies are Bielicki (2009), van den Broek et al. (2009), Chen et al. (2009), Chrysostomidis et al. (2009), Coleman (2009), Kazmierczak et al. (2009), Kemp and Kasim et al. (2010), Odenberger and Johnsson (2009, 2010), and Svensson et al. (2004).

[8] Note that although other studies (e.g. Kjärstad and Johnsson, 2009) look at European countries, Morbee et al. (2011) and Mendelevitch et al. (2010) are the only studies that look at all the EU countries plus Norway.

[9] Morbee et al. (2011) build upon a generic spatial cost-minimization model of CO_2 pipeline deployment developed by Middleton and Bielicki (2009a,b).

Figure 1:
Illustration of a potential European CO_2 pipeline network in 2050



Source: **Morbee et al. (2011).**

Mendelevitch et al. (2010) argue that the economics of CCS depend heavily on three factors: the price of CO_2, the geological storage capacity, and public acceptance of onshore storage. To explore the effect of these factors on optimal pipeline infrastructure, they employ eight different scenarios, of which two, a business-as-usual scenario and an offshore 120 scenario, are described more in detail. In the business-as-usual scenario, the price of CO_2 is assumed to rise linearly from € 15/t in 2010 to € 43/t in 2050, and a total storage capacity estimate of 100 GT is used, which includes both onshore and offshore storage. In this scenario, CCS is economically feasible and 498 Mt CO_2 would be stored annually via CCS in 2050. Optimal pipeline networks would be built in Poland, Germany, the Netherlands, Belgium, France, and the UK.

However, they would be only partially interconnected, e.g., one between Poland and Germany. Total pipeline length would add up to 2,897 km. In the Offshore 120 scenario, the CO_2 price would rise as high as € 120/t by 2050 and onshore storage would not be used due to public opposition. In this scenario, the optimal pipeline network would have to be significantly longer (15,889 km) and interconnected, covering most countries of Northern Europe. Nevertheless, CCS would not be economically feasible for the EU MSs in Central and Eastern Europe due to the long distances to offshore storage sites.

Both Mendelevitch et al. (2010) and Morbee et al. (2011) conclude that regional coordination is warranted in regions where national borders separate such important CO_2 sources as industrial sites and power plants from storage sites. European coordination becomes particularly important in scenarios with high carbon prices and limited storage capacities (such as the Offshore 120 scenario in Mendelevitch et al., 2010), where a complex pan-European pipeline network would have to be built.

Although the above figures are based on various assumptions, some of which may not adequately reflect conditions in the future, they still provide a useful key insight for the German CCS policy. Germany, located in the center of Europe, is responsible for a large volume of CO_2 emissions and can also provide significant storage capacity. Thus, it could have a significant influence on the configuration of CO_2 pipeline networks throughout Europe and thus also on the development of CCS in the European countries. Specifically, the configuration would be considerably different depending on whether Germany decided to use (a) both onshore and offshore storage, (b) only offshore storage, or (c) no CCS in any form. Since pipelines would be shared with other countries to a large extent, Germany's decision would in effect restrict the storage options available to other European countries.

Neither of the two studies provides a quantitative assessment of the potential impact of German CCS policies on the rest of the European countries with respect to the cost effective construction of a transport infrastructure. However, the impact of German CCS policies would seem to be economically significant, as shown by the following rough calculation. If we assume that CCS were to begin in 2030 and handle volumes equivalent to 10 % of the current annual EU emissions (around 400Mt CO_2/yr), and if we assume a modest € 5/tCO_2 differential in transport and storage costs between the most economical CO_2 transport networks and those that are restricted by policies, the accumulated amount of additional costs would run up to € 40 billion by the year 2050. Germany's policy stance on the deployment and use of CCS is surely not the only determinant of the economic feasibility of CCS in Europe, but given its economic size, its central geographical location, and its impact on the cost of CCS activities for all European countries, it is fair to say that Germany would exert the largest influence on the implementation of CCS and its associated costs in Europe as a whole.

4. Conclusion: German CCS policy should take regional coherence into account

CO_2 storage opportunities and the location of coal-fired power plants are located far apart throughout Europe, suggesting the need for a region-wide CO_2 pipeline network or at least a considerable number of cross-border transport pipelines. Regionally coherent policy would be needed to embed a CCS infrastructure into an evolving European electricity system. However, the current EU's CCS Directive leaves the decision to allow carbon storage on their territory to individual MSs and makes no provision for limiting local bans on CCS. Such EU policy should be reconsidered, as it could distort optimal pipeline infrastructure development and make pipeline construction more expensive.

Germany, for example, is the largest emitter of CO_2 in Europe, has the second largest storage capacities, and is located in the middle of Europe. A German ban on onshore storage of CO_2 could not only unnecessarily increase the size of a transport network in Europe, but also the costs of building CCS infrastructure.

It is worth stressing that the issue of building CCS infrastructure is a policy question that requires deliberation starting today, even if building most of the projects were likely to commence at least a decade later. Although CCS is not yet a fully established technology, steps should be taken now to set up a policy framework given the long time horizon that investment decisions in CCS infrastructure and power generation facilities would require. Moreover, the current uncertainty about the future of CCS also discourages private investment in CCS research and could thus hinder an even more efficient and effective use of this technology. As the present situation indicates, the implementation of CCS runs the risk of being deployed only in isolated cases, which would influence future energy mixes and might hamper the realization of stringent climate goals.

Even if the use of renewable sources to produce energy increases in the future, coal will likely remain an important energy source for the next 20 years, particularly in Germany where nuclear power is to be phased out. In this context, CCS is a powerful option to reduce CO_2 emissions to the atmosphere. Impeding the use of and research on CCS by not establishing appropriate regulations or even by prohibiting CO_2 storage at this early stage, therefore, would pose the risk of losing one potentially important tool to combat climate change.

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