EUROPEAN pathways
jointly with
NEPP north european power perspectives

Results

March 2012

Linking techno-economic modeling of Europe's electricity sector to large-scale CCS infrastructure optimization

The following preliminary conclusions can be drawn of the research that has been done so far:

- **Even though being both considerably more expensive and requiring larger systems than onshore storage, offshore storage is the most likely alternative when storing large quantities of CO_2.**
- **Onshore storage of large quantities of CO_2 is associated with substantial difficulties, and is therefore considered unlikely to be realized. This is due to export dependency to a few, very large aquifers in densely populated areas, such as the Paris basin, where both storage capacity and annual injection capacity is highly uncertain, but also on the acceptance among the public and need of pressure reduction due to water production.**
- **The quantity of CO_2 that needs to be stored according to Pathways' Market scenario (for the period up to 2050) is too large to be contained in those offshore sinks that have been identified in the joint research project of CTH and JRC. This is true given the conditions of this project, i.e. use of the conservative theoretical storage capacity value that was estimated in the GeoCapacity project, and a minimum of 45 years injection time in the aquifers.**
- **The same identified sinks are however able to contain the quantity of CO_2 that needs to be stored according to Pathways' Policy scenario.**

The on-going collaboration with the EU Commissions Joint Research Centre (JRC) on large-scale CCS links annual CO_2-flow by country provided by Chalmers ELIN model to a model developed by JRC optimizing a bulk CO_2-pipeline network. The bulk system provided by JRC is thereafter developed into a detailed CCS network with collection and distribution pipelines with use of Chalmers databases on CO_2-sources and sinks. The on-going work develops a CCS system transporting 15.2 Gt CO_2 between 2020 and 2050 as provided by Chalmers Policy scenario. JRC's work indicates significant increases in cost moving from onshore to offshore storage with investments for a bulk system alone more than doubling from € 14 billion to € 29 billion. Chalmers work shows that cost are rising substantially also when the bulk system is developed further into a detailed network of collection and distribution pipelines with total investments for the German system alone reaching € 9.3 billion in the case of onshore storage. Still, specific cost is modest, e.g. calculated to € 5.1/ton CO_2 in Germany. The introduction of a minimum injection period of 45 years in aquifers forces large volumes of CO_2 to be exported to France and Poland indicating that large-scale CCS in Europe will only be possible if substantial part of the CO_2 is stored offshore.

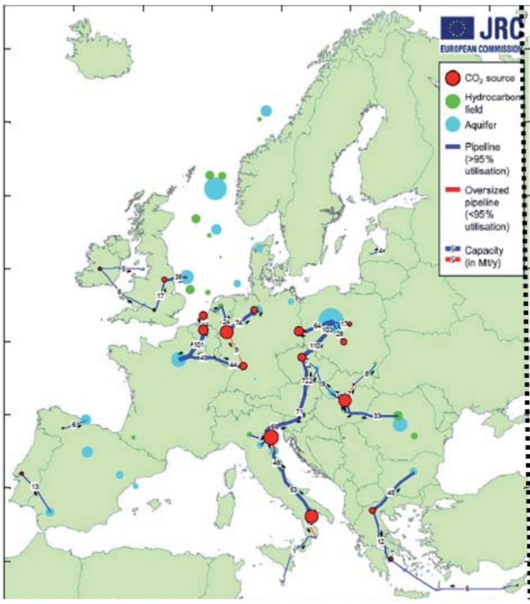

Figure 1a : Storage allowed in onshore aquifers. Total investments € 14.0 bl, total network length 10,430 km.

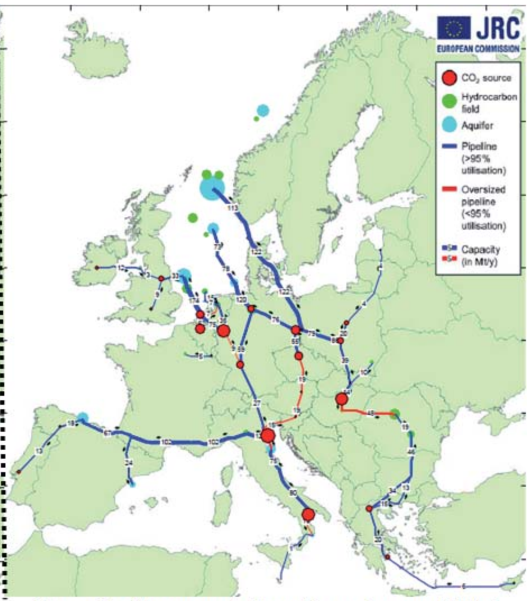

Figure 1b : Storage <u>not</u> allowed in onshore aqf. Total investments € 29.1 bl, total network length 15,200 km.

Offshore storage will add significantly to cost

Figure 1 shows JRC's bulk pipeline system in 2050 based on the Policy scenario with Figures 1a and 1b illustrating a case where storage in onshore aquifers is and is not allowed respectively. Onshore storage is allowed in oil and gas fields in both cases since these have proved to be closed reservoirs. The system is based on clustering of sources and sinks (red circles denote cluster of sources, blue denote cluster of aquifers while green denotes cluster of oil/gas fields) with JRC applying the conservative storage capacity given by the GeoCapacity project. In total some 15.2 Gt CO_2 is transported to storage sites between 2020 and 2050 as envisaged by the Policy scenario.

Designing a detailed network requires accurate geographical information

Ongoing work applies the information provided by Figure 1 along with Chalmers databases on power plants and CO_2 storage sites to develop a detailed collection and distribution system. The geographical distribution of CCS plants is done by applying the information provided by ELIN's Policy scenario to replace existing plants according to age. Part 3 has restarted its work several times since initial very sparse information about storage sites in Germany, Italy and Poland have been replaced by more detailed data. Figure 2a shows how Chalmers initially envisioned distribution of aquifers in Germany based on communications with Vattenfall and the German Bundesamt für Geowissenschaften und Rohstoffe (BGR) while Figure 2b shows the actual distribution as provided by Greenpeace based on work performed by BGR. The black dots and lines in Figure 2a shows CCS plants and distribution pipelines respectively while red circles show large gas fields and light yellow circles denote aquifers. Each aquifer was assumed to have a storage capacity of 100 Mt CO_2 with a combined storage capacity corresponding to the conservative estimate provided by GeoCapacity (6.3 Gt). In Figure 2b, aquifers are shown as green circles with size depending on storage capacity and where the largest aquifers are able to store around 300 Mt if a conservative approach is being applied, i.e. 6.3 Gt aggregated for all German aquifers.

The collection and distribution network will add significantly to cost

The different distribution of storage sites and, more importantly, storage capacity, as shown in Figures 2a and 2b has however a relatively limited effect on the system and its costs. While total pipeline length reached 5,116 km in the system in Figure 2a, corresponding length in the system in Figure 2b reached 5,046 km. Investments were reduced by € 1 billion in the system to the right, from € 10.3 to € 9.3 billion while specific cost went down from € 5.98/ton to 5.11/ton. However, the detailed German system will alone require investments corresponding to two thirds of the entire European bulk system as provided by JRC (see Figure 1a).

Large-scale CCS in EU likely to require offshore storage

A second factor that strongly affected the work in part 3 was the proposal by JRC to apply an upper limit on annual injection capacity in an aquifer. This is a highly reservoir specific parameter which is usually not known. However, after contacts with leading geologists (among others Erik Lindeberg, Sintef, Norway and Franz May, BGR, Germany) it was decided to apply a minimum injection period of 45 years. This led to that large amounts of CO_2 had to be exported from, among others, Belgium, Germany and Italy, to large aquifers in the Paris basin and in Poland. This is highly questionable for several reasons; a) the large opposition to onshore storage experienced in other parts of Europe, b) the risk of domestic opposition in France and Poland against storage of large amounts of foreign CO_2 and c) applied storage capacity and annual injection capacity in French aquifers corresponds to the conservative theoretical value given by the GeoCapacity project which is subject to significant uncertainties. Therefore, if France and Poland for some reason cannot (or will not) store large amounts of foreign CO_2, the risk is that offshore storage is the only remaining option for large-scale CCS in EU.

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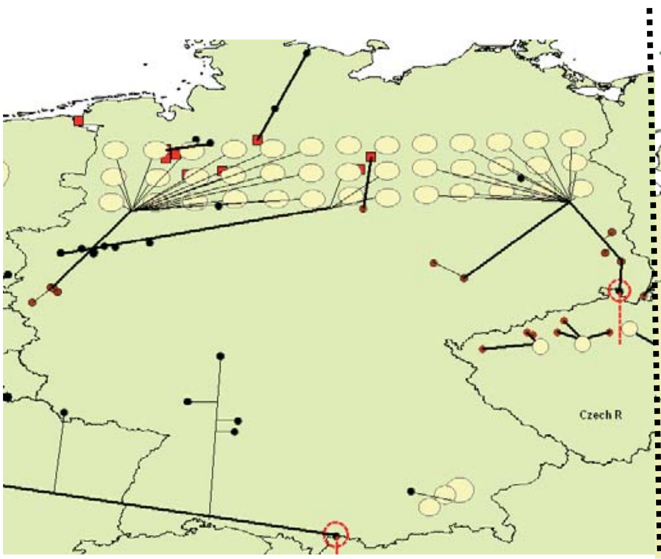

Figure 2a

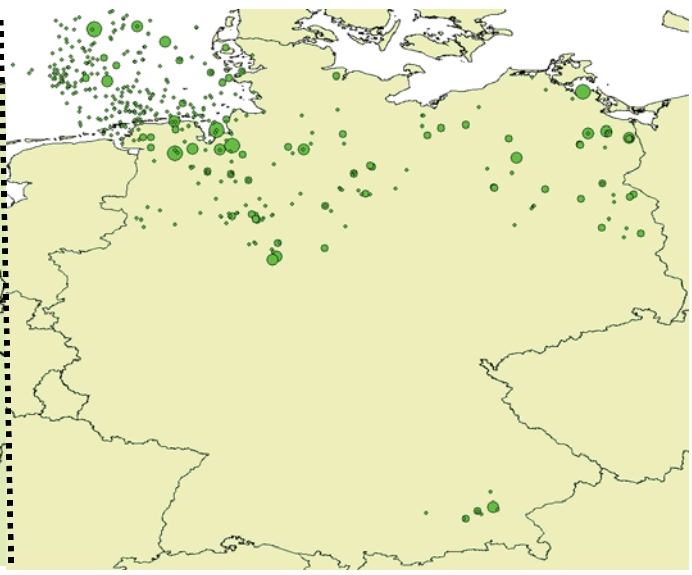

Figure 2b