SIMULATED CO_2 PIPELINE NETWORKS FOR CCS IN FRANCE

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Carbon capture and storage (CCS) may be a key option against climate change, but it will cost billions of euros just to build the pipeline infrastructure required to transport the CO_2 from sources to reservoirs. As a wave of large-scale demonstration projects is being prepared in OECD countries, early planning of how the CO_2 pipeline network may be designed in the long term will help to control the total social costs. This study applies *SimCCS*, a CO_2 system model by Middleton and Bielicki (2009), to a developed country with little extant CO_2 pipeline infrastructure: France. We ask two questions. First, considering a range of plausible scenarios for the future of the technology in the country, do we find any pipeline corridors common to all solutions? Second, how does a network designed for 10 Mt per year compare with a network for 60 Mt per year?

SimCCS was used as follows. A cost surface, i.e. a raster grid of the cost to lay a pipeline across each grid cell, was estimated using geographical datasets including protected areas, existing gas pipelines, rivers, railroads, highways, land cover, and population densities. Given the location of sources and reservoirs as network nodes, the model generated a set of potential routes between all possible close node pairs. Based on these potential routes, given the costs of capture, building and operating pipeline, storing and exporting CO_2, the model minimized the total cost to meet a given target quantity of CO_2 stored.

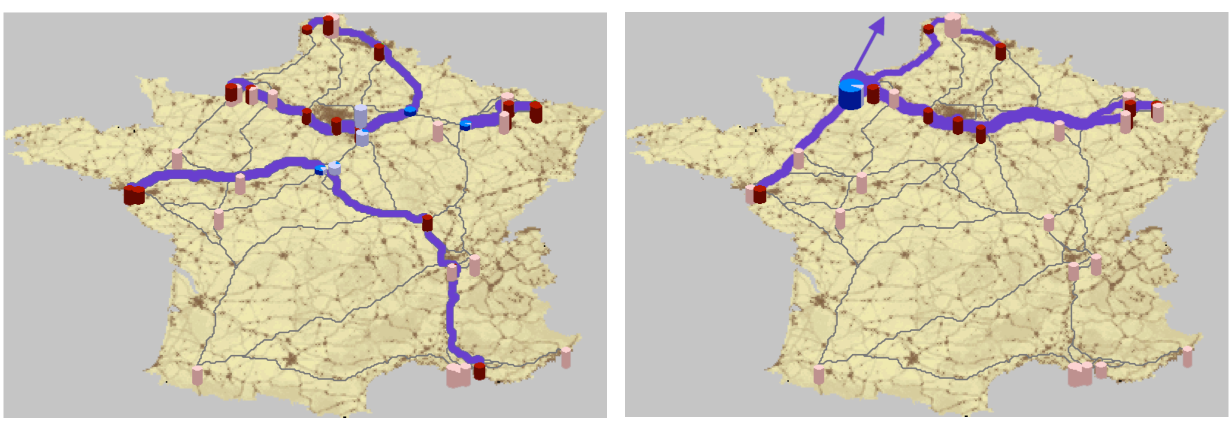

Figure 1: Optimal CCS network for 30 $MtCO_2$/yr in France according to two storage scenarios. Left, an “Onshore scenario” where storage is only permitted in the Parisian sedimentary basin. Right is a “North sea scenario” where only exports through Le Havre (arrow) are permitted. Captured sources are in red, non-captured sources in pink, sinks in blue, unused sinks in light blue. The network is in purple.

Storage goals from 10 Mt to 60 Mt were examined. We modeled the forty largest CO_2 sources in France, for a total of 80 MtCO_2 per year. Four CO_2 storage scenarios were considered. In an “Onshore scenario” storage is permitted only in the Paris basin aquifers, while in a “North sea scenario” only exports towards the North sea through Normandy are allowed. The other two scenarios open up an hypothetical storage option reachable off the Mediterranean shore. Thus a “Mix scenario” allows domestic onshore and the Mediterranean option, and an “Offshore scenario” allows export to the North and Mediterranean seas.

Figure 1 compares “Onshore” and “North sea” scenarios for a common 30 MtCO_2/yr target, while Figure 2 compares the “Onshore” scenario for targets 10 MtCO_2/yr and 60 MtCO_2/yr. At 30 MtCO_2/yr and considering the 15 \$/tCO_2 export cost in the model, the Mediterranean option was not used, so results from the scenarios “Onshore” and “Mix” are the same, as are those from “North sea” and “Offshore”.

We found three segments of network common across most scenarios: As apparent from Figure 2, left, one is in the East (Lorraine region), another is in the North (Nord–Pas de Calais region). Also, all scenarios with targets over 20 MtCO_2/yr use a corridor along the Seine river between Paris and Le Havre.

The model builds about 2 500 km of pipelines for the 60 MtCO_2/yr target. If this number is to be reached in 30 years, that is about 83 km of pipeline per year to open. We ran simulations with the target quantity increasing from 10 MtCO_2/yr to 60 MtCO_2/yr in steps of 10 MtCO_2/yr. Initially, the network extends in size, reaching for the cheaper sources. Between 30 MtCO_2/yr to 50 MtCO_2/yr, the network extends in capacity, subnetworks merge, CO_2 flows are aggregated into 20–24 inches trunklines. Finally the 60 MtCO_2/yr network, compared to the 50 MtCO_2/yr, is again longer in length due to several ramifications.

Average system cost is about 52 \$/tCO_2 in the Onshore scenario. Capture costs represent 70% to 90% of this. System-wide optimization appears mostly to use the sources in the order of increasing capture cost, and connect those to the available sinks.

In summary this study displays that some pipeline corridors are to be constructed if CCS is deployed in France. Moreover small-scale network designs are compatible with large-scale ones, but not the capacities (i.e. pipeline diameters). Since pipeline network development should be motivated by returns to scale at long-term, it may be relevant to push for the early construction of such oversized corridors, for instance by public–private partnerships.

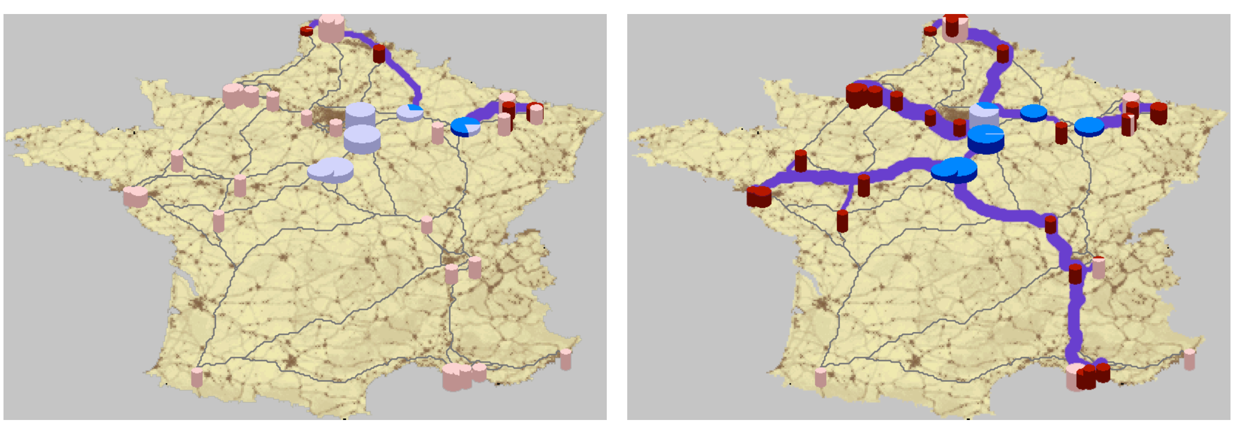

Figure 2: Optimal network topologies comparison between 10 MtCO_2/yr (left) and 60 MtCO_2/yr (right) for the “Onshore scenario”. The relative diameter of the pipelines is shown by the width of the purple line.