SOCECO2. Économie et sociologie de la filière capture et stockage géologique du CO2

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Simulated CO_2 pipeline networks for CCS in France

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Abstract

Introduction

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 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.

We apply *SimCCS*, a CO_2 system model developed by Middleton and Bielicki (2009), to a developed country with little extant CO_2 pipeline infrastructure: France. We ask two main questions:

1. Considering a couple of plausible scenarios for the future of the technology in the country, do we find any pipeline corridors common to all solutions?
2. How does a network designed for 10 Mt per year compare with a network for higher storage goals?

Scenarios studied

Storage goals from 10 Mt to 60 Mt were examined. We modelled the forty largest CO_2 sources in France, for a total of 80 $MtCO_2$ per year. Two storage scenarios are considered:

- An *onshore scenario, where* storage is permitted only in the Paris basin aquifers;
- An *offshore scenario* exports CO_2 towards the North sea through Normandy and toward an hypothetical storage option reachable off the Mediterranean shore.

Evolution of common network corridors in the simulations

Figure 1 compares the two scenarios for a common 30 $MtCO_2$/yr target, while **Figure 2** compares several targets (10, 40, 50 and 60 $MtCO_2$/yr) for the "onshore scenario". Three segments of network are always apparent: one is in the East (Lorraine region), another is in the North (Nord–Pas de Calais region). Also, scenarios with targets over 20 $MtCO_2$/yr use a corridor along the Seine river between Paris and Le Havre.

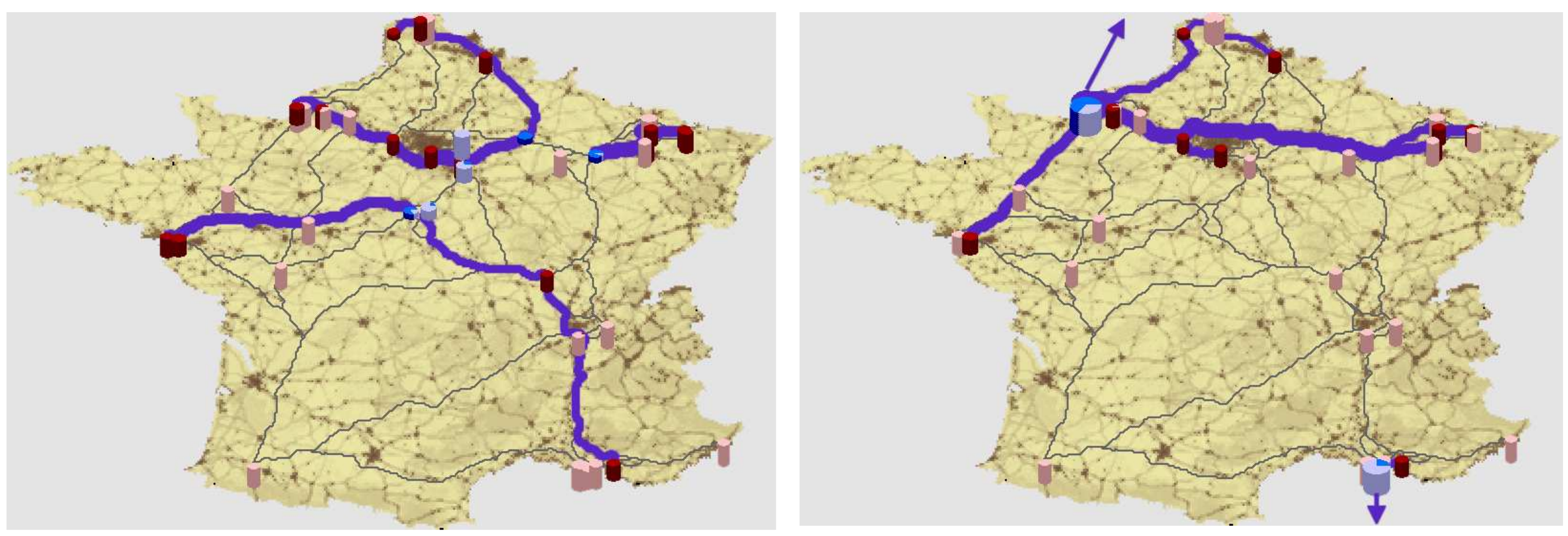
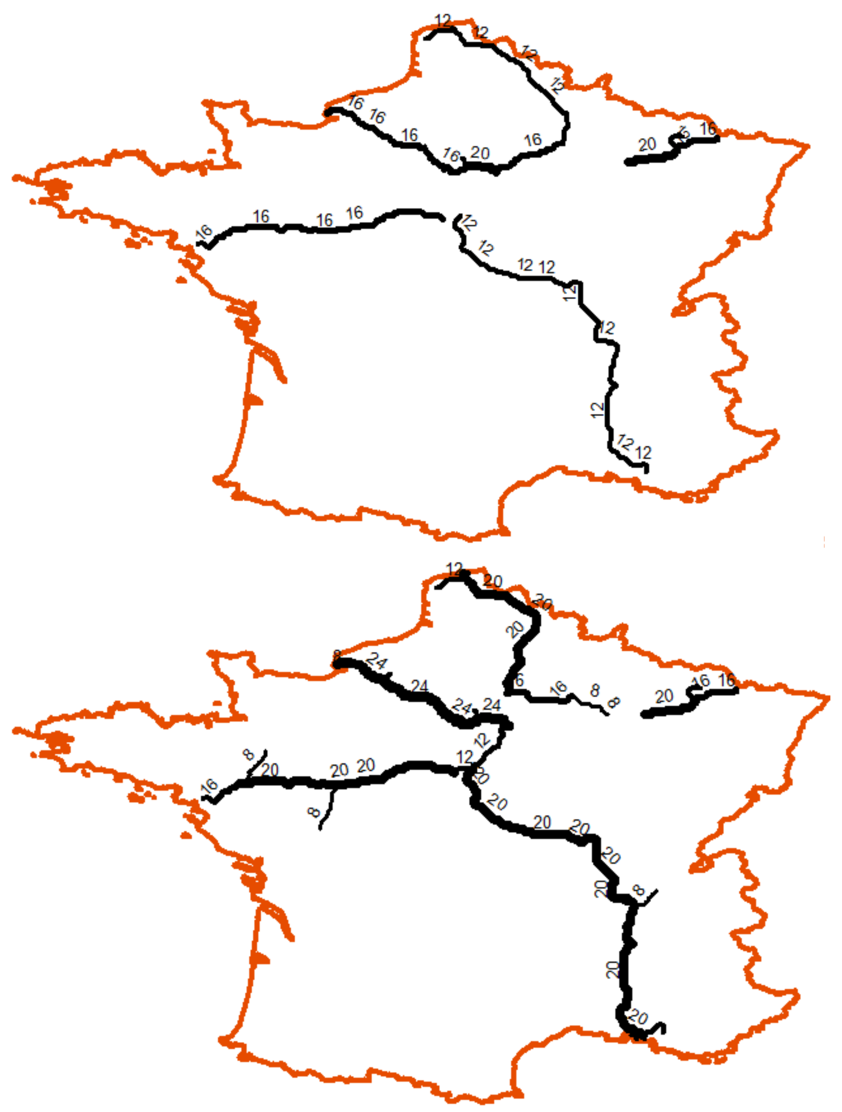


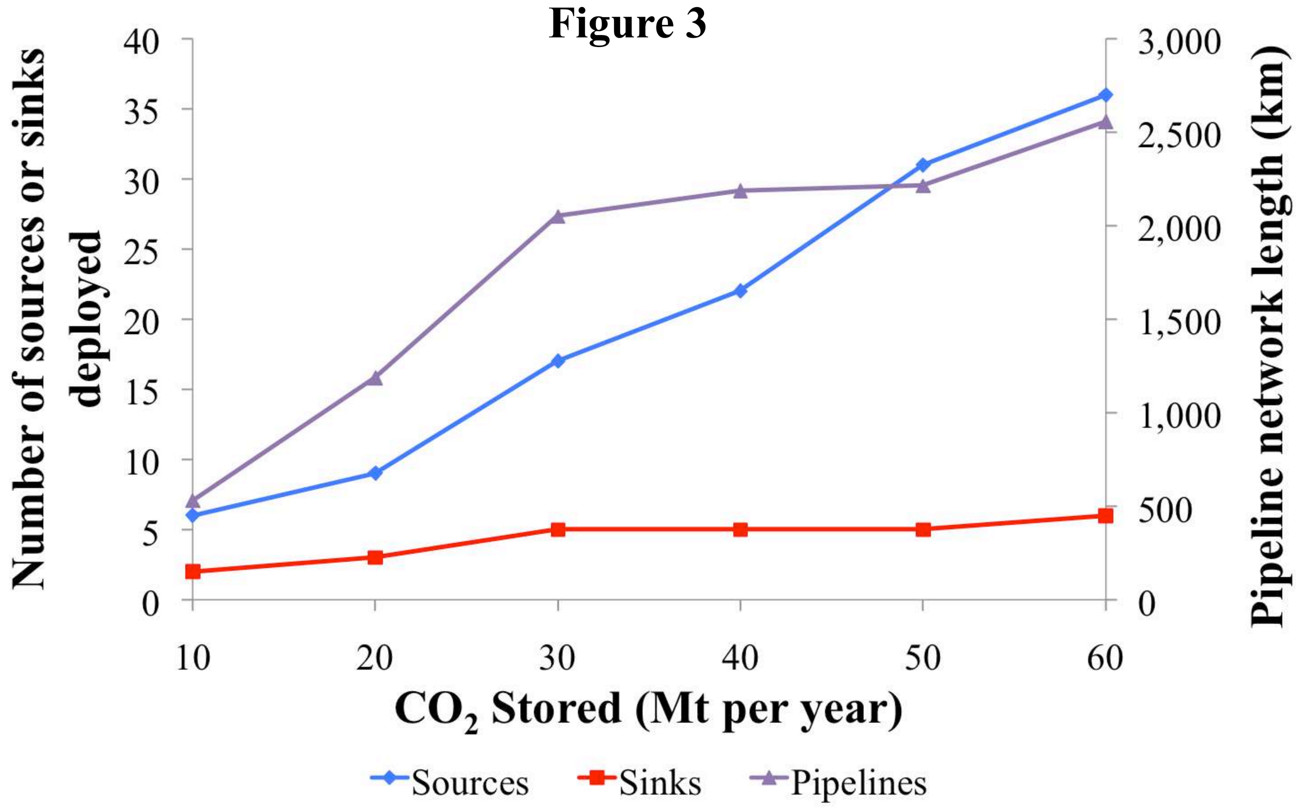
Figure 1. Optimal CCS network for 30 $MtCO_2$/yr in France for the "onshore scenario" (left) and the "offshore scenario" (right). Captured sources are in red, non-captured sources in pink, sinks in blue, unused sinks in light blue. The network is in purple. Arrows symbolise pipelines linking a hub to the offshore reservoir.

Figure 2. CCS pipeline for the "onshore scenario" for two different CO_2 targets: 30 $MtCO_2$/yr (up) and 60 $MtCO_2$/yr (down). The figures correspond to pipeline diameters (in inches).



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 (**Figure 2** and **3**). 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.

Figure 3



SimCCS model

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 (**Figure 4**). 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.

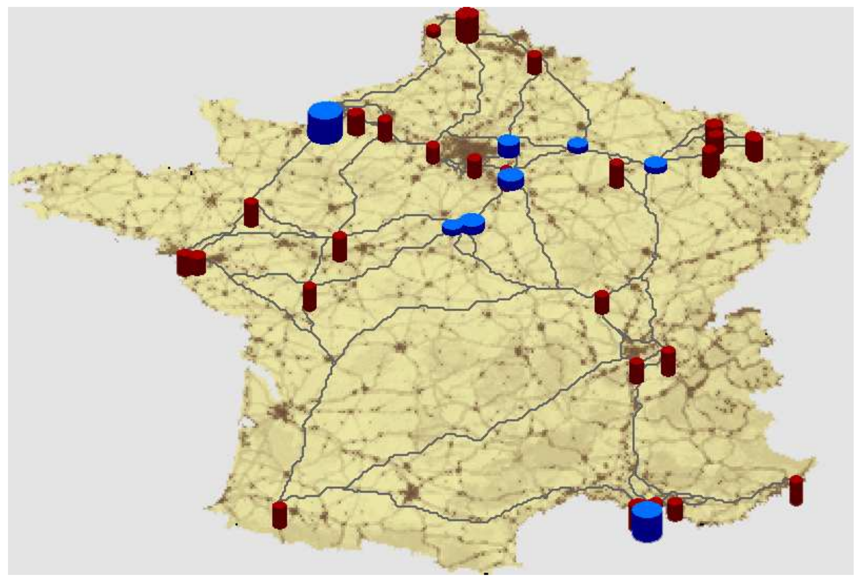


Figure 4. Potential pipeline routes (grey) between CO_2 emitters (red) and CO_2 sinks (blue).

Conclusions

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

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.

Literature cited

Middleton, R.S., and J.M. Bielicki (2009). A scalable infrastructure model for carbon capture and storage: SimCCS. *Energy Policy 37*(3), 1052-1060.