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Energy Procedia 37 (2013) 3212 – 3220

Energy Procedia

GHGT-11

Planning CCS Development in the west Mediterranean

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Abstract

Transport and storage of CO_2 are the elements in the CCS chain with the lowest cost, but they may well prove to be the elements defining the timeline for CCS development. The EU FP7 COMET project aimed to pave the road towards CCS development in the West Mediterranean (Portugal, Spain and Morocco). This paper provides the main highlights of the work conducted within COMET. The project addressed the temporal and spatial aspects of the development of the energy sector and other industrial activities in relation with CCS and its participation to CO_2 emission reduction taking into account location, capacity and availability of CO_2 sources and of potential CO_2 storage formations. Special attention was given to a balanced optimization on transport modes, matching the sources and sinks, meeting optimal cost - benefit trade-offs, for a CCS network infrastructure as part of an international cooperation policy.

Keywords: CO_2 Transport; Portugal; Spain; Morocco

1. Introduction

Carbon dioxide Capture and Storage (CCS) is a vital component of a portfolio of low-carbon technologies, as it is able to reduce carbon dioxide (CO_2) emissions substantially from both the energy

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doi:10.1016/j.egypro.2013.06.208

sector and other industries [1]. The significant role foreseen for CCS is, however, based on four main conditions [2]:

1. CO_2 capture technology will be available;
2. The option will be economically competitive;
3. Sufficient and suitable underground storage capacity will be available and,
4. CO_2 transport infrastructure is available or construction of such an infrastructure can be built within the near future.

Until recently, most research focused, on reaching the first three conditions on time. The need to have a suitable transport infrastructure, its implications over time and its related costs are, more recently, attracting attention and getting priority in the international R&D agenda [3]. The challenge is to develop long-term strategies for CO_2 source clusters and CO_2 pipeline networks that optimize source-to-sink transmission. To address this challenge, governments need to initiate regional planning exercises and develop incentives for the creation of CO_2 transport hubs across all regions [4, 5]. Unlike research on CO_2 capture technologies, which is not country dependent, research on CO_2 transport and storage needs to be developed at the local-regional level. Some proponents of CCS go even further, arguing that the development of infrastructure will be a pre-requisite for the widespread deployment of CCS on the scale needed to meet the low carbon objectives [5].

Due to the fact that potential CO_2 storage sites are not evenly distributed and that some countries, considering their significant levels of CO_2 emissions, have only limited potential storage within their national boundaries, the construction of a European pipeline infrastructure spanning across State borders both, onshore and offshore could become necessary [6].

CO_2 distribution networks can comprise one, or a combination of, transport modes including: truck, ship (liquefied or compressed), train and pipeline (new and existing, offshore and onshore). At the core of designing an efficient and effective CO_2 transport network are questions related to how, how much, where and when CO_2 will be captured, and where and when can it be adequately, safely and permanently stored.

The establishment of a CCS network in its simplest form includes the planning, construction and operation of a transport infrastructure linking the supply of an individual CO_2 capture facility with a single storage facility (this is an example of a point-to-point system). However, the system will move beyond point-to-point configurations, several studies [3,4,7,8] have already indicated that configurations involving multiple-sink-source configuration would be needed over time. It is therefore necessary to study the development of trans-nationally planned or integrated infrastructures, designed to accommodate an expected growing supply of CO_2 from multiple point sources, with ever fluctuating volumes over the pipeline's economic life as carbon constraint thresholds change, source emission evolve in time and storage sites are exhausted and other are discovered [4,5].

2. CO_2 transport infrastructure planning and COMET

Several studies have aimed to develop optimizing configurations of transport infrastructures. For instance, a study planning and designing a CO_2 transport infrastructure in the Netherlands, incorporating of both temporal and spatial aspects, was carried out in 2010 [7].

In this study, a toolbox was developed that integrates ArcGIS, a geographical information system with spatial and routing functions, and an energy bottom-up model based on linear optimization (Markal). Application of this toolbox led to blueprints of a CO_2 infrastructure in the Netherlands. Another example is the work done in the CO_2Europipe project which developed a roadmap towards an infrastructure network for the transport and storage of CO_2 in North West Europe, in the period 2020 - 2050. CO_2Europipe concentrated on CO_2 source-sink matching to 2050 using scenarios based on extrapolated projections from the PRIMES economic growth model.

COMET is the first large-scale integrated study of the costs, barriers and challenges to the deployment of a large CO_2 transport and storage infrastructure in the West Mediterranean area. The overall strategy of COMET is depicted in figure 1, but can be summarized in three fundamental tasks:

1. Harmonized inventory and mapping of CO_2 sources and storage capacities in the region
2. Least cost modelling of national and regional energy systems and pipeline routes
3. In-depth assessment of selected transport network

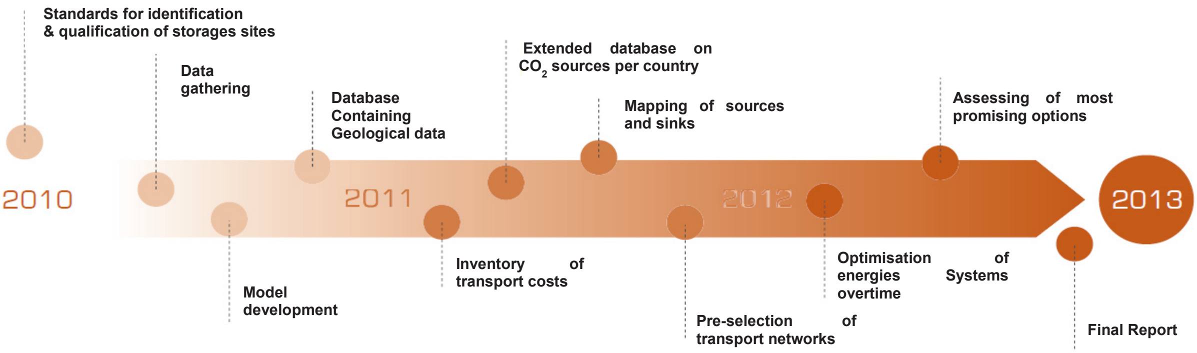

Figure 1 – Timeline of COMET and main deliverables

2.1. Harmonized inventory and mapping of CO_2 sources and storage capacities in the region

2.1.1. CO_2 Sources

The main CO_2 point sources in Portugal, Spain and Morocco were identified and a database was produced containing relevant information, including CO_2 emissions from 2005 to 2010 and geographical location. In 2009, about 378 Million tonnes of CO_2 were emitted in the West Mediterranean area [9,10], of which about 170 Mt were generated by large stationary sources like power plants and industrial sources (cement, refineries, iron and steel, etc). This corresponds to about 13% of the emissions of the European Union in the same year [9]. COMET has identified 288 large point sources the three countries (see Figure 2). A distribution of these sources by sector is shown in Figure 3. Power plants represent more than 50%, of the total number of sources, followed by the cement plants and oil refineries.

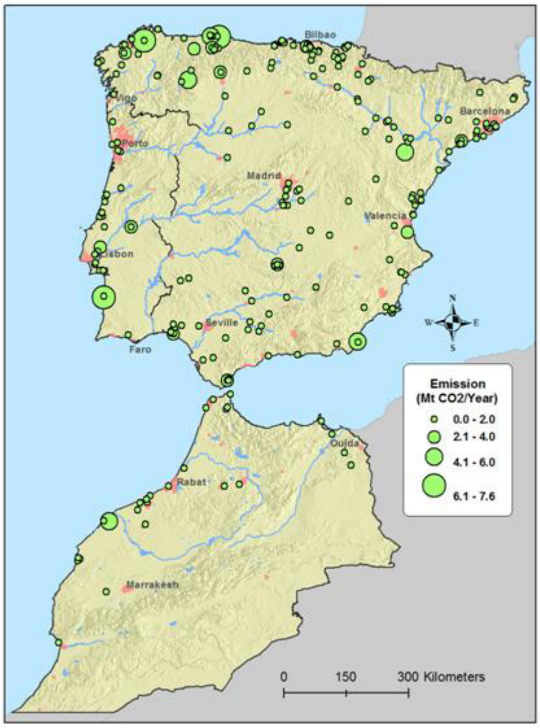

Figure 2 - Location of large CO_2 point sources in the West Mediterranean area

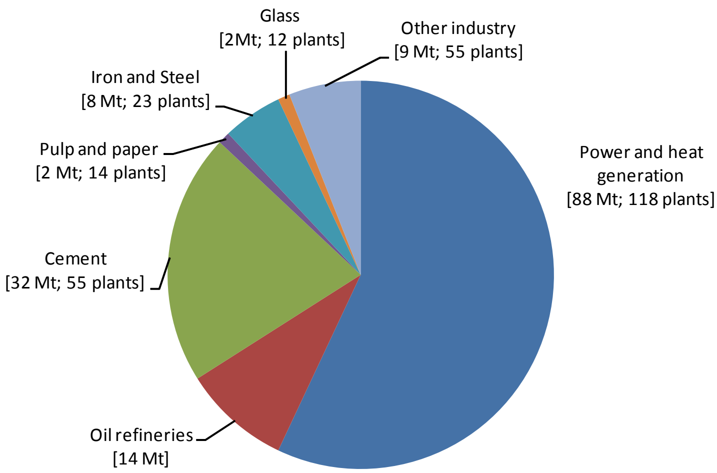

Figure 3. Distribution of emissions by sector in the study area. The numbers in brackets show the amount of CO_2 emissions and the number of plants.

2.1.2. CO_2 Storage reservoirs

In COMET a screening of suitable reservoirs for CO_2 storage was conducted. Potential storage sites were identified and CO_2 storage capacity potential was assessed. For Portugal this has been the first assessment of CO_2 storage capacity, while for Spain the already identified storage capacities have been updated through a more focused study.

For Morocco study covered only the northern territory, because the purpose of the COMET, storage basins should be as close as possible of CO_2 emission sources which are for the most part concentrated between the towns of Agadir in the south and Tangiers to the north. COMET identified 163 locations accounting for a potential storage capacity. Most of this capacity is located in Spain, followed by Portugal and Morocco. Figure 4 depicts the storage capacities estimated by sedimentary basin in the region. Notice, however, that the pacity in Morocco, due to confidentiality reasons.

Figure 4. Location of potential storage areas and their estimated capacities in the West Mediterranean region.

2.1.3. Geographic Information Systems (GIS) integration

The identification of these 288 sources (with expected emissions volumes) and 163 sinks (with expected storage capacities) allowed to define clusters of sources and sinks, and to identify isolated sources. To reach economies of scale, neighboring CO_2 sources and sinks were gathered in source and sink clusters. CO_2 collection and distribution within each cluster is made by so called satellite networks.

The information on both sinks and sources has been integrated in a Geographic Information Systems (GIS). Routing algorithms in GIS were used to find optimal route(s), and associated costs. This was performed taking into account land use, hypsometry, crossing of railways and roadways and existing pipeline corridors. By using GIS tools it has been feasible to jointly analyses all desired spatial constrains influencing the transport cost and to implement spatial algorithms to minimize a given variable, i.e. transport cost.

A schematic overview of the procedure used for the development of optimization algorithms is illustrated in Figure 5.; i) terrain factors, representing the relative cost variation for building a pipeline in a given GIS cell, are attributed to different land uses, terrain slope classes, crossing and pipeline corridors; ii) map algebra with the different terrain factors allows to retrieve a cost surface for the whole study area, i.e., the cost for building a pipeline in each GIS cell; iii) the least cost path is found by minimizing the cost found by integrating all cell costs along every possible route linking sink and source.

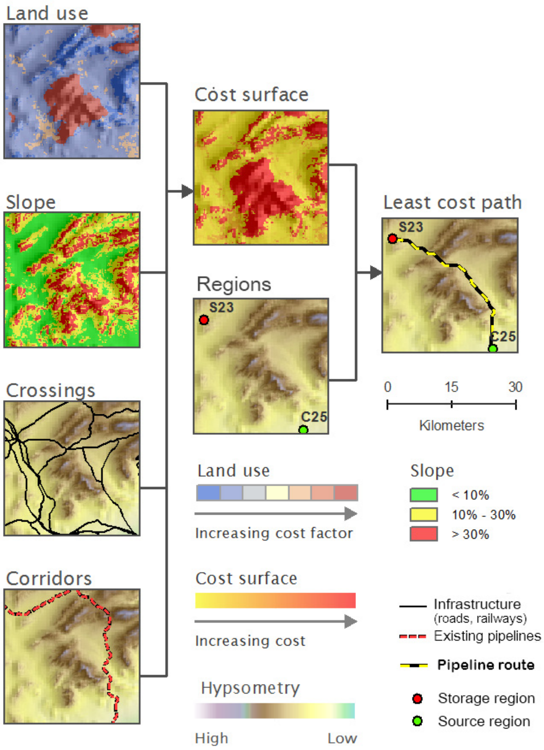

Figure 5 -Procedure for defining least cost routes between clusters of CO_2 sources and sinks

2.2. Least cost modelling of national and regional energy system

Given the lifetime expectation for any power production or industrial unit, investors will not envisage CCS as an alternative unless there is confident level of certainty regarding its deployment in the context of the expected evolution of the energy system, including energy intensive industry. COMET identified transport modes and least-cost networks and defined taking into account the expected evolution of the energy demands and energy markets in the West Mediterranean from today until 2050 under different scenarios and constrains, using the optimization model MARKAL/TIMES.

The MARKAL/TIMES models in COMET represent the energy systems of Morocco, Portugal and Spain and their possible long term developments (2005-2050). Based on the TIMES techno-economic paradigm developed by the Energy Technology System Analysis Program (ETSAP, International Energy Agency), the model includes all the steps, from primary resources in place to the energy services demanded by energy consumers, through a detailed representation of economic, engineering and emission aspects of the chain of processes which transform, transport, distribute and convert energy from supply sectors into final services (residential, commercial, industry, transportation).

Running each model means finding the optimal energy-technology pathway to satisfy the demands for final services, taking into consideration the available energy resources and any constraints imposed to the energy system, such as emission limits. Optimization is based on the maximization of the total surplus of the energy system, which, in the simplest case, is equivalent to minimize the total system costs over the entire time horizon. Thus, the model indicates the optimal mix of technologies (capacity and activity) and fuels at each period, the associated emissions, the mining and trading activities, the quantity and prices of all commodities, the equilibrium level of the demands for energy services. This is done in time series from the base year to the time horizon of the model for a given scenario.

TIMES COMET show the most cost effective source-sink combinations between the three countries, taking into account the possible future development of the whole energy sector in Morocco and in the Iberian Peninsula. Moreover, they were coupled with a geographical representation of capture and storage in order to allow a detailed representation of CO_2 routes from capture to storage (Figure 6).

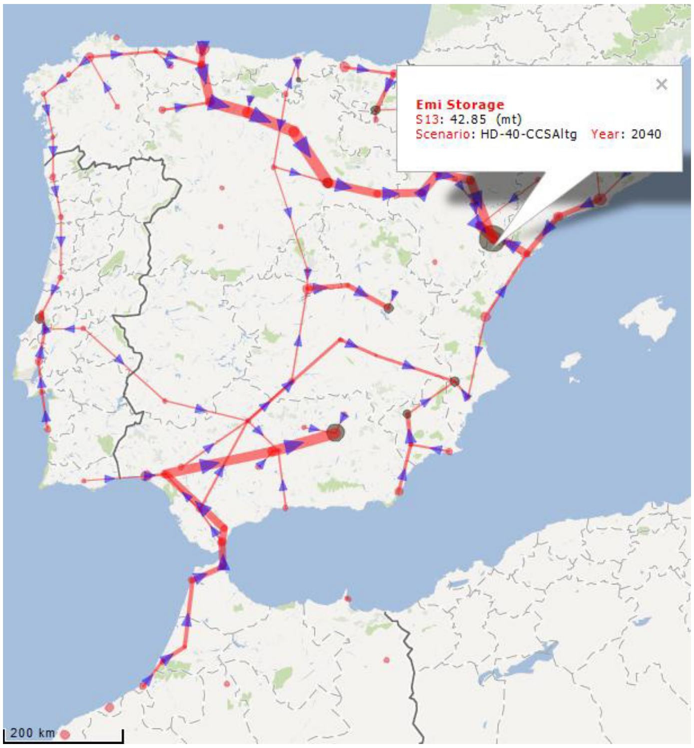

Figure 6 - CO_2 fluxes in Morocco, Portugal and Spain in 2040, assuming a high development of the demand for energy services, 40% emission reduction in 2050 and the need to follow the existing natural gas pipeline network.

2.3. In-depth assessment of selected transport networks

In order to assess the viability of the modeling results, national workshops were organized, in Morocco, Portugal, and Spain with the main objective to get detailed feedback from national stakeholders. Based on the preliminary results of the TIMES-COMET model, the stakeholders advised on the data gathered, scenarios, energy system modeling results, and CO2 transport networks. All comments from the stakeholders were evaluated on whether they could be implemented in the GIS least cost-routing or the TIMES-COMET energy model activities. The necessary adaptations were made, and new least cost trajectories were calculated and TIMES-COMET selected specific CO2 trajectories (where, when, how much CO2 transported).

Multiple scenarios were studied among others distinguished by level of CO_2 emission reduction, and the option to cross boundaries or not. The resulting development of CO_2 infrastructure could then be further analysed and visualised in maps. Figure 7 presents one example of the results obtained for one of the scenarios studied at COMET.

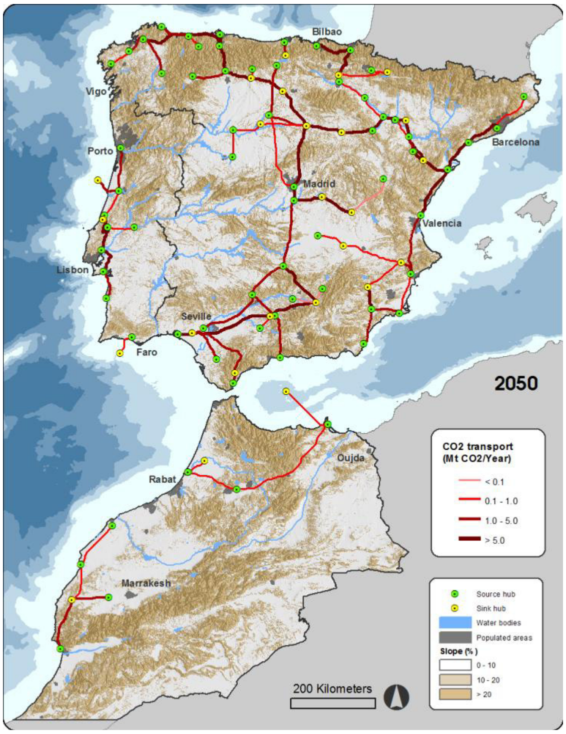

Figure 7 – Possible CO_2 transport infrastructure

3. Conclusions

COMET has provided a systematic and harmonized assessment of the potential to deploy CCS in the West Mediterranean area. This included a first identification of potential storage sites and the estimation of available capacities in Portugal and Morocco where clear gaps in knowledge were present since no work in this area had been conducted so far. Joint large scale transnational infrastructures can then be planned, benefiting from the scale of the investments in order to achieve better financial performances. COMET compared the advantages of building such transnational infrastructures against more nationwide focused alternatives.

The results of the project, provides a framework for similar studies across Mediterranean area and other parts of the world.

Acknowledgements

The success and results of COMET project relied on the partners of the project and we would like to thank all of those institutions not represented in the list of authors of this paper for their work and efforts in the project. The complete consortium consists of the Laboratório Nacional de Energia e Geologia (LNEG) Portugal; Geophysical Centre of Évora (CGE) Portugal; Utrecht University (UU) the Netherlands; Instituto Geológico y Minero de España; Bureau de Recherches Geologiques et Minieres (BRGM) France; University Mohamed V Agdal - Institut Scientifique de Rabat (UM5A-ISR) Morocco; Office National des Hydrocarbures et des Mines ONHYM Morocco; University Mohammed Premier (UMP) Morocco; Applied Systems Analyses, Technology and Research, Energy Models (ASATREM) Italy; Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Spain; Fundação da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa FFCT Portugal; Forschungszentrum Juelich GmbH JUELICH Germany; EDP Portugal; Endesa Spain; Galp Energia Portugal; Office National d'Electricité (ONE) Morocco, and Tejo Energia Portugal.

COMET is co-funded by the EU 7th Framework Programme, contract no. 241400.

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