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Carbon capture and storage: Lessons from a storage potential and localization analysis

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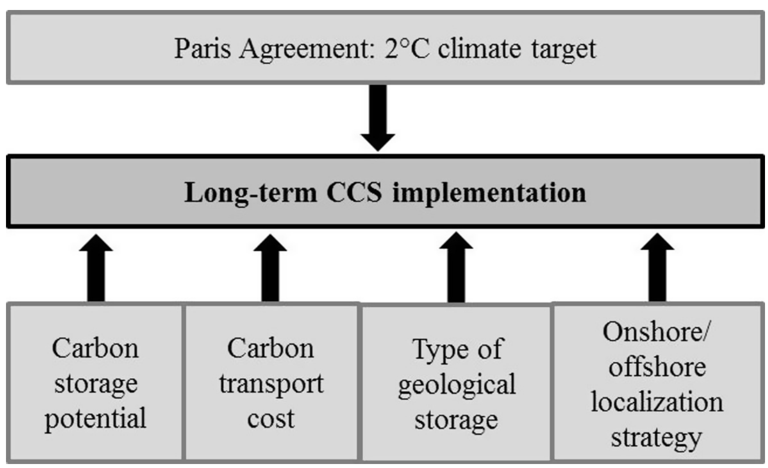
HIGHLIGHTS

- CCS significantly contributes to reaching the 2 °C climate target.
- CCS remains determinant except with the lowest potential of carbon storage.
- The impact of a higher carbon transport cost on the share of CCS is limited.
- The choice of storage site changes in line with the level of carbon transport cost.
- A limitation on onshore storage has a strong impact on the penetration of CCS.

GRAPHICAL ABSTRACT



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ABSTRACT

The challenges of climate change involve totally rethinking the world's energy system. In particular, CCS technologies are still presented as a solution to reach ambitious climate targets. However, avoiding the required Gt of CO_2 emissions by investing in CCS technologies supposes the development of carbon storage capacities. This analysis, conducted with TIAM-FR and based on a wide review of geological storage potential and various data, aims to discuss the impact of this potential on the development of the CCS option. We also specify a scenario allowing the exclusion of onshore storage due to a hypothetic policy considering public resistance to onshore storage, and carbon transport costs variation effects. The implementation of CCS is less impacted by the level of carbon storage potential - except in the lowest case of availability - than by the type of sequestration site. However, the development of CCS is lower at the end of the period in the case of a decrease in carbon storage potential. Indeed, the question of type of storage site appears to have a greater impact, with an arbitrage between deep saline aquifers and depleted basins and enhanced recovery. Doubling the cost of carbon transport does not limit the penetration of carbon capture technologies, but it does impact the choice of site. Finally, a limitation of onshore storage could have a significant impact on the penetration of the CCS option. The explanation for this limited deployment of CCS is thus the higher cost of offshore storage more than the level of storage potential.

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1. Introduction: The place of CCS technologies in the future climate regime

After decades of negotiations and regional divisions and prompted by a large-scale awareness, an historic climate agreement was adopted by consensus by all 195 parties at the UNFCCC, on December 12, 2015, in an attempt to solve the climate issue. Thus, the 21st Conference of Parties (COP 21) marked a decisive stage in the transition to a decarbonized world, with countries calling for a more ambitious long-term goal. In new words for a new world, they recognized the 1.5 °C goal (without formalization) as the main long-term objective of the Agreement, *"(h)olding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C*" (Article 2.1(a))". Furthermore, they recognized the need for net-zero emissions, involving phasing out fossil fuel use in the long-term, *"(...) to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*" (Article 4.1)". This historic agreement marked a major milestone in climate policy and in the transition initiated by the Nationally Determined Contributions (NDCs). Indeed, all countries signed the agreement, and almost all countries previously submitted their NDCs to UNFCCC, representing more than 98% of global GHG emissions. Notably, the ten largest CO_2 emitters, representing nearly 76% of global emissions, submitted a contribution: by order of issue, China, USA, Europe (a single contribution for the 28 Member States), India, Russia, Japan, South Korea, Canada, Indonesia and Saudi Arabia.

Considering these NDCs, and despite unprecedented international mobilization, the world still appears to be heading to an increase of between 2.7 and 3 degrees Celsius [1] or, according to Climate Action Tracker, between 2.4 and 2.7 °C considering a full implementation of the NDCs [2]. Yet at the same time, the Paris Agreement can be qualified as a historic event and the world's greatest diplomatic success, given that countries' initial pledges appear sufficient to clearly limit the increase of global temperature, along with the institutionalization of a new paradigm, as highlighted in Bodansky [3]. Thus, to place us on a compatible trajectory with the 2 °C or 1.5 °C boundary, the Paris Agreement requires that each country review these NDCs every five years from 2020, without lowering its targets and while encouraging the other states to do better. In addition, countries should aim to peak their GHG emissions as soon as possible, and achieve neutral emissions during the second half of the century.

In this context, challenges for climate change involve totally rethinking the world's energy system, especially the technological mix that will satisfy energy demands in line with climate issues and policy. Not only must countries act, but technological progress must also find an adequate response to countries' ambitions to expand the pool of available (or not) technologies and their mitigation potential. Among these decarbonized options, Carbon Capture and Storage (CCS) has persistently been put forward as a potential, even expected and necessary, solution to achieve CO_2 emissions mitigation objectives [4,5]. Indeed, CCS technologies are still presented as a solution to reach ambitious climate targets despite persistent controversies, in terms of (i) the significant and uncertain expenditure that this technology requires, (ii) insufficient investment and progress as regards its plausible large-scale deployment along with infrastructures (e.g. transport, shared platform), (iii) incentive support in comparison with other options, such as renewables, and (iv) the risks of storage to the environment and human health, which raises questions of social acceptability and the appropriate place of CCS within the portfolio of GHG abatement strategies.

More precisely, an increasing body of literature assesses the attainability of stringent GHG mitigation targets, depending on a wide range of different reduction options, and the technological 'readiness' of advanced technologies, in particular the industrial scale of CCS and the combination of bio-energy carbon capture and geologic storage (BECCS) [6]. Introducing CCS to abate emissions increasingly appears incontrovertible to reduce future CO_2 emissions in line with the limit of a 2 °C temperature increase. This is all the more the case if we consider that fossil fuels will remain the dominant sources of energy over the next decades. Furthermore, among the technological options to mitigate GHG emissions, BECCS is gaining increasing attention, as this alternative offers a unique opportunity for net carbon removal from the atmosphere while fulfilling energy needs [7]. When stringent targets are applied, negative emissions become a valuable option [5], Azar et al. [8]; [9–14]. Moreover, from 4DS to 2DS[1] climate scenarios of IEA [15], CCS contributes to 15% of CO_2 emissions reduction. Comparing 2DS and 6DS, CCS contributes 12%. In TIAM-FR (according to results presented below), the same strong climate constraint, i.e. 2.6 W/m^2 without overshoot, 19% of power generation come from plants with CCS (based on fossil or biomass resources) in 2050. Renewables then represent 50% of power generation, with nuclear and hydro representing 16% and 11% respectively.

However, the feasibility of avoiding the required Gt of CO_2 emissions by investing in CCS technologies remains questionable. Could the potential use of these technologies be enough to satisfy this need? This question of plausibility also concerns renewables. In the total primary energy supply, the shares of renewables, biomass, and alcohols can appear high. Their size might increase significantly with a more stringent target, but this depends on the cost and efficiency of renewable technologies, and their comparability with fossil fuels. Their future technological development is still an uncertain variable that should be taken into account. For example, significant integration of renewables could not be possible without investment in storage technologies. Considering the McKinsey abatement curve, a large portfolio of technologies is available, some of which are economically advantageous. "*But some others are yet complicated and expensive*" [16,17]. CCS is still quite expansive, but according to IEA, Alberta's Quest project, a new Canadian CO_2 storage project initially developed in order to cut emissions from oil sands, provides further proof of the value of CCS in reducing GHG emissions. However, the question is whether private companies are willing to invest in CCS projects. In a study of Norwegian oil companies, Emhjellen and Osmundsen [18] show that CCS projects are unlikely to be implemented by private companies due to their low ranking and negative net present value. CCS oil projects became profitable with the introduction of a significant subsidy (68% of investments). Indeed, CCS appears to be one of the options with a high potential to reduce CO_2 emissions. However, building CCS at this scale for climate change mitigation requires developing incentive policies and creating a regulatory framework to support business models that enable wide-scale adoption [4]. This implies that governments must play a decisive role in CCS technologies. The International Energy Agency, in its latest Energy Technology Perspectives report, specifies that moderate progress in CCS was made in 2015 and that significant investments in projects and technology development by industry and governments are needed to get CCS on track to meet the expected target of annual CO_2 storage [15]. "*Investment in storage resource development will de-risk projects and shorten the development time. Storage characterisation and assessment are often the longest aspect of project development and outside the skill base of CO_2 capture project developers*" [15]. Indeed, the potential for CCS deployment is also closely connected to the potential for carbon storage [19]. The question of site location, in terms of offshore or onshore

[1] 2DS for a 2-degree scenario and 6DS for a 6-degree scenario.