EVALUATING THE USE OF BIOENERGY WITH CARBON CAPTURE AND STORAGE TO ACHIEVE ENERGY TRANSITION AND DECARBONIZATION

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Overview

Energy and climate are both at the heart of societal challenges. To ensure that we remain on a compatible trajectory with the 2°C or 1.5°C boundary, the Paris Agreement requires that GHG emissions need to peak as soon as possible, so that countries must aim to achieve neutral emission in the second half of this century. The challenges of climate change involve rethinking the world's energy system and notably, the success of a large-scale energy transition could involve more responsible exploitation of fossil resources One option still presented as a solution to reach ambitious decarbonization targets is carbon capture and storage (CCS) technologies, particularly when associated with bioenergy resources due to the negative emission the latter allow. A growing body of literature assesses the achievement of high CO_2 emission reduction targets through the deployment of CCS on an industrial scale and the combination of these technologies with the increasing use of biomass. Indeed, faced with the threat of climate change and tensions over resources (energy or water), greater use of bioenergy is considered a possible track. BECCS is increasingly invoked in integrated assessment models (IAMs) as an option that delivers negative emissions, particularly if mitigation is delayed further (Jackson *et al.*, 2017). In the latest IPCC Assessment Report (AR5), 101 of the 116 scenarios with a limited atmospheric concentration at 430-480 ppm rely on BECCS and about 67% of these have a BECCS share in primary energy exceeding 20% in 2100 (Fuss *et al*., 2014). However, avoiding the required Gt of CO_2 emissions by investing in CCS technologies requires developing carbon storage capacities and, when associated with bioenergy, a plausible and sustainable potential for biomass resources. little is known about the global potential of emerging and future negative emissions technologies, nor about the sustainability and cost of large-scale deployment needed to meet "safe" climate stabilization targets. Furthermore, avoiding the gigatonnes of CO_2 emissions expected from investing in CCS technologies will require developing significant carbon storage capacities. The results of the study published by Viebahn *et al.* (2015) strengthen the interest of this question by showing that "*the most crucial pre-condition that must be met is a reliable storage capacity assessment based on site-specific geological data*". In the same manner, the large deployment of BECCS is based on a significant use of biomass resources whose potential level is critical for the sector's plausible development strategies. In this context, The aim of this analysis is to discuss the influence of carbon storage and biomass resource potentials on the possible development of BECCS technologies.

Methods

This analysis is conducted with the optimization model TIAM-FR (*TIMES Integrated Assessment Model*, a bottom-up, long-term, multiregional model). As regards the mathematical resolution of the problem, the model minimizes the total discounted cost of the world energy system. It optimizes over the defined time horizon the discounted cost of the energy system under the constraint of demand satisfaction. Written in GAMS language, it responds to a problem of minimization linear programming under constraints of the total discounted cost of the energy system. Thus, the entire technologicaly detailed energy system is represented, with the objective of satisfying energy service demands at the lower cost, under technological and/or environmental constraints posed by the user. One of the interests of this model is its very long time horizon, until 2100, making it well placed to consider global environmental problems such as global warming, which is at the heart of international debates. Emission reduction is achieved through technology and fuel substitutions. Notably, TIAM-FR integrates several carbon capture and sequestration technologies derived from fossil and/or bioenergy resources and this analysis highlights the role of carbon storage and biomass resource potentials in the future development of a BECCS option. More precisely, based on an advanced methodology of biomass potential assessment (Kang, 2017) coupled with detailed data on storage potential, including onshore and offshore classification, this study shows how such potentials may limit the development of (bioenergy with) carbon capture and storage technologies. We investigated various scenarios featuring different levels of potential and different long-term climate targets.

Results

First, alternative contexts in terms of carbon storage and biomass potentials impact the development of BECCS to different extents. Indeed, regarding the electricity sector, it is interesting to note that a lower level of CO_2 storage capacity, as assumed at the medium level of 1,706 Gt (against 10,142 Gt), does not induce a decrease in investments in CCS technologies. This is not the case for the low assumption of carbon storage potential, where a decrease of around 12 percentage points occurs when the available capacity of storage is low, i.e. 572 Gt, whatever the level of biomass potential. On the other hand, Table 1 highlights that the impact is more significant in particular regarding BECCS development.

Table 1: Share of CCS in the world production of electricity in 2050

Ambitious climate scenario - 70% GHG mitigation target		Biomass potential		
		High	Medium	Low
Carbon storage potential	High	45% *(BECCS: 70%)*	39% *(BECCS: 55.9%)*	27% *(BECCS: 18.1%)*
	Medium	45% *(BECCS: 69.8%)*	39% *(BECCS: 56.3%)*	27% *(BECCS: 18.2%)*
	Low	33% *(BECCS: 93.9%)*	28% *(BECCS: 76.7%)*	15% *(BECCS: 33.5%)*

The lower the carbon storage potential, the higher the share of BECCS in CCS development. More precisely, in the medium biomass potential case, BECCS increases to 76.7% of CCS investment against 56% in the higher carbon storage potential cases. This can be explained by the fact that, in 2050, the development of CCS is not limited by the potential of carbon storage when the latter is assumed to be high and medium. However, when the potential of carbon storage is low, as assumed in the low case, not only are CCS investments limited (representing 28% against 39% in the biomass base/medium case), but BECCS is privileged as a potential solution due to its negative emissions, in order to meet the drastic climate constraint. This higher level of BECCS development (compared with fossil CCS) when the carbon storage potential is at its lowest occurs in all cases, whatever the level of biomass potential. Indeed, in the case of highest biomass potential, CCS development decreases from 45% in the high and medium cases of carbon storage, to 33% in the low case of carbon storage, but the share of BECCS increases from 70% to 93.9%. In the same way, in the lowest case of biomass potential, the CCS development decreases from 27% in the high and medium cases of carbon storage, to 15% in the low case of carbon storage, but the share of BECCS increases from 18.2% to 33.5%. However, note that biomass potential has a more significant impact on the development of both CCS and BECCS. In case of lower biomass potential, CCS technologies represent between 27% and 15% of low-carbon power generation against between 45% and 33% for the highest level of biomass resources. In terms of sequestrated CO2, according to the potentials of carbon storage and biomass resources, the development of CCS technologies in the power sector prevents from 15.8 Gt to 4.4 Gt of CO2 from going into the atmosphere, including from 12 Gt to 2.2 Gt of negative emissions. It is interesting to note that the effect of carbon storage and biomass resource potentials on the development of BECCS is similar in other sectors of the energy system.

Conclusions

The feasibility of avoiding considerable Gt of CO_2 by investing in these technologies is still debatable and will strongly depend on how biomass resources are developed, insofar as the more sustainable and conservative the constraints, the more limited the biomass resource potential. The challenge is therefore to maintain a beneficial balance *in fine*. As regards carbon storage potential, it seems to be sufficient to satisfy the climate constraint by developing CCS technologies, but it will need to overcome acceptability issues, the consideration of which would lead to a significant reduction in the level of carbon storage potential, and thereby, as evidenced by these results, the deployment of CCS and BECCS. Deploying these technologies at this scale for mitigation purposes therefore requires the implementation of incentive and regulation policies. Significant development of CCS will also involve making storage sites socially acceptable. Another critical factor is to take into account that the benefits of BECCS negative emissions are only effective in the case of sustainable use of biomass. In this area, the restoration and preservation of forests is another key factor, along with many other so far unsolved challenges. Therefore, given the influence of carbon storage and biomass resource potentials, and, in turn, the role played by states in these areas, it seems important to quickly establish official guidelines and positioning, which would allow better visibility and anticipation of the role that BECCS can play in the future.

References

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