Techno-economic assessment of bio-based Carbon Dioxide Removal using TIAM-FR

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Overview

Mitigating climate change requires actions to transition from a highly carbon emissive economy to a neutraleconomy. In more quantitative terms, they are translated into the Nationally Determined Contributions (NDC) in the framework of the Paris Agreement (PA), for climate change mitigation and adaptation. Ahead of the COP26 and the expected NDCs update, an increasing number of countries pledged (politically or through their NDCs) to meet a Net Zero (NZ) emission target [1][2], where the target year ranges between 2050 and 2070. Reaching net zero carbon emissions around 2050 is needed to limit the temperature increase to 1.5 degrees by the end of the century. This entails a rapid transition to clean energy production and requires the use of Carbon Dioxide Removal (CDR) to compensate for the emissions from the hard-to-abate sectors [3]. CDR constitutes a set of technical and natural approaches or a combination of both [4] where bio-based CDR is an integral part.

Carbon emissions are directly linked to the increase in temperatures. Their concentrations are distributed in three reservoirs: the atmosphere, the land and the ocean. Accounting for the carbon budget is still not fully understood by scientists, as some discrepancies still exist between the budgeting of emitted carbon and absorbed ones such as the total absorbed carbon does not match the totally emitted [5, p. 16]. Furthermore, there's an existing asymmetry between the CO_2 emissions and removals the atmosphere: the former would rise the temperature at higher values than what the latter could lower it [6]. Enhancing and increasing removals will be one of the solutions for achieving a carbon neutrality but economic questions, in addition to technological and effectiveness matters, are rising like in creating dedicated markets for removal and reduction of carbon given these uncertainties [7] which is one of the question we would like to address here. The importance of these questions appear to be significant especially that voluntary markets funding carbon removal solutions are increasing. In these markets, carbon offset can indeed be done on a reduction or removal basis, where the latter includes natural carbon capture and technology carbon capture. Nevertheless, it requires policy implications on a regional level e.g for the EU ETS and the global level in the climate negotiations to develop demand for CDR.

Afforestation/reforestation (AR) and bioenergy carbon capture and storage (BECCS) are part of the bio-based CDR. In terms of development, the former is a well-known approach that provides ecosystem, biodiversity and human well-being benefits. It requires effective management to be successful, and thus it is supported by actions like the REDD+. However, it presents limitations around the sequestration on the long-term, their localisation and the agricultural land occupation. In contrast, the latter presents potential in energy generation and long-term geological sequestration of CO_2 but its deployment is still staggering. In fact, it depends on cost impacted by bioenergy crops productivity, electricity and storage costs, land availability and policy support. By addressing their limitations and synergies, we aim to reconciliate between these solutions in a long-term discussion for an enriched and realistic assessment of the evolution of the world energy system using the TIMES Integrated Assessment Model (TIAM), which is based on techno-economic optimization to find optimal pathways in line with the above mentioned subjects and policies.

Methods

In context of the limitation of the temperature increase and carbon neutrality, the carbon removal technologies and approaches appear as solutions in the majority of the Integrated Assessment Models (IAMs) [8]. With the long-term prospective approach, based on energy system modeling, we consider the different plausible evolutions to make strategic decisions as early as possible. The structure underpinning long-term energy models relies on mathematical optimization techniques, representing the economy and technology and the interactions with the environment, hence the impact of socioeconomic systems on the climate. Hence, we would determine but not limited to, the optimal configuration of the energy system in terms of technology capacities to install or withdraw, their location, the optimal moment in time for installation and finally the anthropogenic emissions. Moreover, we would be optimizing the costs and in the end providing knowledge-based policy recommendations. We use the TIAM-FR, the French version of the TIMES Integrated Assessment Model, representing the world energy system in 15 regions. TIMES is a methodological corpus developed under the IEA's Energy Technology Systems Analysis Program (ETSAP)[1]. This bottom-up optimization model gives a detailed description of technologies and end-uses constituting the Reference Energy System (RES) linking the different sectors constituting the world energy system. It is driven by end-use demand with

[1] www.iea-etsap.org

the aim of supplying energy services at minimum global cost while making decisions on investments, operation, primary energy supply, and energy trade. It allows the representation and implementation of technical, geographical, demand and environmental constraints. In the model, all kind of known technologies of bioenergy production are modelled, several energy crops are available as resources alongside their potentials, and biomass trade was made possible in [9] and the regional potentials of carbon capture is incorporated [10]. We integrate the climate module, and obtain the temperature rise, at a horizon going to 2100, according to the radiative forcing of the obtained GHG from the model optimization. Our analysis would be based on the decisions taken today in the context of the PA and the NZ pledges.

Results

First, we reviewed the countries' updated NDCs and their new targets and aggregated them according to the regions in TIAM-FR. In addition, we will develop a contrasting scenario integrating the political pledges of the countries (which are not yet in NDCs). In consequence, we will display the plausible trajectories for the reduction of emissions that are associated to these new targets and the future technological mix. Particular emphasis will then be given to the bio-based CDR solutions in the EU i.e the natural climate solutions and the combined technology/natural solution BECCS. The EU have extented the criteria related to sustainability of its bio-resources, and emphasizes that the two main challenges for our environment are climate change and biodiversity. In modeling terms, the potential of natural solutions need to be implemented while accounting for the emissions removal and reduction. For BECCS, additional sustainability criteria and high yield bioenergy crops choices would allow to investigate its place. Finally, the study ensures important information regarding the carbon costs and policy formulation with the deployment of CDR, with an opening on the relative markets and financial mechanisms, bearing in mind the controversies existing around CDR in delaying near-term emission reductions.

Conclusions

The presented work highlights the role of CDR with a special focus on bio-based solutions due to their potential and relation to natural and ecological system. In context of net-zero targets, reliable sequestration needs to be deployed with a comprehensive outlook. Through scientific-based decisions it is possible to implement effective policies and mechanisms that ensure these solutions viability. TIAM-FR would be the useful tool to do so, given the large scope of modelled technologies and sectors, the techno-economic and environmental constraints for applying a realistic approach and the use of the climate module for viewing the temperature variation while accounting to CO_2 and non-CO_2 emissions. The results would allows to conduct a technical and policy-oriented discussion and address other issues like adaptation to climate change with natural solutions, a topic that will be part of our future research.

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