Contributions of natural climate solutions to carbon neutrality

Sophie CHLELA, Mines Paris-PSL, CMA - Centre for Applied Mathematics, sophie.chlela@minesparis.psl.eu
Sandrine SELOSSE, Mines Paris-PSL, CMA - Centre for Applied Mathematics, sandrine.selosse@minesparis.psl.eu

Overview

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 [1]. They can be constituted by natural climate solutions (NCS), technologies or a combination of both. In this context, it is found that energy and land sectors (hereafter referred as agriculture, forestry, land, and land use (AFOLU) sector) could provide less emissive energy system like by using biogenic source of energy production and by reducing emissions and eliminating carbon dioxide for instance by changing land management practices. Nevertheless, the main points to be retained are the management of supply and demand, the cost implications of these solutions and changing to sustainable consumption patterns ensuring the durability of solutions and the availability of resources for future generations.

Alongside the Nationally Determined Contributions (NDC) targets for net zero GHG emissions set out by Europe, the strategies include a clear consideration of emissions removal. In the context of the Green Deal, the Commission agreed on the legislative proposal that sets targets for carbon removals by natural sinks (through land use, forestry and agriculture) that will need to remove 310 million tons of CO2eq from 2026 to 2030 [5] through the amendment of Regulation (EU) 2018/841. Further to that, the EU has recently proposed a "certification of carbon removals to help reach net zero emissions" where the Innovation Fund will finance, but not limited to, Bioenergy Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS), the New European Bauhaus will recognize the carbon storage capacity of wood-based and energy-efficient building materials, and the QU.A.L.ITY criteria will be used to develop tailored certification methodologies for the different types of carbon removal activities [6]. Moreover, voluntary carbon markets (VCM) utilize CDR, and mostly natural ones to offset emissions. Currently they represent only 7% however models finds that by 2030, 44% of the VCM will be avoidance credits and 56% will be removal [7]. A better assessment of the cost-effectiveness of the solutions would help in setting the standards and help support these projects, to finally avoid high financial burdens due to the negative emissions requirements.

Methods

Through long-term prospective approach, 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 and 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 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. To address the role of the AFOLU sector, we soft-link TIAM-FR with GLOBIOM of the International Institute for Applied Systems Analysis (IIASA). GLOBIOM is a global economic land use model and we use a model emulation. The idea is that GHG reduction through the AFOLU sector and land-based biomass for bioenergy potentials involves setting biomass costs and marginal abatement cost curves (MACC) of AFOLU mitigation conditional on biomass demand as well as a GHG price trajectories. Furthermore, the arbitration between the vast portfolio of CDR options (related to AFOLU, to technologies or a combination) includes a consideration of the various effects that theses options by integrating sustainable development through Sustainable Development Goals (here SDG 2, 6, 12, 13 and 15).

[1] www.iea-etsap.org

Results

The implementation of climate policies is vital to successfully draw the path to the net-zero emission targets. Based on both the technical and political means, we precisely explore the future of the world energy mix to achieve a decarbonized target and focus on the long-term need for CDR under such constraints. With TIAM-FR, we project the activity of the global energy system to 2100 according two scenarios:

1. A "current policies" scenario in which each region is constrained to follow its NDCs and carbon neutrality only for the countries that have pledged to this goal.
2. A "successful" scenario including NDCs and forcing all regions to achieve emissions neutrality in compliance with the goal of the Paris Agreement.

From the array of NCS, the shares of afforestation/reforestation (AR) and BECCS and are explored and a techno-economic arbitration is presented. Note that in terms of development, the former is a well-known approach that provides ecosystem, biodiversity and human well-being benefits but presents limitations around the sequestration on the long-term, their localisation and the agricultural land occupation which would be assessed through GLOBIOM linking. In contrast, the latter presents potential in energy generation and long-term geological sequestration of CO_2 but its deployment is still staggering. We would determine the cost implications impacted by bioenergy crops, electricity production 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 with a focus on the Europe region.

Conclusions

The presented work highlights the role of CDR with a special focus natural climate solutions due to their potential in GHG emissions mitigation. 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 with GLOBIOM would be the useful combination 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 ability of using climate parameters for assessing 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.

References

[1] IPCC, "AR6 Climate Change 2022: Mitigation of Climate Change," Apr. 2022. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/ (accessed Apr. 08, 2022).

[2] G. Berndes *et al.*, "Forests and the climate," KSLA, Stockholm, Conference report, Dec. 2018. Accessed: Jan. 03, 2023. [Online]. Available: https://www.ksla.se/wp-content/uploads/2018/12/KSLAT-6-2018-Forests-and-the-climate.pdf

[3] K. Zickfeld, D. Azevedo, S. Mathesius, and H. D. Matthews, "Asymmetry in the climate–carbon cycle response to positive and negative CO2 emissions," *Nat. Clim. Chang.*, vol. 11, no. 7, Art. no. 7, Jul. 2021, doi: 10.1038/s41558-021-01061-2.

[4] A. Torvanger, "Business Models for Negative Emissions From Waste-to-Energy Plants," *Frontiers in Climate*, vol. 3, 2021, Accessed: Mar. 30, 2022. [Online]. Available: https://www.frontiersin.org/article/10.3389/fclim.2021.709891

[5] "EU agrees to increase carbon removals," *European Commission - European Commission*. https://ec.europa.eu/commission/presscorner/detail/en/IP_22_6784 (accessed Feb. 01, 2023).

[6] "Commission proposes certification of carbon removals," *European Commission - European Commission*. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7156 (accessed Feb. 01, 2023).

[7] "Removal reconsidered: Carbon Dioxide Removal in the Voluntary Carbon Market going forward," *BeZero*. https://bezerocarbon.com/insights,removals-in-the-vcm (accessed Apr. 03, 2023).

[8] S. Frank *et al.*, "Land-based climate change mitigation potentials within the agenda for sustainable development," *Environ. Res. Lett.*, vol. 16, no. 2, p. 024006, Jan. 2021, doi: 10.1088/1748-9326/abc58a.

[9] J. Fuhrman, H. McJeon, S. C. Doney, W. Shobe, and A. F. Clarens, "From Zero to Hero?: Why Integrated Assessment Modeling of Negative Emissions Technologies Is Hard and How We Can Do Better," *Frontiers in Climate*, vol. 1, p. 11, 2019, doi: 10.3389/fclim.2019.00011.

[10] S. Kang, "La place de la bioénergie dans un monde sobre en carbone : Analyse prospective et développement de la filière biomasse dans le modèle TIAM-FR," phdthesis, Université Paris sciences et lettres, 2017. Accessed: Dec. 01, 2021. [Online]. Available: https://pastel.archives-ouvertes.fr/tel-02096031

[11] S. Selosse, "Chapter 12 - Bioenergy with carbon capture and storage: how carbon storage and biomass resources potentials can impact the development of the BECCS," in *Bioenergy with Carbon Capture and Storage*, J. C. Magalhães Pires and A. L. D. Cunha Gonçalves, Eds., Academic Press, 2019, pp. 237–256. doi: 10.1016/B978-0-12-816229-3.00012-0.