CCIS Webinar 4: Carbon Dioxide Removal June 10, 2020

Moderator Peter Lawrence: - Introduction and motivation of the Community Climate Interventions Strategies Project, Carbon Dioxide Removal webinar.

The fourth webinar, in the series of nine webinars, included four presentations covering land management, agricultural, forestry and biofuel production and consumption, energy transformation, chemical and industrial processes, and the capture and geo-sequestration of carbon to achieve a range of possible Climate Intervention Strategy objectives. The four speakers were all experts in their fields and provided individual perspectives on how deliberate human actions can address the imbalances in the global carbon cycle caused by current fossil fuel emissions and land use and land cover change.

The first presentation, "Trade-offs and co-benefits in land-based, climate change mitigation", was given by Mark Rounsevell. Mark is the Professor of Land Use Change at the Karlsruhe Institute of Technology, the Head of the Land Use Change Research Group, and the David Kinloch Michie Chair of Rural Economy and Environmental Sustainability in the School of GeoSciences at the University of Edinburgh.

Mark's presentation introduced the idea that approximately 30% of governments Nationally Determined Contributions (NDCs) under the Paris agreement relate to options for land-based, climate change mitigation. The dominant activities of the NDC being Bio-Energy, with and without Carbon Capture and Storage (BECCS). Recent science-policy assessments such as IPCC and IPBES have raised concerns about the application of these two options over large land areas where they compete with food production, nature conservation, water resources, and impact on other components of the environment.

Mark presented the work of Smith, et al. (2019), which lists the practices that co-deliver food security, climate change mitigation and adaptation, and combat land-degradation and desertification. The paper looked at the global impacts and co-benefits of land based carbon management. The presentation then looked at a more focused European study on the benefits and challenges of bioenergy production and re/afforestation while maintaining food production and biodiversity conservation. The presentation concluded with an exploration of the role that dietary preferences, pet food consumption, and food system waste can have on agricultural production and land use.

The overall conclusions was that large-scale bioenergy production is likely to be irrelevant at best for many regions of the world, and at worst, it will have large impacts on food security, biodiversity and water resources. This was in direct contradiction with the third presentation and in general alignment with the second presentation. Mark further concluded that afforestation/reforestation has fewer negative externalities than bioenergy, but will still compete for land, in agreement with the second presentation. Finally, it was concluded there are other land-based mitigation options that could play a role in carbon sequestration, with important co-benefits that need further exploration.

The second presentation, "How can terrestrial systems help deliver the Paris Agreement targets?", was given by Stephanie Roe. Stephanie is a researcher at the University of Virginia and a Senior Consultant at Climate Focus.

Stephanie's presentation introduced the importance of land based Climate Intervention Strategies as it currently accounts for 25% of global Green House Gas emissions, 30% of the carbon sink from increasing CO_2 and has strong influences on albedo and evapotranspiration. She also identified the current activities

and resources that the land sector provides to society and the environment with the examples of food, livelihoods of 70% of people, habitat and biodiversity, water quantity and quality, bioenergy, minerals, fiber, culture and recreation. She then identified the feasibility of carbon management to achieve 1.5 and 2.0 C climate pathways, and how these activities may require tradeoffs to achieve the UN Sustainable Development Goals (SDGs).

Stephanie then provided a road map assessment to 2050 that combined top down inter-model comparisons based on Integrated Assessment Models, and bottom up literature reviews of land sector potentials. The top down models achieved the climate targets through decreases in food crops and pasture, increases in natural forests, and a large uptake of BECCS by 2050. The reduction in emissions of CO_2, CH_4 and N_20 came from reduced LULCC and agriculture, while negative carbon emissions came through forestry and BECCS. The bottom up approach from literature syntheses generally agreed with the global carbon mitigation potential of the top down studies but with a much wider portfolio of activities with regional focuses and differences.

A key limitation of the top down approach was that IAMS optimize for cost, however, they do not measure economic costs and impacts due to climate change. Stephanie also raised the need to better incorporate socioeconomic and environmental 'safeguards' to avoid undesirable scenarios? The presentation concluded land management could feasibly and sustainably contribute ~30% of mitigation to deliver on the 1.5 °C goal of the Paris Agreement with 70% still needing to come from energy transformation. This would be a ~60% increase to existing carbon sink.

The third presentation, "The Role of BECCS in Achieving Deep Greenhouse Gas Emission Reductions", was given by André Faaij. André is the Director of Science of TNO Energy Transition, the largest energy research organization in the Netherlands and the Distinguished Professor of Energy System Analysis at the University of Groningen.

André's presentation opened with the IPCC Special Report on Global Warming of 1.5 degrees C showing the four illustrative scenario pathways of the report. The major point being that the greater the increase in energy demand in the scenarios the greater the need for climate intervention activities to offset fossil fuel use early in the century, with the highest energy pathway requiring the large-scale implementation of CDR through BECCS.

André presented the use of Flexfuel power and synfuel production through fermentation and anaerobic digestion based processes. He also presented co-firing of coal and natural gas with CO2 capture at bio-refineries. The need for carbon management was extended to steel and cement industries, petrochemical, bio-based chemical, paper and pulp, and agriculture and food industries. The requirement for CO2 storage options at reasonable distance of less than 300 km combined with energy infrastructure that has access to biomass feeder systems. Potential regions for Bio-Energy with Carbon Capture and Storage included: Great Plains US, SE Brazil, East Australia, Central China, Sea harbors NW Europe.

The presentation addressed the major challenges to Industry to transform to a zero carbon footprint. The importance of Industry to address carbon emissions was shown as the consumer of ~50% of primary energy use. A list of possible options included: energy efficiency improvement of existing processes; new inherently more efficient processes; renewable feedstock for biobased industry; renewable energy carriers including green power and green hydrogen; Carbon Capture and Storage (CCS with negative GHG emissions); and recycling/re-use/circular value chains with shifts in markets and products. These changes needed to be made at the Factory level, regional level, structural changes in economy and energy system

and over an investment cycle of 30 years. This was in agreement with the fourth presentation, where these issues were further expanded.

André's presentation concluded with baseline and mitigation scenarios for three CMIP6 SSP projections. In the baseline scenarios liquid bioenergy was most important in SSP1, with additional biobased solids and chemicals used in SSP3. In the mitigation scenarios biomass deployment for bioenergy and biochemicals, in context with the potential dynamics of future land use were essential. Overall, the presentation concluded there is sufficient potential measures to fully decarbonize industry and transport, partly through transforming to negative emission capacity with BECCS options. This was in opposition to the first and second presentations. In the SSP baseline and mitigation scenarios, BECCS options stood out as a fundamental solution linked with CO_2 taxes, innovation programs per sector, and alignment of industry and energy transition to achieve a net zero carbon footprint.

The final presentation, "Negative Carbon Emissions and De-Fossilization of Chemicals and Materials Cycles", was given by Alyssa Park. Alyssa is the Lenfest Professor in Applied Climate Science and Director of the Lenfest Center for Sustainable Energy at the Earth Institute, Columbia University. She also is an Associate Professor in the Departments of Earth and Environmental Engineering, and Chemical Engineering.

Alyssa's presentation opened with the urgency of carbon management to address climate change resulting from a substantial multi-century climate change commitment resulting from past, present and future emissions of CO_2. She positioned that the urgency and scale of the climate change issue will require Negative Emission Technologies. This position was supported by the IPCC Fifth Assessment Report, as well as reports on Carbon Dioxide Removal and Storage from the National Research Council, the Department of Energy, and the National Academies of Engineering and Science. This was followed by a review of Carbon Capture, Utilization and Storage Technologies being investigated through demonstration projects in different locations around the world.

Alyssa stated that for carbon capture processes to be successful they needed capacity and selectivity, low energy requirement and economic feasibility and scalability. The first example given was a post combustion CO_2 Capture Units in Power Plants, followed by Direct Air Capture including Novel Water-lean and Waterless CO_2 Capture Solvents, and with Encapsulated Microbeads. The next component of the presentation focused on utilization and storage of the captured carbon. The first examples looked at mineralization of CO_2 to carbonate and sequestration in geological formations. The next examples looked at a range of uses of captured CO_2 for working liquids, De-fossilization of Chemicals and Materials, as well as many other Carbon Recycling Schemes. This posed the questions of what are the requirements for CO_2 as a feedstock? What are the scales of different options and what is the potential revenue of these industries.

Finally, Alyssa explored BioEnergy with Carbon Capture and Store (BECCS), Conversion of CO_2 to Chemicals and Fuels using Renewable Energy, with an example of jet fuel, and asked which industry path was better for the environment. She concluded that we need to consider all the CO_2 sources and multifaceted solutions for Carbon Capture, Utilization and Storage in order to decarbonize industries. That we also need negative emission technologies including Direct Air Capture to address climate change. And that while we cannot decarbonize chemicals and materials, we can de-fossilize them using CO_2 and renewable energy.

Question and Answers:

Simone Tilmes: What are the current plans to switch to bioenergy in Europe and in the US, given that it seems not to be very beneficial. And how would one address the misconception that bioenergy is beneficial.

Dale Rothman: Did The Planet of the Humans overdo it in its condemnation of bioenergy?

Andrew Lockley: Can cover crops be used for bioenergy?

Brad Ack: The CDR discussion in general is very biased towards terrestrial systems, while the oceans have enormous potential for CDR and permanent sequestration with few tradeoffs and conflicts. Would be good to put together a webinar on some of the various pathways. For those interested in a primer, see Gattuso, J.-P., et al. 2018. Ocean Solutions to Address Climate Change and Its Effects on Marine Ecosystems. Frontiers in Marine Science 5:337.
GESAMP Working Group 41. 2019. High Level Review of a Wide Range of Proposed Marine Geoengineering Techniques (eds Boyd, P. W. & Vivian, C. M. G.) GESAMP Rep. Stud. No. 98 (International Maritime Organization).

James Lavin: for Stephanie: any comment on recent studies showing soil carbon potential lower due to interaction with below meter depths pulling carbon up and additional soil carbon triggering additional microbial respiration activity?

Lianhong Gu: How is pure O2 produced? Is energy consumption in the process of producing pure O2 considered?

James Lavin: Smils in Power Density makes a very strong case biomass energy watts/sq Meter is much less than 1 W/ meter so how can you get anywhere near enough land to make this work?

Amanda Borth: Wow, what a digestible presentation, Alissa! Many thanks :)

Tara Illgner: Agreed, very good presentation, Alissa!

Andrew Lockley: Yeah I could do with the slides. Especially your magic balls

Gene Fry: Yes, Alissa. Very clear and easier to follow. Not hurried. You addressed all the CCS / DAC technologies.

Dale Rothman: I think the issue of the effect of a changing climate on the carbon cycle is significant. If I think of the current discussion on permafrost and methane release, it seems that there is almost a race against time in some cases.

Bruce Hamilton: For Alissa — Please comment on the thermodynamic argument that relative to CO_2 reduction, it is better to use any renewable energy to displace fossil fuel use rather than to make chemicals.

Leslie Field: Fantastic talks, thank you all. Getting this work done at scale, in time, with humanitarian and ecosystem constraints will definitely be very very challenging.

Dale Rothman: For Alissa - I will be quoting you on the idea that carbon capture without storage is like catch and release. To all speakers - very good presentations.

James Lavin: For Alissa, what potential do you see for surface carbonation of minerals, either with aquatic interface, ie, project Vesta, or Paul Kops Green Minerals vs pressured reactors of ultramafic rocks, ie, do you think either can scale—assuming a large payment for CO_2 removal.