June 23, 2022

California Air Resources Board
1001 I Street
Sacramento, CA 95814

Rajinder Sahota
Deputy Executive Officer, Climate Change and Research

Matthew Botill
Division Chief, Industrial Strategies Division

Jeff Kessler
Air Resources Engineer, Industrial Strategies Division

Re: 2022 Draft Scoping Plan – Comments on Technological Carbon Dioxide Removal

To the California Air Resources Board (CARB) team,

The undersigned are pleased to provide feedback comments in relation to the Draft 2022 Scoping Plan (the Plan). With this letter, we comment on the role of technological carbon dioxide removal (CDR) in the Plan, including bioenergy and biofuels with carbon capture and storage (BECCS) and direct air capture with carbon storage (DACCS). This is based on our collective expertise as contributing authors of U.S. technical reports *Getting to Neutral: Options for Negative Carbon Emissions in California* (awarded a Department of Energy Secretary Achievement Award for its outstanding contribution to climate change research) and *Net-Zero America: Potential Pathways, Infrastructure, and Impacts*.

Overall, we commend CARB staff on recognizing the important role of technological CDR to both compensate for hard-to-abate emissions that would otherwise prevent California from achieving net-zero emissions by 2045, as well as remove legacy emissions from the atmosphere. This has been clearly identified by the IPCC's Working Group III as well as *Getting to Neutral* and *Net-Zero America*. We also commend staff on recognizing the importance of planning and investing in carbon management infrastructure, including CO_2 pipelines and storage sites, as well as California's unique situation whereby there are few other locations on the West Coast suitable to perform geologic storage at scale. California's ability to capture and store CO_2 underground appears necessary for state *and* national net-zero goals.

We make three key recommendations to CARB related to technological CDR in the Plan:

- **First, we recommend a diversification of the technological CDR options considered and modeled, including a more substantive role for BECCS.** While DACCS is an essential option that is rightly emphasized in the Plan, *Getting to Neutral* shows that BECCS derived purely from forest, farm, and urban waste is relatively lower-cost, has a large CDR potential (about 80 MMT/year), and can unlock important co-benefits in the form of wildfire risk reduction, improvements to air quality and water supply, as well as rural economic development opportunities throughout the

state. A more substantive role for BECCS can reduce the overall cost of the Plan and, alongside DACCS, increase the odds of achieving an ambitious goal of 100 MMT per year of CDR by 2045. Promising BECCS pathways include the use of gasification and pyrolysis technologies to produce liquid and gaseous fuels, such as hydrogen, with carbon capture and sequestration.

- **Second, we recommend a revision to the methodology for estimating forest biomass availability in collaboration with stakeholders.** The current method combines use of the California Biomass Residue Emissions Characterization (C-BREC) model and a staff-led Socially Beneficial Residues Management (SBRM) model, culminating in an estimate of (on average, statewide) 2.4 dry tons of residues being mobilized per treated forest acre into BECCS. This is significantly lower than estimates contained in alternate analyses, including *Getting to Neutral* (based upon a peer-reviewed method), as well as expert elicitation from land managers which typically range from 10-15 dry tons per acre. A detailed review of both the C-BREC Model Framework and Natural and Working Lands Appendix I, in addition to written correspondence with staff, suggests that a combination of subjective C-BREC assumptions, treatment/residue scenario selection within C-BREC, as well as the limited scope of the SBRM model are driving the 2.4 tons per acre estimate. We recommend that these approaches (detailed below) are reviewed and revised. Overall, we view forest biomass estimates around 10-15 dry tons per acre as robust.

- **Third, we recommend that CARB consider developing a plan for a DAC Hub in California.** As part of the Infrastructure Investment and Jobs Act of 2021, $3.5 billion was appropriated to the Department of Energy to support the creation of four "Regional Direct Air Capture (DAC) Hubs". (Note that, despite the name, both BECCS and DACCS technologies are eligible for this funding). Given the limited options for CO_2 storage in the West, we view this as an opportunity to make progress consistent with ambitious decarbonization targets such as net-zero by 2045 (state) and 2050 (national). One promising option is to establish a Hub in Southern California, comprised of geothermal DAC and farm and urban residue BECCS with CO_2 storage in Kern County. A Northern California forest and farm residue Hub is another option, with CO_2 storage in the Delta region.

The remainder of this comment letter, in support of the above recommendations, is arranged as follows. First, we describe the main results of the *Getting to Neutral* report. Second, we provide more specific analysis regarding the treatment of forest biomass in the Plan. Third, we summarize a possible Southern California DAC Hub. Finally, we summarize and re-establish the recommendations outlined above.

***Getting to Neutral* report summary**

Getting to Neutral was a first-of-its-kind study that estimated California's technical potential for CDR. The report found that 100 MMT per year of CDR could be cost-effectively achieved via BECCS (about 80 MMT, derived from waste residues only) and DACCS (about 20 MMT, with a focus on geothermal DAC). The report was notable for its granular consideration of biomass residues, identifying these volumes on a per county basis (Fig. 1). Forest biomass estimates were based upon the assumption that the state would successfully be treating 1 million acres per year for wildfire mitigation, consistent with its current policy

objective. The report made comprehensive techno-economic assessments of each CDR pathway, developing a cost curve (Fig. 2). The cost curve shows that a majority of BECCS pathways – with residues otherwise assumed to be open burned, landfilled, or left to decay – can be delivered for potentially less than half the cost of DACCS. The relatively lower-cost for BECCS is also found in *Net-Zero America* and peer-reviewed literature. The IPCC's WG III routinely envisions BECCS as the most significant technological CDR option.

Figure 1: California biomass residues identified on a per county basis

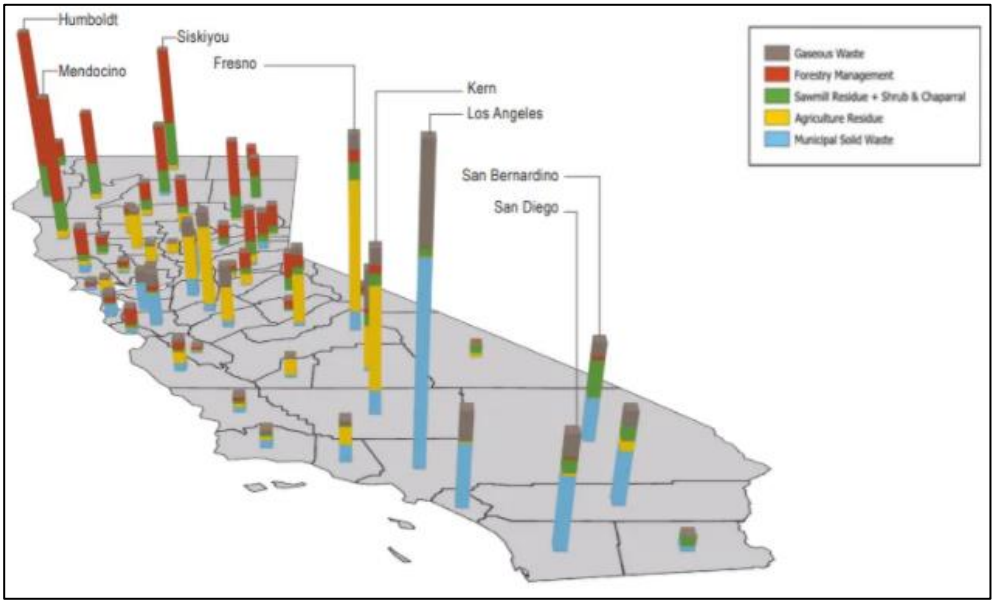
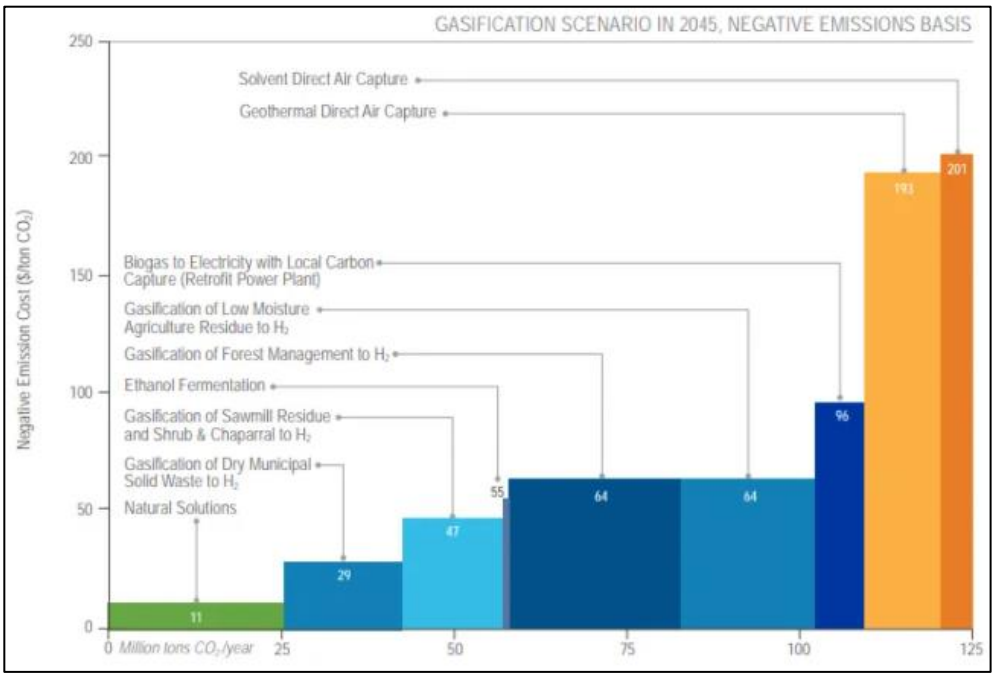


Figure 2: *Getting to Neutral* cost curve, with the cost of BECCS lower than DACCS



The Draft Plan currently assumes that about 9 MMT of BECCS will be obtained (from forest biomass only), offsetting 8 MMT of emissions from the state's Natural and Working Lands, which are anticipated to be a net source of emissions. Therefore, it is implicit that 100 MMT of CDR will be provided via DACCS to achieve net-zero by 2045. While DACCS is an essential option that is rightly emphasized in the Plan, we recommend diversifying technological CDR options, including a more substantive role for BECCS. This could include mobilizing urban and agricultural residues, in addition to usable forest residues, with a goal of delivering BECCS. (Currently, urban and agricultural residues are mobilized for biofuels only. The fate of unused woody agricultural residues in excess of the 4 million dry tons converted into RNG is also unclear[1]). The relatively low-cost of BECCS justifies this, as well as benefits in the form of risk-reduction in the event that DACCS cannot be scaled at the pace necessary to achieve 100 MMT of CDR by 2045. BECCS derived from waste residues puts no/limited strain on land-use change and water resources.

Analysis on the treatment of forest biomass in the draft Scoping Plan

Forest biomass presents arguably the largest CDR opportunity in California. As identified in *Getting to Neutral*, by UC Berkeley scientists, as well as The Nature Conservancy, a strategy to collect and convert forest residues into carbon-negative products may also enable the state's goal of treating one million acres per year. This is essential to reduce the risk of high-severity wildfire, where a single season can emit substantial CO_2 volumes. For example, it is estimated that over 100 MMT of CO_2 was emitted from the 2020 fires. This amount is greater than the total CO_2 reductions achieved in California since 2006[2].

There are substantial differences between the residue estimates identified in the Plan relative to *Getting to Neutral* as well as expert elicitation from foresters and land managers. Specifically, *Getting to Neutral* identifies recoverable forest waste quantities of, on average, 15 dry tons per acre. This is based on a peer-reviewed method developed by UC Berkeley scientists[3]. In contrast, the Plan identifies quantities of 2.4 dry tons per acre. The Plan indicates that the remaining (majority) of residues would be left in the forest, and either managed through open burning (pile and broadcast burning) or decaying methods. This strategy will increase the state's emissions, reducing the likelihood of achieving net-zero by 2045. It also foregoes the opportunity to obtain permanent and durable CDR in the form of forest BECCS.

We undertook a detailed review of the Plan's method to obtain the 2.4 dry tons estimate. We identified key aspects to the method that, based on our understanding of the science and this issue area, are subjective or limited. We provide recommendations to either review or revise these approaches:

- **C-BREC assumption that at least 30% of residues from a fire prevention treatment must remain in the forest.** This underlying assumption is based on a 2011 Department of Energy national study that arguably does not reflect the presently vulnerable state of Western U.S. forests, as outlined in the Governor's Forest Management Task Force Wildfire and Forest Resilience Action Plan. We

[1] *Getting to Neutral* estimates a gross resource total of 13 million dry tons of woody agricultural residue in 2045.
[2] Per the GHG inventory, 2006 and 2019 emissions totaled 484 $MMTCO_2e$ and 418 $MMTCO_2e$ respectively. This equates to a total emission reduction across the time period of 62 $MMTCO_2e$.
[3] For a description of this method, see *Getting to Neutral* (pp. 37-38).

recommend that this assumption is reviewed with expert stakeholders to ensure that it is aligned with the contemporary state of California's forests.

- **CARB assumption that regions are, in effect, 'indifferent' to residue collection.** We understand that, based on the rationale that there is limited data available regarding residue collection decision-making, it was assumed that each possible residue collection scenario in C-BREC was equally plausible. In other words, a scenario where 70% of residues were collected was considered equally likely as those where 50% or 30% of residues were collected. An average of these scenarios was then taken to obtain the final C-BREC "mobilizable" biomass estimate. From what we understand, this estimate is contained in the third column of Table 34, Appendix I.

  If this is the case, we recommend a revision to this approach. Specifically, and provided there is more than a truly nominal amount of gross residues per acre and/or the project in question is not extremely small, land managers do not *plan* to leave residues in forests. This is because doing so can maintain a wildfire risk to surrounding forests and communities. Similarly, land managers do not *plan* to open burn, notably pile burn. Pile burning typically occurs when land managers make a trade-off decision to reduce fire risk at the expense of emitting some criteria pollutants. As a matter of approach, when faced with a choice of recovering all available residues (not otherwise needed for ecological reasons) or just a portion of them, managers would prioritize full residue recovery. This reflects goals to reduce fire risk and CO_2 emissions and support rural economic development. As a result, it would be more accurate to assume high residue utilization scenarios in the Plan. Moreover, we note that the residue scenario selection method in the Plan is not transparent. Staff should detail their revised approach to residue scenario selection, and collaborate with expert stakeholders to vet its real-world applicability.

- **Use of a "social cost" screen to limit residue mobilization (i.e., the Socially Beneficial Residue Management (SBRM) model)**. CARB staff adopted a unique SBRM model for forest biomass, which prevents residue collection if the "social cost" of leaving residues in the forest is lower than the cost of collecting and converting residues into a biofuel[4]. Social cost is measured as the criteria and CO_2 emissions damages from open burning and decomposition. This social cost screening method is applied subsequent to C-BREC outputs being obtained (e.g., Table 34, Appendix I, "Klamath – Federal" Eco-unit and Land Ownership Type). In a number of cases, the model finds that the social cost of open burning or leaving residues to decay is low.

  There are a number of analytical issues with this method. As a broad statement, it is extremely challenging to bound a social cost assessment. In this case, the method does not include relevant benefits that are likely to partly, if not fully, offset the estimated damages. These benefits include, but are not limited to, wildfire risk reduction to communities and forests, as well as rural economic development opportunities in the form of new manufacturing facilities and associated supply chains. CARB staff could aim to quantify these additional variables with stakeholders, although

[4] This approach is unique, as it does not appear to be applied to other mitigation options. For example, limiting utility-scale solar to the extent the social cost of land-use and visual amenity impacts outweigh the cost of project development.

this is likely to present a very challenging exercise. On the basis that strict local air quality rules already exist under CEQA that will prevent harmful projects, and the assumption that regions will lead in residue collection decision-making, we recommend that CARB discontinue use of this screening method in the Plan.

Reducing the risk of high-severity fires and improving forest resilience is one of California's most pressing climate problems. A robust forest biomass strategy that has the capacity to manage at, or near to, the gross resource total from ecological land management appears essential to support this goal. A forest biomass strategy that prioritizes CDR can help achieve net-zero emissions by 2045 or sooner.

Description of a possible Southern California DAC Hub

The Department of Energy's (DOE's) Regional DAC Hubs program appears to be an important opportunity to support the necessarily rapid deployment of technological CDR options consistent with ambitious decarbonization targets, such as net-zero emissions by 2045 (state) and 2050 (national). According to the DOE, eligible mechanisms for direct atmospheric CO_2 capture are anticipated to include both chemical direct air capture technologies and BECCS, among others[5].

DAC hubs should be sited within reach of suitable sites for sequestration and be planned in conjunction with CO_2 pipeline infrastructure. The region of Southern California spanning from the Salton Sea in Imperial County, through southwest San Bernardino County to the Southern San Joaquin Basin in Kern County, is an ideal location for an initial DAC and sequestration hub project (Fig. 3)[6]. These counties are economically distressed, with nearly 20% of the population below the poverty line. These counties also suffer from poor air quality, in part due to in-field burning of agricultural residues. Siting a DAC and sequestration hub in the region would promote creation of green jobs in an economically depressed region and may have beneficial air quality effects if it involves BECCS due to the avoidance of biomass burning and replacement of fossil road transportation fuels with cleaner biofuels.

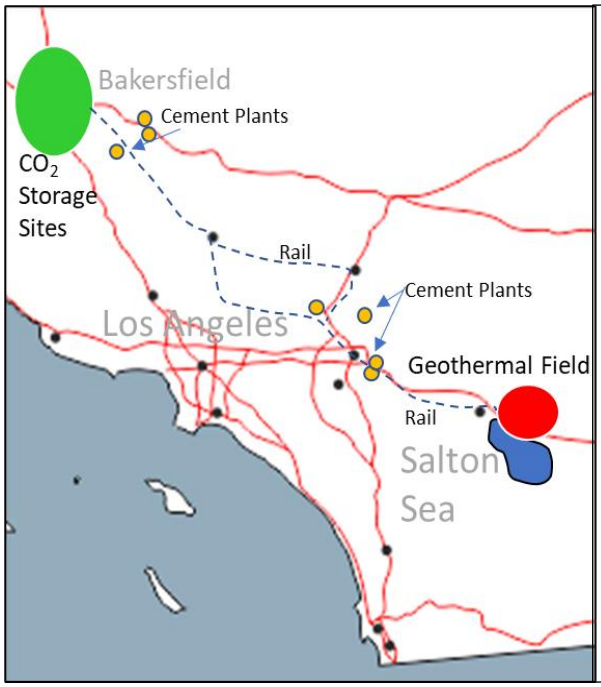
This Southern California region is currently a large producer of oil and natural gas. Siting a DAC and sequestration hub in the area would allow conversion of those oil/gas jobs into carbon management jobs while aiding in state and national decarbonization goals. San Bernardino County also houses several large CO_2 emitters (cement producing facilities) that are hard to decarbonize, where operations will likely persist for the next several decades. Construction of BECCS facilities to convert agricultural residues into energy products and sequesterable CO_2 synergizes carbon removal and air quality improvement goals. There are opportunities to synergize carbon removal with industrial carbon capture at the sequestration site to realize economies-of-scale for CO2 pretreatment and injection.

[5] See DOE-NETL Notice of Intent DE-FOA-0002746.

[6] Note that while we describe a possible Southern California DAC Hub, Northern California also has potential as a DAC Hub, with select geothermal DAC as well as substantial forest and farm BECCS opportunities, industrial CO_2 capture opportunities in the Bay Area, as well as high CO_2 storage potential in the Sacramento-San Joaquin Delta and other areas of the Sacramento basin.

Sourcing low-carbon energy (heat and electricity) to drive processes at a DAC hub is important for ensuring that processes remove carbon from the atmosphere on balance. Imperial, Kern, and San Bernardino Counties generate large amounts renewable energy: combined, they produce about 40% of the renewable solar electricity, 55% of the wind energy, and 30% of the geothermal energy in the state, with the potential to expand capacity. The Salton Sea geothermal region in Imperial County has an abundance of low-carbon waste heat from the geothermal power plants suitable for low-temperature DAC processes. Approximately 3 million tonnes of CO2 could be captured per year using fluid flows from existing geothermal power plants and wells, with the potential for capturing an additional 11 million tonnes of CO_2 per year using untapped geothermal sources[7].

Figure 3: Possible Southern California DAC Hub



DAC Hub Summary

The DAC Hub would be comprised of multiple components. Geothermal DAC facilities would be sited at the Salton Sea. CO_2 storage would occur in Kern County. BECCS facilities that mobilize agricultural residues otherwise pile-burned or left to decay could be sited proximate to the CO_2 storage sites. CO_2 could be transported by rail or pipeline from the Salton Sea to Kern County, taking advantage of an existing rail corridor/right-of-way, and supporting CO_2 capture from clusters of high-emission cement facilities. The oil and gas expertise in the region can be supported via a fair and equitable energy transition strategy by benefiting from job opportunities in carbon management.

However, this region is not suitable for DAC approaches that require high humidity or consume large quantities of water[8]; much of the water consumed in the region is brought in from out of the state as the region is frequently in a state of drought and over 90% of the fresh water is earmarked for agricultural use. DAC approaches that collect and recycle the water that is used in the process may still be suitable.

Conclusion

California's attributes of abundant biomass waste, untapped geothermal reserves, and world-class geology make it well-placed to advance technological CDR for state, national and global benefit. The latest IPCC Working Group III report highlights the "essential" role of technological CDR to compensate for hard-

[7] For more information, see *Getting to Neutral* (pp. 81-84).

[8] Fasihi, Efimova & Breyer (2019) assess the water demands of alternate DAC systems. Low-temperature systems, such as the Climeworks technology, are found to actually capture water as a by-product of the system operations. In other words, water demand is not a constraint on these systems. High-temperature systems are found to have a positive water demand.

to-abate sources as well as legacy emissions already in the atmosphere. CARB's recognition of this role for technological CDR in the state's net-zero portfolio is therefore aligned with the latest available science. However, there are areas for improvement related to the modeled role of technological CDR in the 2022 Draft Scoping Plan that we have sought to communicate with this letter:

- First, we recommend a diversification of technological CDR options, including a more substantive role for BECCS. This can help mitigate the risk that DACCS cannot be upscaled as quickly as required to meet ambitious mitigation targets. Moreover, as BECCS is lower cost than DACCS, this can reduce the total cost of the Scoping Plan and California's energy transition.

- Second, we recommend a revision to the methodology for estimating forest biomass availability in collaboration with stakeholders. The Plan estimates mobilizing only 2.4 dry tons per acre. This is a very low number, and suggests that, on average, feasibly 80+% of residues accruing from an ecological thinning treatment are open burned and/or left in the forest to decompose.

- Third, we recommend that CARB consider developing a plan for a DAC Hub in California. The Department of Energy's Regional DAC Hubs program appears to be an important opportunity to support the necessarily rapid deployment of technological CDR options consistent with ambitious decarbonization targets, such as net-zero emissions by 2045 (state) and 2050 (national). Above, we highlighted the attributes of a possible Southern California DAC Hub.

Respectfully submitted,

Roger D. Aines – *Lawrence Livermore National Laboratory*

Sarah E. Baker – *Lawrence Livermore National Laboratory*

George Peridas – *Lawrence Livermore National Laboratory*

Daniel L. Sanchez – *University of California – Berkeley*

Bodie Cabiyo – *University of California – Berkeley*

Eric Larson – *Princeton University*

Chris Greig – *Princeton University*

Sam Uden – *Conservation Strategy Group*