May 3, 2022

California Air Resources Board
1001 I Street
Sacramento, CA 95814

Dear CARB Board Members and staff,

Thank you for the opportunity to comment on the April 20th Public Workshop: 2022 Scoping Plan Update - Initial Air Quality & Health Impacts and Economic Analyses Results Workshop.[1] As stated in our previous comments on the March 15th Initial Modeling Results Workshop,[2] we deeply appreciate the hard work that ARB staff and the Scoping Plan modeling teams are doing to prepare a strategy to achieve California's ambitious climate goals. We are energy modeling and policy experts from Stanford University focused on technical and policy innovation towards an equitable and sustainable energy transition. These comments reflect our personal views and not those of Stanford University, the Woods Institute for the Environment or the Climate and Energy Policy Program.

As in our previous comments, we understand that the initial modeling results presented at this workshop are intended as a preview and summary of the full modeling results that will be released with the draft Scoping Plan Update in May. Our comments in this letter focus on two topics that were prompted by the workshop presentations and staff responses to questions posed by workshop participants. We hope to see further

---

[1] CARB, Public Workshop: 2022 Scoping Plan Update - Initial Air Quality & Health Impacts and Economic Analyses Results Workshop (April 20, 2022), https://ww2.arb.ca.gov/events/public-workshop-2022-scoping-plan-update-initial-air-quality-health-impacts-and-economic.

[2] Michael Wara et al., Public Comment on 2022 Scoping Plan Update – Initial Modeling Results Workshop (April 4, 2022), https://www.arb.ca.gov/lists/com-attach/65-sp22-modelresults-ws-BWQFcVMwUFxWI1Az.pdf

information and elaboration on these topics included in the draft Scoping Plan Update and its associated modeling data release:

1. The details of, and evidentiary basis for, the cost assumptions regarding early retirement of internal combustion engine (ICE) vehicles, particularly in Alternative 1.

2. The details of, and evidentiary basis for, the cost assumptions regarding Carbon Capture and Sequestration (CCS) on major petroleum refining operations, including assumptions about federal and state policy support.

1. Costs of early retirement of ICE vehicles

Slides 6-8 of the workshop presentation by Energy and Environmental Economic, Inc. (E3) illustrate the assumed cost implications of Alternative 1's retirement and replacement of all ICE vehicles in California with zero-emission vehicles (ZEVs) by 2035 (as well as replacement of gas appliances in buildings). It is our understanding from the workshop presentation and discussion that one factor leading to the high costs of Alternative 1 in 2035 is the assumption that such ICE/ZEV replacements result in scrapping of large numbers of ICE vehicles before their end of life. This makes sense from a PATHWAYS modeling perspective, however it is not the only reasonable scenario for how a conversion to a fully zero carbon fleet might occur. If instead, early-retired ICE vehicles were assumed to be resold outside of California, costs of this policy pathway would potentially be much lower. While (implicit or explicit) scrapping may be one option for effectuation of an early reduction of ICE vehicles in California, we could also imagine a policy approach involving the phaseout of legal registration of ICE vehicles in California. Under tha, in our view more likely policy approach, owners of ICE vehicles would have the opportunity to sell their vehicles either to used car brokers who would move them out of state or directly to out of state buyers as is not uncommon today. We note that a scrapping requirement would be difficult to enforce without paying vehicle owners for the trade-in value of their vehicles. In the draft Scoping Plan, we suggest that ARB clearly state its policy assumptions regarding this transition and consider evaluating the effect on costs of alternative policy assumptions.

2. Costs of CCS for refineries and federal and state policy support

Slide 6 of the April 20 workshop presentation by E3 shows sources relied upon for cost estimates for CCS and Direct Air Capture. Slide 8 of the workshop presentation by E3 illustrates modeled state-wide cost implications of policy scenarios including both DAC and CCS at refineries and other installations. While DAC comprises a substantial fraction of total costs in all scenarios that utilize it, petroleum refining CCS costs are not readily apparent.

We note that in Slide 6 of the E3 presentation at the Modeling Results workshop on March 15, 2022, Alternatives 3 and 4 assume that 33 to 39% of the refinery capacity in California is online in 2035. Slide 10 from the March 15th E3 presentation indicated that petroleum refineries are assumed to capture 90% of current carbon dioxide equivalent emissions by 2030. We wonder whether these data should be interpreted to mean that (a) most refineries close and a few remain open and implement CCS (perhaps 3 to 4) or (b) that a large number of refineries implement CCS retrofits at 90% capture but operate at a reduced output in future (as is envisioned in the Stanford-EFI study where 9 out of 13 California refineries implement CCS). Whichever scenario is the correct one, very large capital costs are implied but not evident in the April 20 E3 presentation.

Our assessment of actual CCS projects implemented at new refineries, as opposed to retrofits of existing refineries which are likely to be more complex because of space constraints and the need to utilize existing refinery components, indicates capital costs at hydrogen facilities of between $621 million (Port Arthur) and $338 million (Quest) per Steam Methane Reformer (SMR). More recently, Shell estimated that costs might fall by 30% for a facility similar to Quest to be built at the Scotford refinery in Alberta. SMR units are relatively speaking, simple as compared to the combination of SMR, Fluidized Catalytic Cracker (FCC) and Combine Heat and Power (CHP) needed to implement a more complete CCS refinery project. The only operating refinery in the world that attempts to capture as much of its CO2 emissions as is technically feasible, the Sturgeon refinery, in Alberta, cost upwards of $10 billion to achieve a 70% capture rate.

In any case, implementing CCS at a significant number of refineries in California is very likely to be a multibillion dollar investment per refinery. It is not clear where these costs appear in the estimates provided in Slides 7 and 8 of the April 20 E3 presentation. We are concerned by statements that incremental industrial stock costs are not included in the evaluation of overall costs (slide 8) given the potential magnitude of CCS retrofit costs. We believe that these costs might be anywhere from $8 to 90 billion dollar investment over a decade - although perhaps achievable for a lower cost given experience gained at the Alberta projects. We emphasize that these project costs will be imposed on the citizens of California in one way or another if they are either required or incentivized by state climate policies. They should be included in any analysis of statewide economic costs of climate policies and it is not clear at least from the summary figures presented to date that they are.

One possible explanation for the very low costs associated with petroleum refinery CCS retrofits evident in the E3 figures is that existing policies that reduce the costs to refiners of implementing these projects are included in the estimation of statewide policy cost (for an example of this approach, see Stanford-EFI, 2020, which includes LCFS and 45Q tax credit assumptions and finds a negative cost for SMR and FCC units as a result[3]). We respectfully request that ARB provide further information about the assumed costs of CCS retrofit projects at refineries in the modeled scenarios, including any assumptions about currently applicable policy incentives that may offset project costs.

These costs might be defrayed to some degree by LCFS credits, but we note that the emergence of a large number of renewable diesel projects is currently having a significant impact on LCFS credit values. Prices have fallen from approximately $200

[3] An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions, Stanford University and Energy Futures Initiative, 2020. See page 66 of the Stanford-EFI report for an example of building LCFS credit prices into assumptions regarding costs.

per ton in the 2018 to 2021 period to a current low of $113. Cost assumptions predicated on the availability of LCFS credit revenues are not well founded at this point, absent major structural changes to the program. This is particularly true given the Scoping Plan Update's vision (under all scenarios) of much reduced need for liquid fuels (and so reduced demand for LCFS credits). In any case, Californians pay for LCFS credits in their retail gasoline and diesel fuel prices. Therefore these costs should not be excluded from an analysis such as the Scoping Plan Update process that aims to evaluate statewide costs of California climate policies.

3. Conclusion

There are a wide variety of factors, currently unknowable, that may drive future costs of any large scale deployment of either DAC or CCS. The best available science on these costs combined with recent project level experience suggests that while these costs are still highly uncertain, they are very likely to be nontrivial. We don't presume to know what these costs will be but are interested in understanding the assumptions made by ARB that are necessary to arrive at model outputs for the Scoping Plan Update process.

We note in closing that in the last scoping plan, ARB made commendable efforts to evaluate uncertainties in its economic modeling. Given the longer time horizon for this plan - 23 years (2022 to 2045) vs 13 years (2017 t0 2030) as well as the much heavier reliance on technologies that have not yet seen widespread deployment, uncertainty analysis of projected technology costs is perhaps even more critical.

Thank you again for the opportunity to comment on the initial economic modeling results for the 2022 Scoping Plan Update. We hope our comments will be helpful in preparing the draft Scoping Plan Update. Please be in touch if we can further support your efforts.

Sincerely,

Michael Wara JD, PHD
Interim Director for Policy Engagement, Sustainability Accelerator, Stanford University
mwara@stanford.edu

Michael Mastrandrea PHD
Research Director, Climate and Energy Policy Program, Woods Institute for the Environment, Stanford University
mikemas@stanford.edu