April 4, 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 2022 Scoping Plan Update – Initial Modeling Results Workshop.[1] 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.

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 three topics that were prompted by the workshop presentations and staff responses to questions posed by workshop participants. We hope to see further information and elaboration on these topics included in the draft Scoping Plan Update and its associated modeling data release:

1. The "BAU reference" scenario and its underlying assumptions, including the estimated impacts of current regulations that are included in the BAU reference scenario.

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[1] CARB, 2022 Scoping Plan Update – Initial Modeling Results Workshop (March 15, 2022), https://ww2.arb.ca.gov/resources/documents/2022-scoping-plan-update-initial-modeling-results-workshop

2. The expectations regarding the overall structure of the draft Scoping Plan and the degree to which the portfolio of policies and measures necessary to achieve the emissions reductions envisioned in each modeled scenario of the draft Scoping Plan Update.

3. The evidentiary basis for the modeling assumptions regarding Carbon Capture and Sequestration (CCS) on major petroleum refining operations with a 90% capture rate that are included in Alternatives 2-4.

1. The BAU reference scenario and its underlying assumptions

Slide 5 of the workshop presentation by Energy and Environmental Economic, Inc. (E3) describes the BAU reference scenario as follows: "Aligns with current trends and includes the estimated impact of all current regulations and reflects our best estimate of what will happen with no further policy intervention."[2] Policy scenarios in turn reflect an estimated reduction in emissions relative to the BAU scenario as simulated by the modeling framework. In order to understand the policy scenarios, we need to have a clear understanding of the assumptions underlying the BAU scenario.

We note that BAU results were included in some slides in the modeling presentation but not in all. For example, petroleum extraction and refining BAU projections were shown in figures relating to the oil and gas sector. BAU emission projections were not included for all sectors, however.

Given the extended timeline of this Scoping Plan update process - considering a target date that is more than 22 years in the future, we respectfully request that ARB provide a broad description of the California the agency envisions in 2045 and descriptions of the current societal trends assumed in the BAU reference scenario, including population and economic growth assumptions, housing creation and sectoral technology and emissions trends.

[2] E3, CARB Draft Scoping Plan: AB32 Source Emissions Initial Modeling Results (March 15, 2022), https://ww2.arb.ca.gov/sites/default/files/2022-03/SP22-Model-Results-E3-ppt.pdf

In addition, we understand that ARB utilizes many assumptions derived from prior work by ARB and partner agencies (e.g., CEC, CPUC) and other entities (CAISO). Given the significance of the Scoping Plan process for charting a course for California climate policy, as well as its influence on other jurisdictions, a clear articulation of what is assumed in the BAU by sector would be extremely helpful to stakeholders in evaluating differences between scenarios and would improve the substantive contributions of stakeholder comments on the draft Scoping Plan. To be most informative, this information should ideally be provided in terms of changes over time in sectoral technology and energy demand mixes, as well as consequent GHG emissions.

We also request that ARB provide quantitative estimates of the effects of current laws or regulation that will significantly impact future GHG emissions. This is most important for the nearer-term target, 2030. With this information, stakeholders can more easily understand the emission reductions expected from current policies included in the BAU reference scenario versus those expected from modeled policy scenarios. There are many policies, including executive orders (most notably EO B-55-18, motivating consideration of 2045 as a target year for achieving carbon neutrality and EO N-79-20, establishing a goal of ICE vehicle sales phaseout by 2035), statutes (SB100), and implementing regulations that are expected to impact statewide GHG emissions. It would be helpful to all stakeholders to have a complete understanding of which policies and implementation processes are counted toward the baseline and which are counted towards policy scenarios described in the draft Scoping Plan.

Finally, the PATHWAYS model, and ARB's accounting, are generally focused on in-state activity and GHG emissions, taking imports and exports as static. But of course, California's economic wealth is predicated on an open commerce both with other states and with the global economy. We suggest that if ARB's preferred regulatory approach may lead to significant changes in imports or exports of emissions intensive products, these implications, both in the baseline and policy scenarios, should be included in scenario data and/or discussion released for public comment.

We very much appreciated the lengths that ARB went to during the last Scoping Plan Update process (2017) to make information from the PATHWAYS modeling work available to all stakeholders and ask that as much information as possible be provided with the release of the draft Scoping Plan Update to facilitate informed and well grounded comments.

2. Policies and measures in the Alternative Scoping Plan Scenarios

Past Scoping Plan updates as well as the current update reflect California’s commitment toward sustained efforts to lower statewide GHG emissions. Continuously building on the AB32 framework, ARB has worked to integrate new topics and policies as they become relevant to the state's ambitious climate change goals. ARB has wide latitude to interpret the guidance provided by the legislature in crafting a climate change Scoping Plan (and updates) under AB32. ARB has used this authority in the past to ensure that the Scoping Plan update process reflects the needs of the agency for planning towards near- and longer-term compliance goals.

We were struck by questions posed by stakeholders in the Modeling Results Workshop regarding whether emission scenarios, policies and measures, or both would be included in the draft Scoping Plan when it is released.[3] We believe that ARB has wide latitude to produce a Scoping Plan as it sees fit under AB32, and present below a table illustrating past approaches in prior Scoping Plan updates that may be useful to evaluating the approach taken in the current process.

[3] See for example, question and answer during the CARB, 2022 Scoping Plan Update – Initial Modeling Results Workshop (March 15, 2022), at 1h:34m to 1h:37m in the workshop recording.

Table 1: Topics Covered in the initial Scoping Plan and subsequent Scoping Plan Updates.

	2008 Scoping Plan	2013 Scoping Plan Update	2017 Scoping Plan Update
Quantified Emission Reductions	x		x
Specified Policies and Emission Reductions Measures	x	x	x
Identified Opportunities for Emission Reduction Measures	x	x	x
Allocation of Emission Reductions Between Policies	x		x
Evaluation of Potential Costs of Policies	x		x
Cost-Effectiveness Evaluation	x		x
Evaluation of Potential Benefits (economic and non-economic)	x	x	x

3. Experience with CCS in the refining sector

Many of the modeled scenarios presented at the Initial Modeling Results Workshop assume a significant role for CCS retrofits at California oil refineries in the period to 2030. Here, we present results of an initial, focused research effort on the current prospects for and recent performance of CCS at oil refineries or related facilities (e.g., adjacent Steam Methane Reformers [SMRs]).

While it is difficult to find measured capture efficiencies for existing refinery related CCS projects, a recent journal article in *Frontiers in Chemical Engineering* reviewed options for retrofitting oil refineries with CCS.[4] The authors note that, in a disaggregated system like a refinery there are many components that release emissions. Of these components, only the most emissions-intensive can be feasibly and economically retrofitted with CCS: the power station (accounting for ~29% of emissions), the fluid catalytic cracking unit (~19% of emissions), the atmospheric distillation units (~19% of emissions), and the steam methane reformer (~11% of emissions). Together, these components account for ~78% of the average refinery's emissions. If we assume the ambitious capture efficiency of 90% presented earlier, total refinery emissions reductions at the facility scale would be 70%, as shown in the figure below.[5] Importantly, this does not account for the additional energy necessary to power the CCS infrastructure itself (noted below as x%). While we could not find refinery specific estimates of the increased parasitic load to support CCS, we note that at electric power plants, CCS related parasitic load leads to a significant downrate in nameplate capacity - often greater than 15%.

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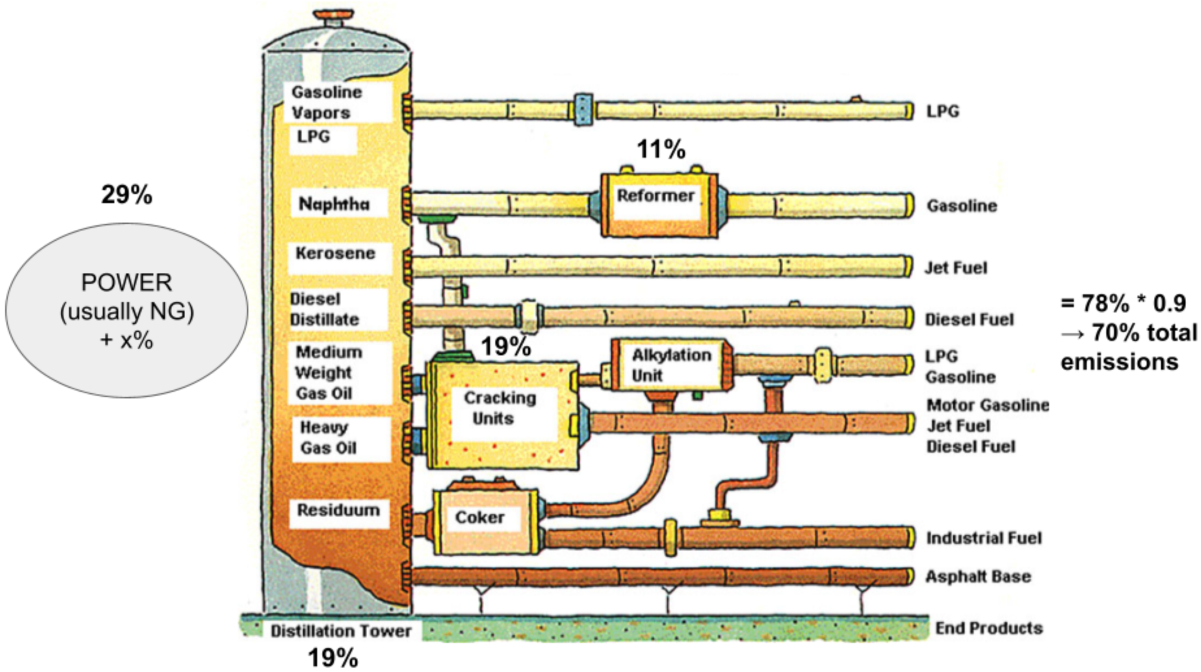
[4] Sunny, N., Bernardi, A., Danaci, D., Bui, M., Gonzalez-Garay, A., & Chachuat, B. (2022). A pathway towards net-zero emissions in oil refineries. *Frontiers in Chemical Engineering, 4*. https://www.frontiersin.org/articles/10.3389/fceng.2022.804163/full

[5] Figure adapted from: Penn State University, The process of crude oil refining. (n.d.) https://www.e-education.psu.edu/eme801/node/470

Figure 1: Major refinery components and percentage of total GHG emissions from these sources with respect to total facility level GHG emissions.



Another study, conducted by the International Energy Agency in 2017, found even lower emissions avoidance potential. The IEA examined a suite of oil refineries with various capacities and complexities, ranging from a simple hydroskimming refinery to a large complex oil refinery. Across the refinery models examined, the researchers found that between 12.4% and 51.5% of emissions could be avoided. As refineries grew in size and complexity, the share of emissions that were possible to avoid with CCS retrofits decreased.[6] Refineries are among the most complex, sophisticated and potentially dangerous industrial facilities, and each refinery is constructed with a specific blend of crudes in mind. We respectfully request that ARB provide further information about the assumptions for capture potential and facility-scale emissions avoidance through CCS retrofits at the currently operating refineries in California.

We also urge that the costs of CCS retrofits on oil refineries are worth examining within the Scoping Plan Update process given their potential magnitude. A study conducted by

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[6] IEA, Understanding the Cost of Retrofitting CO2 capture in an Integrated Oil Refinery. (August 2017). https://ieaghg.org/publications/technical-reports/reports-list/10-technical-reviews/819-2017-tr8-understanding-the-cost-of-retrofitting-co2-capture-in-an-integrated-oil-refinery

Concawe, an oil and gas industry research group, in partnership with the International Energy Agency, examined four existing refineries of various sizes and capacities. It found the cost of CCS retrofits for oil refineries to be much higher than what is typically reported in the literature for other sources (e.g. electric power plants). As they identified, oil refineries require significant resource and energy inputs for CCS in order to affix CCS to existing refinery infrastructure. In their words, “[t]here is no synergy with the refinery. The utilities cost is based on the installation of an additional CHP plant, cooling water towers and waste water plant, which are designed with significant spare capacity in some cases (up to 30% overdesign).” The authors found capture costs to be between $160 and $210 per ton of CO2 avoided. Total capital expenditures were approximated to be between $200 million and $1.5 billion per facility.[7] We believe it is important to consider these potential costs, on a CAPEX and OPEX basis, and to evaluate how they might impact the demand for domestically produced versus imported refined petroleum products.

Evidence from the few existing projects suggests that costs might go even higher than estimated in these studies. For example, the Port Arthur SMR facility, an early refinery related capture project, cost $621 million to construct. The Quest project (4 steam SMRs at an upgrader in Alberta) cost $1.35 billion to construct. The Sturgeon Refinery, the first purpose-built refinery designed to capture a substantial fraction of its GHG emissions (~70%) has so far cost approximately $10 billion and ultimately required the Alberta government to purchase a 50% stake in the project in order to maintain its economic viability. California can afford this level of investment given the strength and size of its economy. But these costs are very large relative to incentives that might be available via the Greenhouse Gas Reduction Fund or the notional value of LCFS credits.

Finally, we note that CCS projects have frequently experienced significant setbacks in their construction phases. Delays not only affect project timelines and contributions to

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[7] Concawe, https://www.concawe.eu/wp-content/uploads/Importance-of-CCS-in-European-refineries-Concawe-27-1.pdf

modeled emission reductions pathways but can also have significant effects on project costs. PATHWAYS scenarios that include CCS to help decarbonize oil refineries presented at the workshop seemed to assume that CCS retrofits would, at least to some degree, become operational beginning in the next several years. However, we were unable to find any examples of projects that completed the construction stage (ie post-permitting) in less than 2 or 3 years in ambitious cases, or closer to 5 to 10 years in others.[8] Given this, we respectfully request that ARB provide further information about the assumed timing of deployment of CCS retrofit projects in the modeled scenarios that rely on CCS retrofits at California refineries.

In sum, we urge ARB to consider the engineering complexity and cost of CCS implemented at refineries - particularly retrofit of existing refineries, before relying on this strategy at refineries in California. We do not take a position on the wisdom of this approach to reducing emissions but urge full consideration of the complexity and economic implications of such an undertaking.

[8] See for example, the Sturgeon Refinery project (8 years) and Quest SMR project (3 years) in Alberta and the Port Arthur SMR project (3 years) in Texas. These are the only three projects we were able to identify that have actual construction timelines, costs, and operational performance data available.

Thank you again for the opportunity to comment on the initial 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,

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