Tanya DeRivi
Vice President, Climate Policy
Western States Petroleum Association

June 24, 2022

(Submitted via the Draft 2022 Climate Change Scoping Plan and by email to Rajinder.Sahota@arb.ca.gov.)

Ms. Rajinder Sahota
California Air Resources Board
1001 I Street,
Sacramento, CA 95814

Re: Comments on the Draft 2022 Scoping Plan Update

Dear Ms. Sahota:

The Western States Petroleum Association (WSPA) appreciates the opportunity to present these comments on the Draft 2022 Scoping Plan documents[1] released by the California Air Resources Board (CARB). WSPA is a non-profit trade association that represents companies that explore for, produce, refine, transport and market petroleum, petroleum products, natural gas, and other energy supplies in California and four other western states. It has been an active participant in air quality planning issues for over 30 years.

Our members form the backbone of California's economy, providing jobs, fueling air, road, and marine transport, and supplying necessary energy to the manufacturing and agriculture sectors. Our industry generates more than $152 billion in total economic output and make significant fiscal contributions to California's state and local governments, including more than $21 billion in state and local tax revenues, $11 billion in sales taxes, $7 billion in property taxes, and $1 billion in income taxes.

While the economic impact numbers are compelling, our industry's greatest asset and contribution to the state's economy are the more than 366,000 jobs supported in the State. We produce 42 million gallons of gasoline and 10 million gallons a day of diesel to support the State's 35 million registered vehicles. All these contributions to the state occur while our members continue to lower the carbon intensity (CI) of their fuels consistent with the low carbon fuel standard (LCFS) program and spur investment in emission reduction technologies and renewable fuels.

[1] 2022 Scoping Plan Documents. Available at: https://ww2.arb.ca.gov/resources/documents/2022-scoping-plan-documents. Accessed: June 2022.

A summary of our key comments on the Draft 2022 Climate Change Scoping Plan is provided below with additional details in **Attachment A** (Technical Comments) and **Attachment B** (Legal Comments):

1. **WSPA agrees with CARB that Alternatives 1 and 2 are infeasible for the reasons stated in the Draft 2022 Scoping Plan Update and are not the right choice for California due to the significant economic impacts and very real concerns over technical feasibility and scalability of the technologies assumed under both alternatives.**

These alternatives raise very real questions as to their technical feasibility and would have the highest costs when compared to the Proposed Scenario, ultimately resulting in a drastic setback for industries across the State, the State's economy and California consumers. WSPA commends CARB for acknowledging the cost burdens and infeasibilities that accompany Alternatives 1 and 2. Specifically, Alternatives 1 and 2 would slow job and economic growth between 3-8 times more than the Proposed Scenario, as noted in **Comment A.1** in **Attachment A**.[2] This impact to the economy is simply unacceptable.

In these alternatives, there is likewise a large economic impact associated with the reliance on zero emission (ZE) technologies. Alternative 1 would mandate early retirement of combustion vehicles, appliances and industrial equipment to achieve a ZE-only outcome by 2035. Alternative 2 would mandate early retirements of medium- and heavy-duty (M/HD) vehicles to achieve a statewide ZE M/HD vehicle fleet by 2045.[3] These early retirements would essentially force certain California businesses to decide whether to move out of the state (leading to economic and environmental leakage) or simply close leading to gross domestic product (GDP) and job losses. It is also critical to consider the impact on consumers and residents throughout the state as early retirement mandates for vehicles and appliances prior to end of life would put significant cost pressures on consumers. Low income consumers would not be economically equipped to commit to such exorbitant transitions without extreme financial incentives from the State.[4]

Alternatives 1 and 2 likewise would assume unprecedented levels of growth in emerging technologies and accompanying infrastructure improvements. The complete elimination of combustion under Alternative 1 would mandate a dramatic reconstruction of California's economy at a pace that is not technically feasible. This is not to mention the significant changes required to daily life and consumer behavior required for this plan to succeed. CARB has simply not demonstrated this scenario to be feasible at any cost.

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2 Draft 2022 Scoping Plan Update. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

3 2022 CARB Draft Scoping Plan: AB 32 Source Emissions Initial Modeling Results. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-03/SP22-Model-Results-E3-ppt.pdf. Accessed: June 2022.

4 Draft 2022 Scoping Plan Update. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

Alternative 1 would require annual buildout rates for solar capacity of 10 gigawatts (GW) and battery storage of 5 GW. Alternative 2 would require annual buildout rates for solar capacity of 5 GW and battery storage of 3 GW. The current build rates for these technologies are 2.7 GW/year and 0.3 GW/year.[5] To put it in other terms, the buildout rates would need to increase four-fold under Alternative 1 and two-fold under Alternative 2 by next year and sustain that rate through 2035 in order to achieve carbon neutrality. Any delay would mean even higher build rates in subsequent years. This protracted level of increase in generation and storage would also have to be accompanied by an equally large increase in electrical infrastructure improvements, expansions, and upgrades. Such development is not technically or economically feasible on the assumed timetables. To expand existing generation and grid capacity in this manner would require trillions of dollars in electric infrastructure upgrades to be funded and delivered at an unprecedented schedule.

The alternatives also require significant buildout of negative emissions technologies to offset emissions left in the system. While WSPA strongly supports the use of negative emissions technologies to achieve carbon neutrality, their deployment will take time and the extra 10 years between 2035 and 2045 will be necessary for the technologies to achieve the scales needed to achieve carbon neutrality.

The buildout mandate for zero emission vehicles (ZEVs) under these scenarios also assumes a phase out of in-state refining and oil & gas production. Alternative 1 would completely eradicate petroleum refining, and Alternative 2 would only allow 25% and 8% of current petroleum refining in 2035 and 2045, respectively.[6] These assumptions are inconsistent with the reality that there will be ongoing demand in California for petroleum products for on-road, off-road, aviation, railroad and marine transport in 2035 and beyond. The scenarios also fail to recognize that regardless of the actions California takes, fuels produced in California are exported to meet demand in neighboring markets, such as Arizona and Nevada. A complete phase out of oil and gas production and refining in California under Alternative 1 would simply shift the demand for fuels from these neighboring states to producers outside of California, causing a leakage of economic activity and emissions that is specifically prohibited in Assembly Bill (AB) 32. Even though Alternative 2 does not strictly eliminate the industry, it also does not account for the ongoing demand for fuel exports from California. Ultimately, in both alternatives there would still exist significant petroleum products demand and failure to acknowledge such would leave millions inside and outside of California stranded.

Recommendation: CARB should eliminate Alternatives 1 and 2 from consideration.

5 Ibid.

6 Ibid.

2. WSPA has reviewed the Proposed Scenario (Alternative 3) along with its key assumptions and believes that significant improvements can be made to improve the feasibility of the Alternative to achieve the State's goals in a more cost-effective manner.

WSPA continues to be concerned with CARB's reliance on a ZEV-only approach in achieving the state's greenhouse gas (GHG) and air quality goals within the transportation sector. As we have commented during the Scoping Plan's development and through the Advanced Clean Trucks (ACT), Advanced Clean Fleets (ACF), and Advanced Clean Cars II (ACC II) rulemakings, CARB's analyses fail to evaluate the cost-effective air quality and GHG reduction benefits that other technology options such as near-zero emissions vehicles and low-carbon and renewable fuels could deliver. Ramboll's case studies of the heavy-heavy duty truck (HHDT) fleet[7] and the light duty automobile (LDA) fleet[8] demonstrate that there are alternative pathways using renewable other low carbon fuels that can dramatically reduce transportation sector carbon emissions without ZEV mandates. As we recommended in our previous letters outlined in **Attachment C**, we again request CARB undertake this analysis and consider the benefits of utilizing these technologies and timelines for achieving carbon neutrality and improving air quality in highly-impacted communities.

There are other examples throughout the Scoping Plan where constraints are placed on sectors that are not cost-effective. Removing or relaxing these constraints could reduce economic costs without sacrificing the overarching carbon neutrality goal. Examples of unnecessary constraints include not allowing any emissions from hydrogen production in 2045 (as is allowed for every other sector), not allowing CCS on natural gas power plants in the electricity sector, and limits on renewable fuels. As shown in the study conducted by NERA Economic Consulting ("NERA Study") (**Attachment D**), a market-based scenario without these multiple mandates and constraints could achieve emission reductions equivalent to the Proposed Scenario at lower cost. The NERA Study also shows how a rigid ZEV-only approach in the transportation system has a very concerning ripple effect on other sectors. Allowing a more flexible approach in the transportation system, opens up the range of possible solutions which can achieve carbon neutrality more cost-effectively.

The Proposed Scenario acknowledges that any effort to achieve carbon neutrality will be heavily reliant on carbon sequestration and negative emissions technologies. WSPA strongly supports the use of carbon capture and storage (CCS) and carbon dioxide removal technologies (CDR) (e.g., direct air capture [DAC]). We also strongly agree with CARB that significant effort needs to be undertaken within the state to streamline and speed up permitting for CCS and other low-carbon technology options. As detailed in the NERA Study (**Attachment D**), an increase in the use of DAC from the Proposed Scenario could be used to

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7 The Ramboll HHDT study is available here: https://www.arb.ca.gov/lists/com-attach/78-sp22-kickoff-ws-B2oFdgBtUnUAbwAt.pdf. Accessed: June 2022.

8 Ramboll. 2022. Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study. Available as Attachment D at: https://www.arb.ca.gov/lists/com-attach/477-accii2022-AHcAdQBxBDZSeVc2.pdf. Accessed: June 2022.

more cost effectively balance emissions from sectors that are more costly to decarbonize. That would reduce the overall costs of this Scoping Plan Update. If DAC proves to be less costly than the costs assumed by NERA, it is possible to push DAC even harder to balance out emissions at a lower costs. Both CCS and DAC can be further supported economically with reasonable changes to the Cap-and-Trade and the LCFS programs. These changes would provide important market signals to project proponents that the state is supportive of these technologies for the long-term.

As CARB recognized in the 2008 Scoping Plan, there is an important role for Cap-and-Trade in ensuring the state's GHG reductions. For the current Scoping Plan update, WSPA believes that Cap-and-Trade can continue to ensure that economy-wide emissions reductions are accomplished more cost effectively as is required by AB 32 while providing flexibility to accommodate the considerable uncertainties in multi-decade planning forecasts. This becomes even more critical as lower cost emission reduction options are completed and all that is left is extremely costly options. WSPA suggests that CARB should expand Cap-and-Trade's role in achieving carbon neutrality.

WSPA agrees with CARB that a complete phaseout of oil and gas extraction and refining is simply not feasible by 2045 due to real concerns over leakage. California refineries supply fuels to other U.S. states including states in the Southwest. Through the possible future application of CCS technologies for industrial emissions and production of low-carbon and renewable liquid fuels at California refineries, California's exports could play a pivotal role in reducing the CI of fuels consumed in other states compared to fuels produced elsewhere.

The Proposed Scenario does pose significant potential for leakage of emissions due to its technology forcing mandates. The Draft 2022 Scoping Plan ignores the life cycle emissions of "zero emission" vehicles and does not assess the leakage of emissions that would be caused by increased mining activities, battery production, recycling, and disposal under the proposed LDV and medium-duty vehicle (MDV)/heavy-duty vehicle (HDV) ZEV mandates. It also does not consider the life cycle emissions that would be caused by a dramatic development of electric infrastructure, including solar panels, wind turbines, and grid-scale battery production impacts. All of these have considerable embedded GHG emissions and would largely be produced outside California. Further, actions to phase down California's oil and gas extraction and refining would cause increased production and refining of liquid fuels outside of California from operations with higher GHG intensities. All of these unconsidered impacts would represent emissions leakage. AB32 requires CARB to minimize "leakage" of GHG emissions from California's economy.[9]

<u>Recommendation</u>: CARB should modify the Proposed Scenario to reduce the number technology mandates and constraints, and place greater emphasis on the power of market mechanisms such as Cap-and-Trade that encourage innovation and are more likely to deliver cost-effective reductions.

[9] Health & Safety Code section 38562(b)(8).

3. WSPA believes that Alternative 4 faces many similar challenges to those presented under the Proposed Scenario (Alternative 3).

While Alternative 4 does ease some of the technology implementation timelines, it does not address the main underlying concerns with heavy electrification. Alternative 4 will still require unprecedented deployment of solar and battery storage technology (annual buildout of 6 GW and 2 GW in comparison to the historic annual maximums of 2.7 GW and 0.3 GW respectively), does not address the significant concerns with grid reliability and infrastructure expenditures required to support electrification, nor does it abate the leakage of emissions that would be associated with global mineral mining, battery production, and battery recycling as a result of the Scoping Plan.

Recommendation: While Alternative 4 has fewer technology mandates than Alternative 3, it still relies too heavily on unprecedented deployment of electricity expansion. Again, CARB should modify its recommended Alternative to more fully embrace other low-carbon solutions.

4. A study conducted by NERA Economic Consulting shows that a market-based approach to the Scoping Plan has the capability to achieve carbon neutrality by 2045 at less economic cost.

Given the criticality of this Draft 2022 Scoping Plan, WSPA commissioned a study with NERA Economic Consulting (“NERA”), provided in **Attachment D**, to explore additional scenarios that could achieve the state’s climate goals. Scenarios were required to achieve net-zero emissions by 2045. From this work, two primary comparative scenarios were developed and explored more deeply. One scenario, which approximates the Proposed Scenario, relies to a greater extent on sector-specific mandates (the “Regulatory” scenario), while the other relies to a greater degree on market forces by use of a unifying price signal (the “Market” scenario).

Comparative results from the two studies are compelling. While both scenarios achieved carbon neutrality by 2045, the Market scenario did so with just over half the adverse economic impact as projected by differences in state gross domestic product (GDP). Perhaps even more notably, the Market scenario actually resulted in a greater volume of earlier emission reductions in its trajectory to reach carbon neutrality. As CARB is well aware, achieving earlier emission reductions when feasible is a desired outcome of climate policy.

The report illuminates there are important trade-offs for CARB to consider between these two scenarios, with an important underlying message that forcing deeper emission cuts in certain sectors leads to unnecessarily higher costs to achieve the same 2045 goal. This conclusion, coupled with the recognition that a mandate-heavy approach carries greater technology risks, makes it compelling to update the Draft 2022 Scoping Plan to rely more on market-based approaches.

The full NERA report (“NERA Study”) that documents this analysis is provided as **Attachment D**. WSPA would welcome the opportunity to further explore these important conclusions with you with an aim to develop a plan that achieves the state’s objectives at lower cost.

Recommendation: WSPA maintains that a technology neutral, market-based approach to achieving California's GHG reduction goals is more technologically and economically feasible and CARB should make serious considerations as to what approach would best serve California.

5. WSPA agrees with CARB that an improved and streamlined project environmental review and permitting process is necessary to deliver the Draft 2022 Scoping Plan Update.

The environmental review process under the California Environmental Quality Act (CEQA) has proved to be a significant barrier to projects and permitting certainty in the past. The following actions should be considered while creating a streamlined process for obtaining permits and for review and litigation under CEQA for eligible low carbon projects:

- Create a new agency under to Office of Planning and Research to act as a lead agency for eligible low carbon projects that opt into the streamlined process for environmental review and litigation.
- Streamline the environmental review process under CEQA by establishing aggressive timelines for completeness determination, preparation of environmental impact report or negative declaration, recirculation period, and project approval.
- Streamline the litigation process to facilitate quick resolution including expedited preparation of the administrative record.
- Provide flexibility for local, regional or state agencies that act as lead agency for eligible low carbon projects to access aspects of the expedited environmental review and litigation process.

Recommendation: CARB should work with the Office of Planning and Research to develop an improved and streamlined project environmental review (under CEQA) and permitting process for the low-carbon projects that are essential for the implementation and delivery of the Draft 2022 Scoping Plan Update.

Conclusion

The Draft 2022 Scoping Plan should ultimately be constructed with an eye towards supporting and fostering technological innovation. Doing so could create a foundational framework that would attract more investment into the market which would help the state achieve its long-term climate goals. WSPA strongly recommends that CARB remove technology mandates and restriction in the Proposed Scenario (Alternative 3) and rely more heavily on technology-neutral market-based approaches, to achieve emission reductions with additional support from the Cap-and-Trade program. As noted in our previous comment letters, we believe that such market-based approaches will achieve carbon neutrality in the most cost-effective manner.

Thank you for the consideration of our comments. WSPA would welcome the opportunity to discuss these comments and recommendations in more detail with you. Please feel free to contact us at tderivi@wspa.org, jverburg@wspa.org, and sellinghouse@wspa.org, with any questions or concerns.

Sincerely,

Tanya DeRivi
Vice President
Climate Policy
WSPA

cc: Jim Verburg, WSPA Director Fuels

Sophie Ellinghouse, WSPA Vice President, General Counsel and Corporate Secretary

Attachment A: Technical Comments
Attachment B: Legal Comments
Attachment C: List of Previous WSPA Comments on the Draft 2022 Climate Change Scoping Plan
Attachment D: Economic Impacts of Achieving California's 2022 Draft Scoping Plan's "Proposed Scenario" by NERA Economic Consulting dated June 2022

ATTACHMENT A
Technical Comments

As noted in the cover letter, detailed technical comments on the Draft 2022 Climate Change Scoping Plan are provided below:

Alternative 1 and 2

A.1 CARB's own economic modeling shows that Alternatives 1 and 2 are economically infeasible.

Alternatives 1 and 2 are not economically feasible pathways to meet the State's GHG goal. Consider the following outcomes of the two alternatives that are described in the Draft 2022 Scoping Plan Update.[10]

- Alternatives 1 and 2 would slow job growth 5 times and 3 times more, respectively, than the Proposed Scenario.
- Alternatives 1 and 2 would slow economic growth 8 times more than the Proposed Scenario in 2035 and 5-6 times more in 2045.
- In terms of scenarios for the Natural and Working Lands (NWL), Alternative 1 would result in direct costs 25 times greater than those relative to the Proposed Scenario.
- Alternative 1 would also require the highest stock costs in both 2035 and 2045 to meet the demand for ZEVs and appliances and the elimination of fossil fuel combustion. The replacement of this equipment near 2045 would likewise result in additional stock costs.

CARB must allow for an economic turnover of vehicles and appliances that allows for consumer choice, to comply with the economic limitations faced by both industries and consumers. CARB should also consider the unprecedented cost of incentives and funding that would be needed to meet the demands of Alternatives 1 and 2.

A.2 CARB's modeling shows that an all-electrification option by itself will not reach the State's GHG reduction targets.

Alternative 1 presents an all-electrification scenario with a near complete phaseout of all fossil fuel, biomass-derived, and hydrogen combustion technologies. Alternative 1 calls for early retirement of internal combustion engine vehicles (ICEVs), appliances, and industrial equipment by 2035. To appease this goal, the state would need to establish buy-back programs to account for forced replacement of vehicles and appliances before end of life. It would similarly require forced retrofits of equipment that utilizes high-global warming potential (GWP) equivalent materials and mandatory replacements of existing equipment that utilizes high-GWP equivalent materials to meet its building electrification demands. Alternative 1 likewise entails a complete eradication of petroleum refining, as well as solar and battery development targets at levels impossibly greater than current levels.

CARB's modeling shows how difficult and costly the transition to achieve carbon neutrality by 2035 and 2045 would be under Alternatives 1 and 2. Even with the drastic ambitions mentioned above, Alternative 1 would still require CDR to compensate for non-combustion emissions and short-lived climate pollutants. Without CDR, it would not achieve its 2035 carbon neutrality goal.

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10 Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

Alternative 1 also presents the highest degree of uncertainty around the availability of solar to support the electrification of existing sectors. As referenced in **Comment 1**, these extreme buildouts of electrical generation, grid capacity, and technology production are neither cost effective nor feasible.

WSPA believes that market-based approaches would allow greater innovation within existing markets to accomplish California's GHG targets without the systemic risks associated with an all-electrification approach (e.g., infrastructure readiness, ZE technology readiness, cost). Alternatives 2 through 4 acknowledge the continued use of liquid and gaseous fuels in the State's transportation and industrial sectors through at least 2045. The California fuels industry is already responding to the need to reduce GHG emissions by increasing production of renewable fuels.[11]

Reference Scenario Modeling Assumptions

A.3 CARB has updated their reference scenario modeling assumptions for the light-duty vehicle (LDV) sector to include 40% ZEV LDV sales by 2030, without giving appropriate basis for why this is an appropriate assumption to make.

In CARB's 2017 Scoping Plan, the business as usual (BAU) scenario projected that there would be approximately 3 million LDV ZEVs by 2030 and 4.7 million LDV ZEVs by 2045. However, the BAU scenario in the Draft 2022 Scoping Plan projects that there will be 40% LDV sales by 2030,[12] 3.6 million LDV ZEVs by 2030, and 11.3 million LDV ZEVs by 2045.[13] In the Reference Scenario assumptions table for the Draft 2022 Scoping Plan Update (Appendix H, Table H-14),[14] this sales target of 40% LDV ZEVs is noted and followed by a statement that this is "aligned with CA Institute of Transportation Studies BAU scenario".[15] In the BAU Scenario from the Institute of Transportation Studies, the assumption for ZEV share of LDV sales is reported as 20% by 2030 along with a stock of around 3 million vehicles.[16] This does not align with the value given in CARB's Reference Scenario assumptions table (Table H-14).[17] CARB must give

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11 S&P Global Commodity Insights. 2022. California approves Marathon's and Plillips 66's refinery -to-renewable repurposing. May 4. Available at: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/agriculture/050422-california-approves-marathons-and-phillips-66s-refinery-to-renewable-repurposing. Accessed: June 2022.

12 CARB. 2022. Appendix H - AB 32 GHG Inventory Sector Modeling. May 2. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-h-ab-32-ghg-inventory-sector-modeling.pdf. Accessed: June 2022.

13 CARB. 2022. California PATHWAYS Model Outputs. May 2. Available here: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-PATHWAYS-data-E3.xlsx. Accessed: June 2022.

14 CARB. 2022. Appendix H - AB 32 GHG Inventory Sector Modeling. May 2. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-h-ab-32-ghg-inventory-sector-modeling.pdf. Accessed: June 2022.

15 Ibid.

16 University of California Institute of Transportation Studies. 2021. "Driving California's Transportation Emissions to Zero." April 22. Available at: https://doi.org/10.7922/G2MC8X9X. Accessed: June 2022.

17 CARB. 2022. Appendix H - AB 32 GHG Inventory Sector Modeling. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-h-ab-32-ghg-inventory-sector-modeling.pdf. Accessed: June 2022.

reasoning for increasing the baseline number of ZEV sales beyond this California Institute of Transportation Studies BAU scenario. This is critical because CARB's costs modeled for the alternatives are relative to the BAU. Thus, all the costs associated with the BAU are not captured by the economic analysis presented for the Scoping Plan. We request that CARB include the costs of the BAU in the Scoping Plan as the Plan is meant to lay out a pathway to achieving carbon neutrality from now until 2045, not from 2030 to 2045.

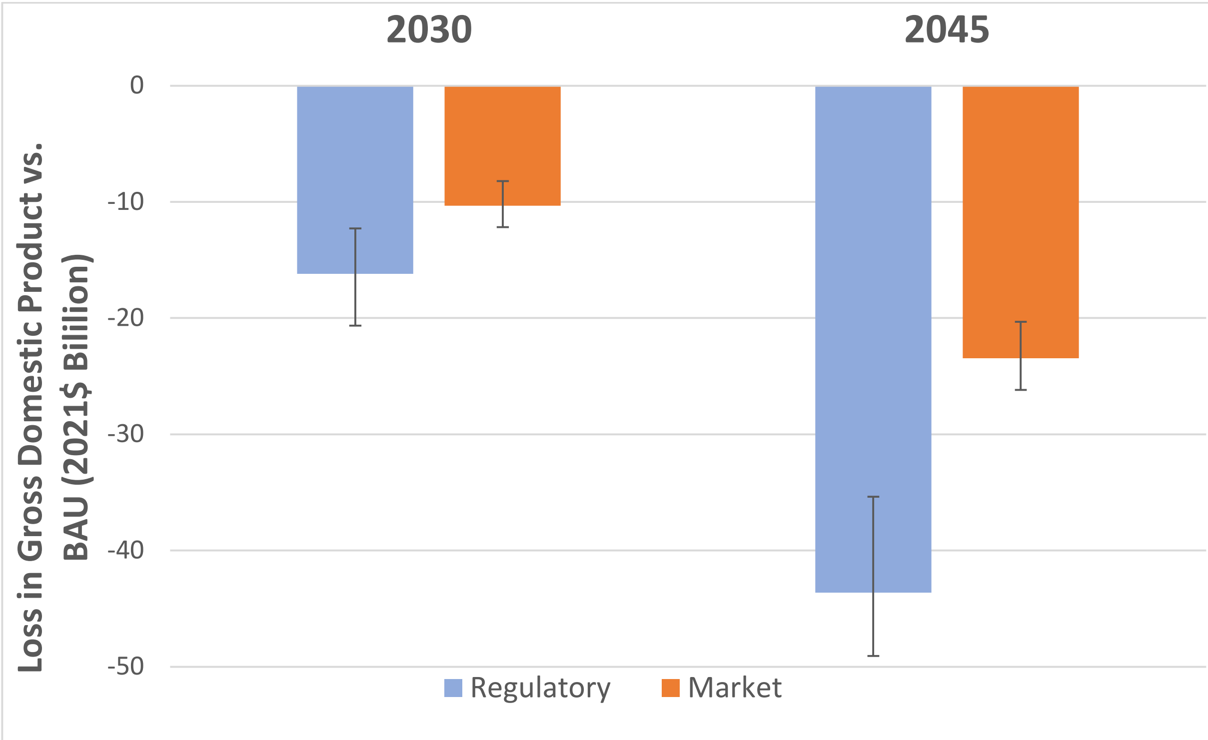
General Comments on Proposed Scenario (Alternative 3)

A.4 Despite addressing many of the feasibility concerns presented in Alternatives 1 and 2, CARB's Proposed Scenario (Alternative 3) is not the most cost-effective path to achieve carbon neutrality. Improvements can be made to Alternative 3 to bring it more in line with a cost-optimized approach like that shown by the NERA Study.

The modeling work that CARB utilized to support the Proposed Scenario (Alternative 3) in the Draft 2022 Scoping Plan, imposes unnecessary technology mandates that would preclude outcomes that would be more cost-effective and technically feasible. For example, CARB placed arbitrary limits on low-carbon and renewable fuels, DAC and other applications for CCS, limits on (plug-in) hybrid electric vehicles (HEVs/PHEVs) that provide important flexibility when there are grid constraints, and unnecessary constraints regarding the production (and use of) hydrogen fuels.

NERA's Scenario Modeling analysis (included in **Attachment D**), identified a market-based approach that delivered the Proposed Scenario results at a much lower cost. Their Market Scenario resulted in approximately 37% less GDP loss in 2030 (i.e., $10 billion versus $16 billion) and 48% less GDP loss in 2045 (i.e., $23 billion versus $44 billion) when compared to a Regulatory Scenario that embodied elements of CARB's Proposed Scenario. This is shown in **Figure A-1**. Expressed in household impacts, the Market Scenario reduced per household consumption impacts from $1,890 to $820 in 2045.

Figure A-1: Loss in Gross Domestic Product vs. BAU



This study shows that the required emission reductions to achieve carbon neutrality by 2045 are achievable with a Market Scenario at much lower cost impacts as compared to the Proposed Scenario. Such a strategy could also reduce the systemic risks inherent to the all electrification option. CARB should replace the constraints on the transportation sector (**Comments A.11, A.12,** and **A.14**), oil & gas sector (**Comments A.15** through **A.20**), and hydrogen sectors (**Comment A.21**) in the Proposed Scenario and increase the reliance on market-based mechanisms (**Comments A.5, A.9,** and **A.10**).

A.5 CARB is missing opportunities to optimize the Scoping Plan by viewing emission reductions for individual sectors rather than across the economy as a whole.

The Draft 2022 Scoping Plan Update is intended to be a long-range road map for California's climate policies through 2045. Optimally, CARB should ensure that multiple decarbonization pathways are available without unnecessarily constraining pathways for individual sectors. While understanding the dynamics of a specific sector is important, there are interface and decision points between them that serve as key points for optimization. The actual optimum will only be apparent many years into the future. The Scoping Plan workshop process has been useful in highlighting current and potential future technologies, but mandating specific pathways for individual sectors at this point, as indicated by overreliance on direct measures and mandates in the Proposed Scenario (Alternative 3), is naïve and more likely to fail to meet the program's goals. Instead, CARB should maintain and prudently expand the role of the Cap-and-Trade Program to enable the most cost-effective emissions reductions to meet the State's climate goals over the next two decades. The NERA Study (**Attachment D**) clearly shows that market-based programs like Cap-and-Trade will allow industries across all sectors to find the most cost-effective technologies to meet the desired emission reduction targets. Such programs will play an increasingly pivotal role year-by-year as the cost per ton of GHG emission reductions increase. We strongly urge CARB to rely more heavily on Cap-and-Trade post-2030 as opposed to suite of direct measures and technology mandates. Refer to **Comments A.9** and **A.10** for further details.

A.6 CARB should publicly post the detailed modeling files that track how emissions benefits were derived for each sector and how the cost impacts for the associated changes to California's economy were determined.

We request that CARB publicly post these to allow the public to understand the full impact of the Proposed Scenario on the State's economy and provide comments, if warranted.

As noted in Appendix H of the Draft 2022 Scoping Plan,[18] the direct costs include the cost of CDR, cost of purchasing capital stock, cost and savings from changing fuel expenditures, and the costs of energy efficiency measures across sectors. While references for the economic and financial assumptions and inputs to the PATHWAYS model are provided in Appendix H, details of the specific financial inputs, copies of the economic modeling files, and a description of uncertainties associated with these inputs and outputs of the model have not been made available in Appendix H or the AB 32 GHG Inventory Modeling Data Spreadsheet. WSPA requests CARB provide these details and files so stakeholders can review and provide appropriate feedback as part of the public process.

A.7 CARB should present the potential range of the cumulative direct costs of the Proposed Scenario relative to the Reference Scenario rather than suggesting single cost value for calendar years 2035 and 2045.

The economic analysis in Draft 2022 Scoping Plan estimates the direct costs for the Proposed Scenario (Alternative 3) relative to the Reference Scenario as $18 billion and $27 billion for calendar year 2035 and 2045 respectively. Based on the description of the economic analysis provided in Chapter 3 of the Draft 2022 Scoping Plan, it appears that the annualized costs were computed for each year from 2022 through 2045. We request that CARB present these costs for each year 2022 through 2045 and the cumulative costs from 2022 to 2035 and 2022 to 2045 to allow public to understand the full impact of the Proposed Scenario on the State's economy. CARB must also provide the range in projected costs associated with the quantitative uncertainties of this proposal to better portray the magnitude of these changes.

It is critical that stakeholders and the public understand the full cost of the transition. While we appreciate the economics shared, it is all relative to the BAU. Since the BAU includes significant actions and costs, CARB should include the total cost of the transition alongside the costs of achieving Alternative 3 compared with the BAU. Since the Scoping Plan is focused on achieving carbon neutrality in 2045 and the BAU is an important part of that process, CARB should be transparent on the costs of the full transition.

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18 CARB. Draft 2022 Scoping Plan Update. Appendix B Draft Environmental Assessment. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-b-draft-environmental-analysis.pdf. Accessed: June 2022.

A.8 CARB should analyze the critical mineral demand that would directly result from the technology forcing mandates within this Scoping Plan given the high level of demand for critical mineral resources in ZEVs, solar technology, and grid battery storage.

While the draft environmental analysis (draft EA) for the Proposed Scenario acknowledges the 2022 Scoping Plan could result in additional mining for critical minerals for the manufacture of batteries and fuel cells, it fails to assess the amount of mineral resources that would directly result from the Proposed Scenario. Hence, CARB has no factual basis to conclude that the effects on mineral resources "would be less than significant."[19] CARB has also not developed the factual record needed to conclude that mineral resources needed to meet the Proposed Scenario will be accessible.

The findings of the 2021 International Energy Agency's report titled *The Role of Critical World Energy Outlook Special Report Minerals in Clean Energy Transitions*,[20] indicated that a typical battery electric car requires six times the amount of mineral inputs needed for a conventional vehicle. This report also stated that the rapid deployment of clean energy technologies (including battery electric vehicles [BEVs]) would result in a significant impact on mineral resources, and that there are currently not enough of these mineral resources to meet such a demand level.

CARB must provide a basis for their significance argument, including but not limited to an estimate of the minerals volumes and GHG emissions required to manufacture the solar panels, batteries and fuel cells suggested under the Proposed Scenario, the potential strain on global mineral resources, and impacts to the global supply chains for lithium, cobalt, nickel, and other critical minerals. The assessment should include sensitivity analysis to determine how costs and availability may be affected by mineral scarcity and global supply chain disruptions.

While CARB did not provide mineral resource estimates for the proposed regulation, CARB does acknowledge that the Proposed Scenario (Alternative 3) would involve unprecedented levels of growth for solar panels, batteries, and fuel cell production to upgrade and expand electric grid infrastructure (i.e., 90 GW solar generation and 40 GW battery storage by 2045), increased hydrogen generation (41 GW of additional solar generation needed by 2045), and increased penetration of battery electric, plug-in hybrid, and fuel cell electric vehicles (FCEVs) (19.2 million BEVs, 3.8 million PHEVs, and 3.8 million FCEV by 2045). The unprecedented ramp-up in production would require a similar scale of mineral extraction growth that cannot be assumed or disregarded. CARB must characterize and evaluate these impacts; not rush to suggest that they are "not significant".

It is also important to note that mineral resources critical to the production of solar panels, batteries, and fuel cells are primarily found outside the State. So, GHG emissions associated

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19 CARB. Draft 2022 Scoping Plan Update. Appendix H AB32 Inventory Sector Modeling. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-h-ab-32-ghg-inventory-sector-modeling.pdf. Accessed: June 2022.

20 International Energy Agency (IEA). 2021. The Role of Critical World Energy Outlook Special Report Minerals in Clean Energy Transitions. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. Accessed: June 2022.

with mining and processing these minerals that occur outside the State boundary must be included in CARB's analyses. The vehicle life cycle emissions associated with the additional production, use, and disposal of BEVs under the Proposed Scenario would equate to ~110 million metric tonnes (MMT) CO_2e,[21] under the Proposed Scenario's 2045 electric vehicle goal. CARB must acknowledge the extent of these emissions, encompassing raw material mining and vehicle disposal, as well as the environmental burden they place on countries outside of California.

The Use of Cap-and-Trade in Proposed Scenario (Alternative 3)

A.9 We agree with CARB that Cap-and-Trade should be one of the main tools to ensure the state achieves carbon neutrality. CARB should further utilize Cap-and-Trade to minimize the costs of future emission reductions instead of using the program as an emissions backstop.

WSPA agrees with CARB that the Cap-and-Trade Program should be one of the main tools that CARB utilizes to achieve carbon neutrality. The program serves as a global model of a well-designed technology-neutral market-based program to achieve emission reductions. While the Draft 2022 Scoping Plan Update recognizes the need for the Cap-and-Trade Program to "fill the gap" to meet the State's 2030 reduction target, given the uncertain outcomes of sector-specific mandates, it also assumes that this program will play a reduced role with continued addition of legislation or prescriptive policies for individual sectors. WSPA believes that the Cap-and-Trade Program can and must be allowed to do more beyond 2030 as the cost per ton of GHG emission reductions increase. The speculative cost forecasts for potential technologies to eliminate the final hard-to-abate emissions, as well as their uncertain availability, demand a program that can provide flexibility well into the future. Cap-and-Trade should be allowed to play this important role.

A.10 Cap-and-Trade can provide a critical funding source for CCS and DAC (similar to how the LCFS functions now). CARB should create a protocol for projects that deliver negative emissions to generate credits.

As CARB has extensively documented in its Draft 2022 Scoping Plan, [22] CCS and CDR will have to play a significant role if California is to achieve carbon neutrality by 2045. The NERA Study (**Attachment D**) came to a similar conclusion in all of its modeled scenarios. CCS and CDR are capital intensive and need a significant time horizon for deployment and to recover large capital investments, expected to cumulatively be at least in the tens of billions of dollars.[23] Without a clear, reliable basis for creating value to provide value to operators of such technologies, those

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21 Estimated based on the incremental BEV vehicle stock projections for the Proposed Scenario versus Business as Usual (BAU) in 2045 as provided in the 2022 Scoping Plan Documents and Ramboll's estimates for incremental vehicle life cycle emissions for BEVs as compared to ICEVs (presented in **Figure A-5**).

22 Draft 2022 Scoping Plan Update. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

23 Global CCS Institute. 2021. The Global Status of CCS 2021. Available at: https://www.globalccsinstitute.com/wp-content/uploads/2021/11/Global-Status-of-CCS-2021-Global-CCS-Institute-1121.pdf. Accessed: June 2022.

investments will not get made. It is imperative that CARB prioritize creation of such credit generation in the Cap-and-Trade program and provide the accounting necessary to support it.

Transportation in Proposed Scenario (Alternative 3)

A.11 The ZEV strategy in the Proposed Scenario not only interferes with efforts to achieve the federal ozone standard, but actively impedes near-term progress toward attainment.

CARB's narrow reading of the Governor's Executive Order N-79-20 has led to a series of modeling scenarios centered almost exclusively around the accelerated adoption of ZEVs. While the Proposed Scenario (Alternative 3) may not be as aggressive at Alternatives 1 and 2, it still aims to achieve the following actions: 100% of LDV sales are ZEV by 2035 and 100% of MD/HDV sales are ZEV by 2040. These actions would obstruct deployment of near-zero emission (NZE) technologies that could help California attain the Federal ozone standards. AB 32 requires CARB to "ensure that activities undertaken pursuant to the regulations complement, and do not interfere with, efforts to achieve and maintain federal and state ambient air quality standards and to reduce toxic air contaminant emissions." NZE vehicles and other strategies may be more feasible and cost-effective in achieving the Federal ozone standards while still achieving the necessary GHG reductions.

Ramboll's HHDT case study on "Multi-Technology Pathways to Achieve California's Air Quality and Greenhouse Gas Goals"[24] ("Ramboll HHDT Study") highlighted the inconsistencies between CARB's mandate to make reasonable progress toward the ozone standard and its proposed all-ZEV strategy. Ramboll's analysis of multi-technology pathways, which included a combination of lower-emission (75% to 100% lower) vehicle technologies and fuel mixes (including lower carbon-intensity liquid and gaseous fuels), demonstrated that there are faster paths to meeting near-term Federal air quality standards, while making meaningful progress on State climate goals.

The Proposed Scenario (Alternative 3) would depend on current, proposed, and future CARB regulations that would further delay attainment of the federal ozone standard by making it near impossible to invest in existing NZE technologies due to the ZEV mandate.

Again, we recommend that CARB utilize a technology-neutral performance-based approach versus adopting a ZEV mandate for the on-road vehicles (see **Comment A.13** for further details).

A.12 The California fuels industry is providing low-carbon renewable liquid and gaseous transportation fuels today, with projects announced for even more supply in the next few years. CARB must consider a technology-neutral, performance-based approach that embraces renewable liquid fuels rather than a ZEV mandate that has major feasibility challenges and cost impacts.

As transportation becomes more electrified in the future, the nexus of transportation fuel and power generation will become more consequential. While renewable natural gas (RNG) can

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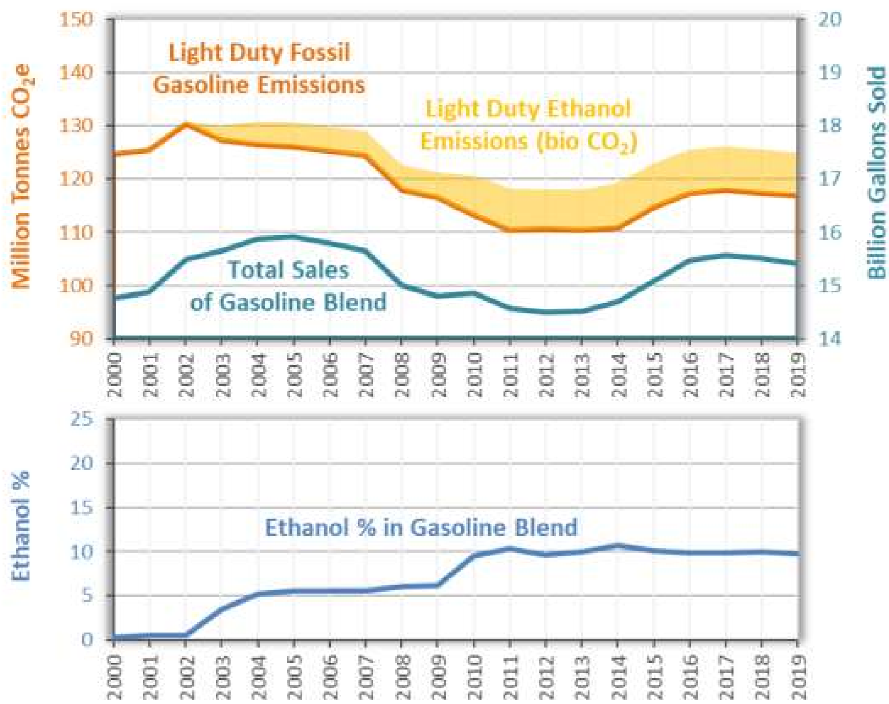
[24] The Ramboll HHDT study is available here: https://www.arb.ca.gov/lists/com-attach/78-sp22-kickoff-ws-B2oFdgBtUnUAbwAt.pdf. Accessed: April 2022.

and should continue to play a role as a transportation fuel, particularly for medium- and heavy-duty applications, it can also play a needed role in light-duty transportation by being the fuel for the generation of low- or negative-emission electricity for this tranche of vehicles. CARB's report on "California Greenhouse Gas Emissions for 2000 to 2019"[25] showed that renewable fuels and biofuels have already offset significant amounts of GHG emissions from both the light-duty and heavy-duty sectors. Because carbon emitted from biogenic fuels is considered carbon neutral, the 10% ethanol blend in LDV gasoline and approximately 27% bio-component percentage in heavy-duty diesel fuels has resulted in a 6.4% and 25% reduction in GHG emissions respectively in in 2019. This is shown in **Figures A-2** and **A-3**.

Figure A-2: Trends in On-Road Light-Duty Gasoline Emissions[26]



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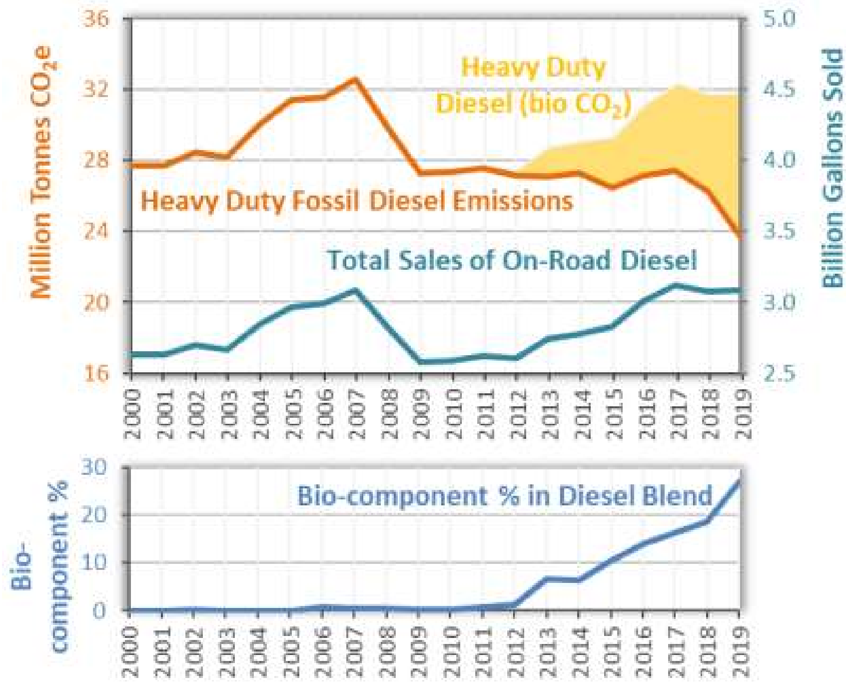
25 CARB. 2021. California Greenhouse Gas Emissions for 2000 to 2019. July 28. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/2000_2019_ghg_inventory_trends_20220516.pdf. Accessed: June 2022.

26 Ibid.

Figure A-3: Trends in On-Road Diesel Vehicle Emissions[27]



The use of renewable and low carbon fuels continues to grow in California and throughout the United States. If all proposed projects and projects currently under production come online, U.S. renewable diesel production would total 5.1 billion gallons per year by the end of 2024, which is over 7% of today's total U.S. diesel production and 142% of California's total diesel consumption in 2020 (diesel, biodiesel, and renewable diesel).[28,29]

The Scoping Plan focuses on the transition of the statewide on-road vehicle fleet to ZE technology.

The Ramboll LDA Study"[30] evaluated whether alternative vehicle technology and fuel pathways could achieve life cycle GHG emission reductions similar or greater than the ACC II proposal, which is reflected in the Draft 2022 Scoping Plan Update as the action to achieve 100% LDA ZEV sales by 2035. This study conclusively showed that performance standards could be an alternative to a ZEV mandate.

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27 Ibid.

28 Energy Information Administration. U.S. renewable diesel capacity could increase due to announced and developing projects. Available at: https://www.eia.gov/todayinenergy/detail.php?id=48916. Accessed: June 2022.

29 "Diesel fuel explained". US Energy Information Administration. Available at: https://www.eia.gov/energyexplained/diesel-fuel/where-our-diesel-comes-from.php#:~:text=In%202020%2C%20U.S.%20refineries%20produced,barrels%20(57.43%20billion%20gallons). Accessed: June 2022.

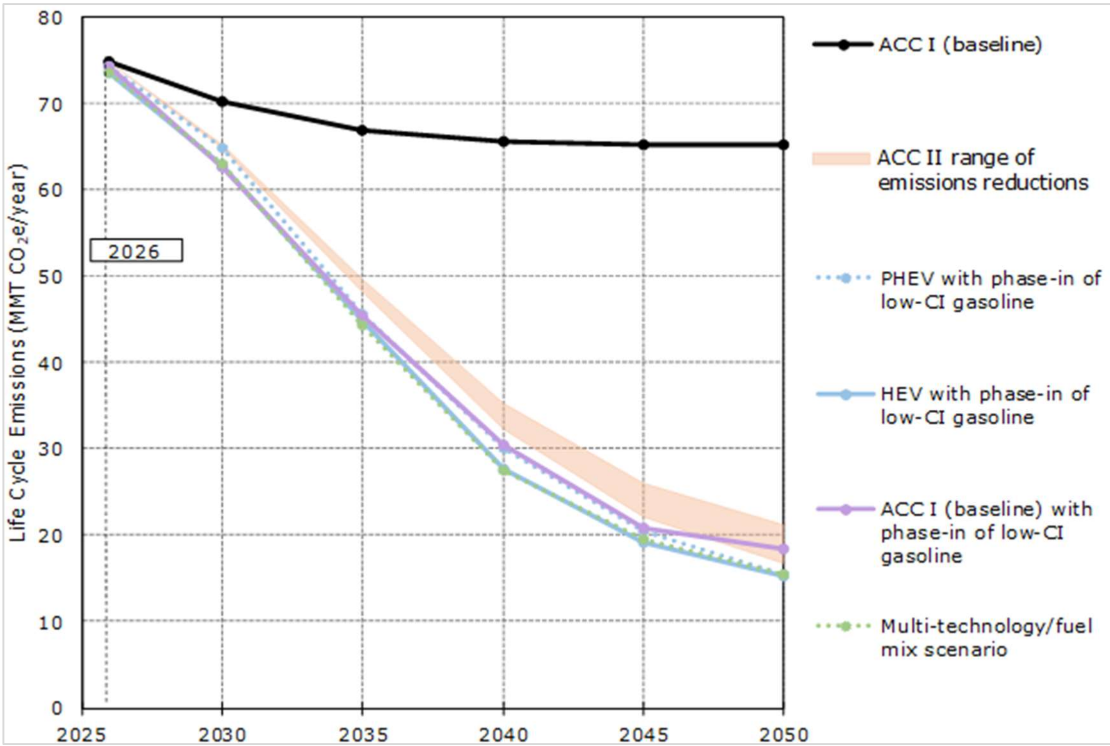
30 Ramboll. 2022. Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study. Available as Attachment D at: https://www.arb.ca.gov/lists/com-attach/477-accii2022-AHcAdQBxBDZSeVc2.pdf. Accessed: June 2022.

Unlike CARB's analysis, Ramboll evaluated the full life cycle impacts of ZEV technologies under the LDA proposal to more completely characterize the potential GHG emissions performance and considered other technology/fuel pathways that would not require a replacement of the entire transportation infrastructure system. These alternative pathways would also not require the wholesale transformation of electric energy production and distribution infrastructure on an unprecedented time scale, but they could utilize existing battery, hydrogen, and low-CI gaseous and liquid fueled vehicles to achieve the State's GHG targets for light-duty transportation. The NERA Study (**Attachment D**) further indicated that the magnitude of grid expansion is reduced by two-thirds in a scenario that allows more flexibility to arrive at an optimal solution for LDAs and HHDTs.

The Ramboll LDA Study showed that a gradual transition to low-CI gasoline with current vehicle technologies (represented by the purple line in **Figure A-4**) could achieve similar life cycle GHG emissions as the current ACC II proposal (represented by the pink shaded region in **Figure A-4**). Importantly, **GHG emissions associated with ZEVs are not zero.** In fact, the GHG emissions from producing BEVs (the "vehicle cycle") is *significantly higher* than other vehicle technology types (see **Comment A.13** for additional details). The failure to analyze these real world GHG emissions distorts the claimed benefits attributed to these vehicles.

Other technologies also achieve similar or lower emissions on a life cycle basis compared to the ACC II proposal. These include HEVs coupled with low-CI fuel (represented by the blue solid line), PHEVs coupled with low-CI fuels (represented by the blue dotted line), and a combination of HEVs, PHEVs, and BEVs with low-CI fuels (represented by the green dotted line).

Figure A-4: Life Cycle Emissions for Key Scenarios in the Ramboll LDA Study California Light Duty Automobile Fleet (2026 to 2050)



The Ramboll HHDT Study performed a similar analysis to identify multiple vehicle and fuel technology pathways that could achieve the near term federally mandated air quality goals while being consistent with the State's long-term climate goals. This study found that expanded implementation of low-NO_X and ZE vehicles, coupled with increased introduction of renewable liquid and gaseous fuels, could deliver **earlier and more cost-effective benefits** when compared to a ZEV-only approach.

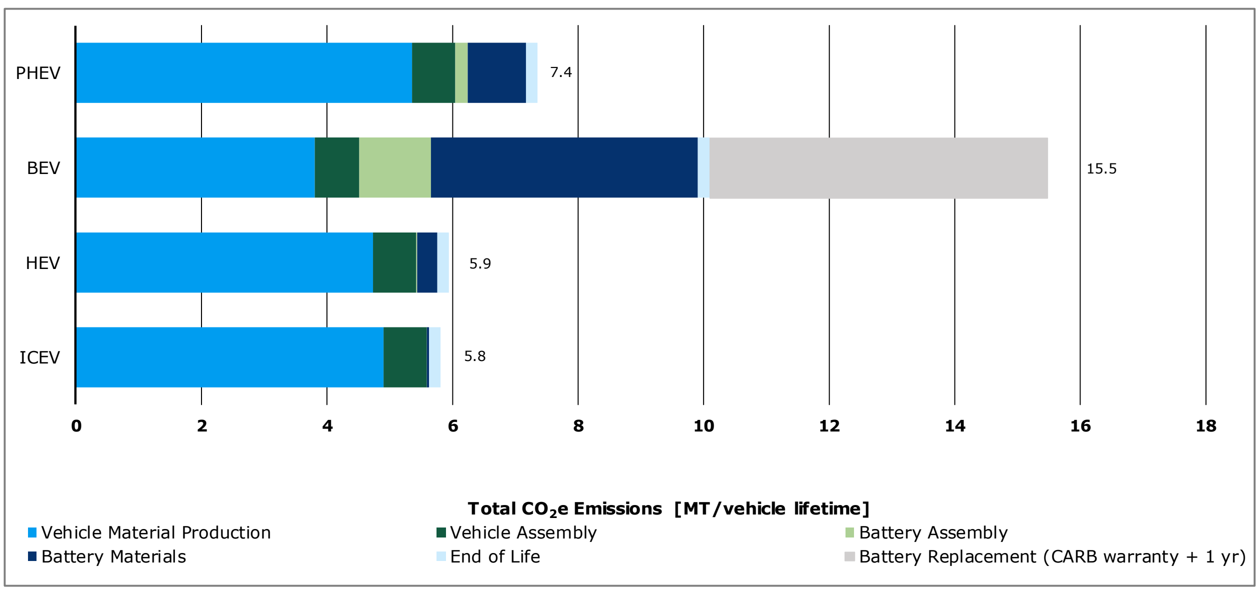
By allowing a technology neutral performance-based strategy for on-road vehicles in the Proposed Scenario, CARB would maintain equitable emission reductions across the transportation sector while significantly abating the technological and economic concerns surrounding the proposed ZEV mandates. We continue to ask CARB to fairly evaluate a plan that allows for this alternative pathway to achieve carbon neutrality with fewer feasibility challenges and lower costs.

A.13 CARB must account for the full life cycle GHG emissions of the vehicle/fuel system for the on-road vehicles in part to ensure that there is no leakage of emissions due to the proposed ZEV strategy.

The Draft 2022 Scoping Plan does not consider the life cycle emissions of "zero emission" vehicles or assess the leakage that would occur as a result of the ZEV strategy that includes the following actions: 100% of LDV sales are ZEV by 2035 and 100% of MD/HDV sales are ZEV by 2040. This is problematic given that AB 32 specifically directs CARB to adopt emission reduction measures which "minimize leakage" with leakage being defined as "a reduction in emissions of greenhouse gases within the state that is offset by an increase in emissions of greenhouse gases outside the state"[31]. Specifically, the vehicle life cycle emissions[32] due to additional BEVs in the fleet in the Proposed Scenario in 2045 (see **Comment A.8**) were not considered but should be included due to the significant differences in these emissions between BEVs and ICEVs, which lead to an additional ~110 MMT CO_2e not considered in the inventory sector modeling for the Proposed Scenario.

The Ramboll LDA Study[33] found that the vehicle cycle emissions for a model year 2026 BEV (10.1 metric tons (MT) CO_2e per vehicle) was about 74% higher than those for a model year 2026 ICEV (5.8 MT CO_2e per vehicle) (see **Figure A-5**). If the BEV undergoes a battery replacement during its lifetime, its vehicle cycle emissions increase to 15.5 MT CO_2e per vehicle, which is ~167% higher than those of an ICEV. The significant emission increases associated with the production of a BEV, as compared to an ICEV, must be included in the emission analysis to fully understand the impacts of the ZEV strategy. It is also important to note that mineral resources critical to the production of batteries are primarily found outside the State. So, GHG emissions associated with mining and processing of these minerals that occur outside the State boundary should be included in CARB's analyses.

Figure A-5: Vehicle Cycle GHG Emission Factors for Different Light Duty Auto Vehicle Technologies



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[31] Assembly Bill No. 32 California Global Warming Solutions Act. Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32. Accessed: June 2022.

[32] Emissions associated with vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling.

[33] Ramboll. 2022. Multi-Technology Pathways To Achieve California's Greenhouse Gas Goals: Light-Duty Auto Case Study. Available as Attachment D at: https://www.arb.ca.gov/lists/com-attach/477-accii2022-AHcAdQBxBDZSeVc2.pdf. Accessed: June 2022.

A.14 CARB's transportation energy demand projections for the E3 scenarios appear to assume significant vehicle miles traveled (VMT) reductions despite the State's previous failure to achieve VMT reductions under Senate Bill (SB) 375. The increased use of low carbon-intensity fuels could provide GHG reductions with much greater certainty than VMT reduction assumptions.

Even with a complete transition to ZEVs, the Proposed Scenarios (Alternative 3) is unable to achieve the State's GHG emission reduction targets without assuming VMT reductions from the remaining vehicles. The proposed VMT reductions of 12% below 2019 levels by 2030 and 22% below 2019 levels by 2045 are highly optimistic given historical increases in VMT and previous failures to reduce VMT. Under SB 375, metropolitan planning organizations were directed to meet GHG emissions reduction targets by incorporating a Sustainable Communities Strategy (SCS) as part of the long-range regional transportation plans. As noted in the CARB's 2018 Progress Report,[34] the anticipated performance of the SCS was a 10% reduction in VMT per capital by 2020 as compared to 2000. However, by 2016, the VMT per capita had increased by ~3%. As noted in the progress report, there are numerous challenges associated with these types of VMT reductions which are dependent on factors outside CARB's purview such as employment rates, fuel prices, job and housing balances, and availability of affordable housing.

CARB should consider the implementation of technology-neutral vehicle/fuel pathways that could achieve the GHG reductions contemplated within these Proposed Scenario (see **Comment A.12** for further details). The increased use of low and negative carbon-intensity drop-in fuels along with the penetration of fuel-efficient vehicle technologies such as HEVs and PHEVs could provide GHG reductions with much greater certainty than the VMT reductions.

Oil and Gas in Proposed Scenario (Alternative 3)

A.15 WSPA agrees with CARB that a complete phaseout of oil and gas extraction and refining is not feasible by 2045. As called for in AB 32, CARB must study and quantify the leakage risk associated with its current policies and the Draft 2022 Scoping Plan Update, as they could eliminate the potential to provide low-CI fuels to other regions and achieve global GHG benefits.

WSPA agrees with CARB's assertion that a complete phaseout of oil and gas extraction and refining is not feasible and would lead to significant leakage, so CARB should refrain from sending artificial market signals.[35] Moreover, California is a critical provider of liquid fuels to other jurisdictions, including to neighboring states (particularly Nevada and Arizona)[36] as well as exports to countries such as Mexico. Given that California refineries have responded to

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34 2018 Progress Report: California's Sustainable Communities and Climate Protection Act. Available at: https://ww2.arb.ca.gov/sites/default/files/2018-11/Final2018Report_SB150_112618_02_Report.pdf. Accessed: June 2022.

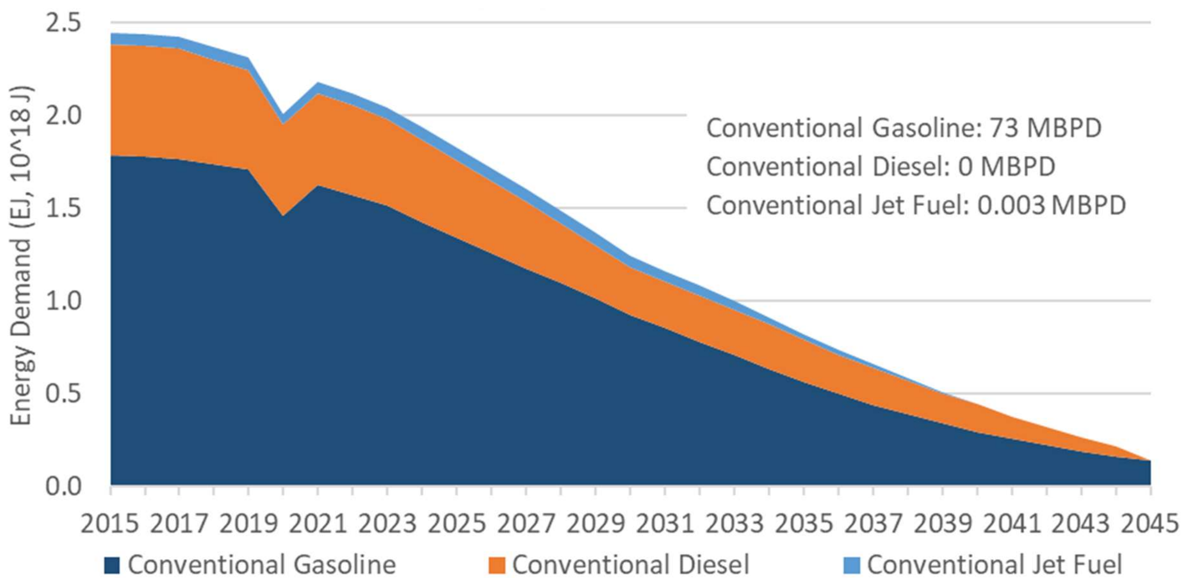
35 Draft 2022 Scoping Plan Update. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

36 Energy Information Administration, West Coast Transportation Fuels Markets, September 2015. See Figure 5 on page 14. Available at: https://www.eia.gov/analysis/transportationfuels/padd5/pdf/transportation_fuels.pdf. Accessed: June 2022.

regulations that result in provision of lower-emission fuels, this benefit is exported to these jurisdictions. This benefit will only grow as greater emission reductions ensue with in-state activities.

Furthermore, CARB's modeling for the residual refining products demand in the state indicates an infeasible outcome. For the Proposed Scenario, CARB models the 2045 in-state demand for refined petroleum products as 73 million barrels per day (MBPD) of conventional gasoline with essentially no simultaneous production of conventional diesel or jet fuel (see **Figure A-6** below).[37] CARB must recognize that refineries cannot operate in a way that only produces gasoline. Refineries will continue to produce the range of products that exist today, and for which there will be demand.

Figure A-6: Energy Demand Under CARB's Proposed Scenario[38]



While the premise for continued use of liquid fuels in Alternative 3 is correct, the basis for the volume of its continued use is flawed. CARB ignores the production of other fuels (e.g., jet fuel) and the continued use of refineries to produce new renewable liquid fuels and hydrogen, as discussed in **Comment A.12** and **Comment A.17**. CARB presumes that other jurisdictions will reduce the use of liquid fuel at the same pace as California. Further, it only considers fuels currently regulated by CARB, which excludes aviation and marine fuels that will be required from California refineries for an even longer period of time. Given that each jurisdiction will be on its own unique decarbonization pathway, it is illogical to premise that California's trajectory will resemble theirs; CARB needs to revisit these assumptions.

In addition to the above concerns about the concluding position for liquid fuels, WSPA is also concerned about the logistical constraints created by the implied loss of refining capacity to

37 Data gathered from CARB Draft 2022 Scoping Plan Update, "AB 32 GHG Inventory Sectors Modeling Data Spreadsheet," "Energy Demand" tab. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-PATHWAYS-data-E3.xlsx. Accessed: June 2022.

38 Ibid.

in-state liquid fuel supply and distribution capabilities. CARB must consider the implications of any such losses, which create a likelihood of inefficient fuels distribution and increased GHG emissions. These concerns would exist both in the concluding position of the Draft 2022 Scoping Plan Update and throughout the transition, during which efficient, effective and reliable supply of fuels for Californians must be maintained.

Further, while we agree with CARB that a production ban is infeasible and would lead to leakage, WSPA believes that CARB should study the leakage risk that could result from potential policies to limit future oil and gas development. These policies could actually result in production volumes well below the rate that would be needed to supply future demand for fuels refined for demand in California and neighboring jurisdictions. As CARB has noted in the Draft 2022 Scoping Plan Update, there is an uncertainty and risk that their direct policies will not be 100% effective in achieving their objectives especially when considering a time period extending all the way out to 2045. In the case of the proposed ZEV mandates, any ban on production would only further exacerbate leakage especially if the proposed ZEV mandates do not fully achieve their goals.

CARB's singular focus on non-electrical emissions occurring within the state ignores the global context of California products and industries. California's suite of climate policies have been successfully incentivizing the production of low CI fuels at existing and new facilities,[39,40] which further reduce transportation emissions within the state and within the states to which California exports fuels. While the achievement of carbon neutrality in California is significant, what is more important is the attainment of global GHG reductions. Towards this aim, the 2022 Scoping Plan Update must consider and give appropriate credit and support to the export of low-CI fuels to help other jurisdictions outside the state achieve their climate goals.

In conclusion, California will be optimally positioned by a Draft 2022 Scoping Plan Update that recognizes the important role that the State's oil and gas industry will play long-term as an integral part of a clean energy future. These facilities can create and preserve good-paying jobs for Californians, many in areas of the State where such jobs are difficult to obtain. The failure to acknowledge the value of the exporting these low-CI fuels outside of the State and adopting a proposal that disincentivizes or eliminates the in-State capacity to produce these fuels would put blue-collar jobs at risk when they could produce a lower-CI fuel and displace higher-CI fuels from jurisdictions outside of California.

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39 Phillips 66 New Releases. 2022. Phillips 66 Makes Final Investment Decision to Convert San Francisco Refinery to a Renewable Fuels Facility. Available at: https://investor.phillips66.com/financial-information/news-releases/news-release-details/2022/Phillips-66-Makes-Final-Investment-Decision-to-Convert-San-Francisco-Refinery-to-a-Renewable-Fuels-Facility/default.aspx. Accessed: June 2022.

40 Martinez Renewable Fuels. Available at: https://www.marathonmartinezrenewables.com/. Accessed: June 2022.

A.16 WSPA continues to request that CARB include modeling for CCS on upstream oil and gas production and that it does so in a timeframe that recognizes the ongoing statutory, regulatory, and permitting challenges facing CCS adoption within the state.

CCS has been acknowledged as an essential technology to deploy for California to meet its climate ambitions.[41] CCS is a versatile technology that can be employed on many existing CO_2 sources, as well as being utilized in tandem with DAC to remove CO_2 from the atmosphere. Given this, WSPA remains concerned that modeling work has failed to include the utilization of this important technology on upstream oil and gas production, where it can effectively be employed as part of the production process. Indeed, many of the earliest cost-effective applications of this technology are likely in upstream production; recognizing this provides a platform for early implementation of CCS assets that can provide earlier CO_2 reductions through their useful life as a production asset, and then be pivoted for further utilization (for example, DAC). CARB should include this technology as part of the modeling scenario that supports the selected alternative in this Scoping Plan. This is a prime opportunity for California to be a leader in advancing a technology which will be critical to achieving carbon neutrality.

As CARB recognizes in its Scoping Plan, the vast majority of CCS implementation, regardless of where and how it is being deployed, will not occur until the 2030s. For this reason, it is important to recognize that the pathway to utilize CCS in upstream production needs to be included now, as the timeline for CCS projects through the existing labyrinth of statutes, regulations, and multiple permitting regimes makes it critical that in be included in now to meet the GHG reduction schedule. Early adopters to this important technology should not be sidelined or this technology will not be implemented in a timely fashion. WSPA appreciates that CARB has recognized the potential for refineries to contribute to onsite and offsite emission reductions through the production of low-CI fuels.

A.17 WSPA agrees that biodiesel, renewable diesel, sustainable aviation fuels (SAF), and hydrogen will continue to play pivotal roles in decarbonizing the economy but asks CARB to expand their scope to include low-CI crude oil supplies, finished fuels such as low carbon or renewable gasoline, and other fuels that could significantly reduce carbon emissions through the application of CCS technologies.

As stated in previous comments (**Comment A.12**), low-CI gasoline could achieve similar life cycle GHG emissions reductions as the current ACC II proposal. CARB must look into expanding programs that incentivize and support the use of low-CI fuels in the combustion-powered fleet that will exist through and beyond 2045, per CARB's modeling assumptions.[42] These fuels could bring immediate tailpipe emissions reductions to existing

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41 Draft 2022 Scoping Plan Update. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

42 CARB. 2022. California PATHWAYS Model Outputs. May 2. Available here: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-PATHWAYS-data-E3.xlsx. Accessed: June 2022.

combustion-- powered vehicles on the road without a need for the turnover of the entire vehicle fleet.

The Stanford Pathways to Carbon Neutrality in California found that "the production of vehicle fuel from biogas becomes economically feasible only when the LCFS and the Renewable Fuel Standard credits are harvested."[43] Continued support for programs that incentivize production of low-CI fuels is vital to the renewable fuel industry in California;.

A.18 We also request that CARB take into consideration the onsite emissions reductions associated with processing of renewables as opposed to petroleum.

The processing of bio-feedstocks in refineries produces carbon neutral, renewable combustion fuels. The complex operations that create and isolate a broad range of molecules through multiple process steps generate a variety of co-products such RNG, renewable fuel gas, renewable propane, and other liquid fuels, providing multiple revenue streams and fuel products from a single feedstock. To further encourage the transition of refinery feedstocks to renewable sources, the value of these and other such streams needs to be accounted for in Cap-and-Trade to offset the significant costs to reconfigure refineries.

A.19 CARB should allow and model the use of CCS on natural gas power plants. This is a better alternative to decarbonize the electric grid and more cost-effective than the existing plans to construct large amounts of new battery and hydrogen storage.

According to the Stanford study "Decarbonizing the Electricity Sector",[44] the size of the future grid will likely drive the total costs for decarbonization. Diversifying generation resources is the most effective way to reduce system generation capacity. Gas generation will likely be needed for reliability in California's energy mix through 2040 and by 2045.

The Proposed Scenario represents unprecedented development of solar and storage (90 GW solar generation and 40 GW battery storage by 2045). The Scenario should consider including RNG, hydrogen and other sources of dispatchable electricity generation to support renewables integration and make the grid more reliable. Low-carbon oil and gas with CCS can achieve the same level of CI reduction as solar and battery storage systems and should be considered as part of the portfolio in the Proposed Scenario to allow for increased reliability while still achieving emission reduction goals.

Currently, natural gas fills a vital role as the marginal generator that fills the gaps left by intermittent or seasonal generation resources, according to the Stanford study.[45] This reliability that natural gas provides will need to be fulfilled by a clean source of dispatchable electricity generation by 2045. There are many low-CI alternatives such as natural gas with CCS, RNG and hydrogen from renewable feedstocks that could fill this role. Further, with appropriate

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43 Stanford. 2022. The Bioenergy Opportunity. Available at: https://sccs.stanford.edu/sites/g/files/sbiybj17761/files/media/file/the-bioenergy-opportunity.pdf. Accessed: June 2022.

44 Stanford. 2022. Pathways to Carbon Neutrality in California. Available at: https://sccs.stanford.edu/sites/g/files/sbiybj17761/files/media/file/DecarbonizingTheElectricitySector_FullReport_0.pdf. Accessed: June 2022.

45 Ibid.

incentives to transition to greater use of RNG in these facilities, a negative emissions pathway is possible. CARB must consider these options in the Proposed Scenario to ensure reliability of the grid, decreased system costs, and sufficient diversification of California's energy mix through 2045.

Sufficient diversification of the grid allows for decreased required system capacity, which in turns reduces the need for overbuilding of renewable resources that are intermittent/seasonal, according to the Stanford study. It would be prudent for the State to utilize existing infrastructure to reduce the amount of stranded assets that would result from the Scoping Plan. There could be potential for converting existing liquid fuels infrastructure from carrying fossil fuels to renewable fuels, allowing for utilization of existing capacity while still meeting CI reduction goals in the grid. The decarbonization of California's economy will be expensive; any use of existing assets that can be adapted to a lower carbon future should be given a pathway in the current Scoping Plan, as this will reduce the timeline and costs for achieving the state's climate goals. The scale of upgrade needed on the grid to meet the Scoping Plan Proposed Scenario is unprecedented, and CARB must ensure that this transition is smooth and reduces risks from hazards such as public safety shut-off (PSPS) events and systemic risks due to dependence on intermittent technologies that may or may not materialize at the scale needed.[46]

CARB should encourage and model the use of CCS on natural gas power plants. This provides a path that allows existing assets to be cost-effectively utilized. This enhances reliability of the grid, given that natural gas power plants are dispatchable. Further, with appropriate incentives to transition to greater use of RNG in these facilities, a zero or negative emissions pathway is possible thus allowing it to meet the requirements under SB-100.

The NERA Study (**Attachment D**), which was not constrained by limits on how to best reduce emissions for dispatchable power, also concluded that utilization of CCS on existing natural gas generating assets was the most cost-effective outcome. That multiple approaches draw the same conclusion is not surprising; making use of existing infrastructure to mitigate the extreme costs of battery storage for worst-case periods (e.g., extended absence of wind, extended duration of low solar energy) makes intuitive sense and the model corroborates the approach.

A.20 WSPA encourages CARB to expand the allowances for low-carbon fuels and broaden incentives for hard-to-abate sectors. Specifically, WSPA encourages CARB to update the LCFS to connect industrial processes that are associated with transportation fuels.

As noted in **Comment A.12**, the blend of renewable fuels within existing fuel stocks have reduced GHG emissions in the transportation sector by 6.4% for LDVs and 25% for HDVs. Similar reductions could be achieved in hard to abate sectors in the commercial, residential, and industrial space. The industrial sector represents 18-19% of the GHG inventory under Alternative 3 through 2045 and additional emission reductions achieved though the deployment of low-carbon fuels would aid in achieving carbon neutrality. The LCFS should be enhanced with extension of the use of book and claim accounting to better incentivize this transition by combining the beneficial capture of methane from non-fossil sources and utilizing this

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46 Ibid.

renewable fuel source to provide reliable, low-carbon fuel for transportation and industrial processes in the State.

<u>Hydrogen in Proposed Scenario (Alternative 3)</u>

A.21 We appreciate CARB's recognition that hydrogen will be critical to achieving carbon neutrality. It is unclear why the Proposed Scenario requires that all hydrogen produced in 2045 must be zero-carbon instead of allowing this sector, like every other sector, to have a small amount of carbon emissions that are offset by DAC and other negative emissions technologies.

WSPA appreciates CARB's recognition that low-carbon hydrogen will play a critical role in reducing GHG emissions from the transportation sector (for heavy-duty vehicles, ocean-going vessels, rail, and aviation) and the industrial manufacturing sector. As noted by CARB, hydrogen can also play a dual role in the electricity sector as a zero or low-carbon fuel for existing combustion turbines and as energy storage for later use. However, it is unclear why the Proposed Scenario suggests that all hydrogen produced in 2045 be zero-carbon while the electricity production is allowed to maintain residual GHG emissions of ~30 MMT of CO_2e in 2045.

In order to produce this zero-carbon hydrogen by electrolysis, the Proposed Scenario (Alternative 3) contemplates the new development of extensive "off-grid" solar (41 GW solar generation needed in 2045) which would be in addition to all the solar development required for the California electric grid (90 GW solar generation by 2045). With the enormous amount of renewables buildout already required to meet the electricity demands from other sectors in the Proposed Scenario, CARB must expect other technology options for the production of low-carbon hydrogen including the use of steam methane reformers (SMR) with CCS. Of note, the Proposed Scenario includes the installation of CCS on refineries across the state, including SMR facilities that currently produce hydrogen for use inside refineries. CARB's modeling shrinks the refining sector significantly from 2030 to 2045 but does not appear to repurpose the SMRs with CCS for low-carbon hydrogen production. There would be an opportunity to utilize SMRs with CCS already equipped for low-carbon hydrogen production for use in other sectors.

The discussions on hydrogen infrastructure during the recent ACF working group meetings made it clear that access to hydrogen and other low carbon combustion fueling sources would be pivotal to transitioning the heavy-duty vehicle fleet. Our industry offers great opportunities to support this transition and minimize carbon emissions in the long term. CARB must allow other options for the production of hydrogen necessary for use within California.

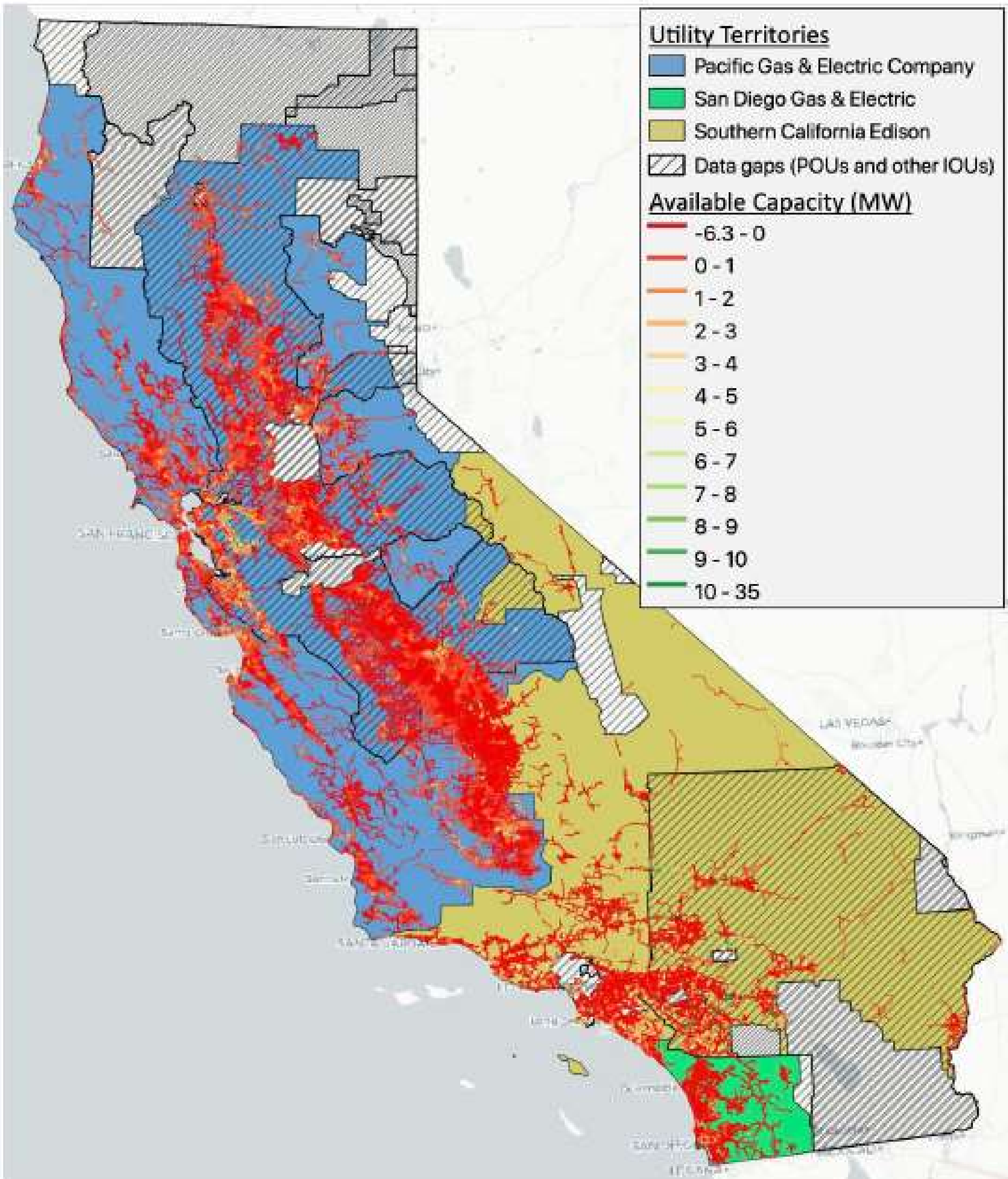
<u>Electricity in Proposed Scenario (Alternative 3)</u>

A.22 CARB understates the impact that the dramatic increase in electrical generation and transmission/distribution infrastructure will have on the State's energy sector as a direct result of this Scoping Plan.

CARB has not provided any analysis of the feasibility of the Proposed Scenario given the significant increase of electric vehicle charging infrastructure, electrical generation and transmission and distribution infrastructure that would be required to support 19.2 million BEVs and 3.8 million PHEVs by 2045. The Capacity Analysis from the California Energy

Commission's (CEC's) EDGE Model (**Figure A-7** below, obtained from the Draft EA for the ACC II Program[47]) shows the grid has no additional capacity to add electrical load for charging for most of these circuits.

Figure A-7: Capacity Analysis from CEC's EDGE Model[48] (dark red indicates no available additional capacity)

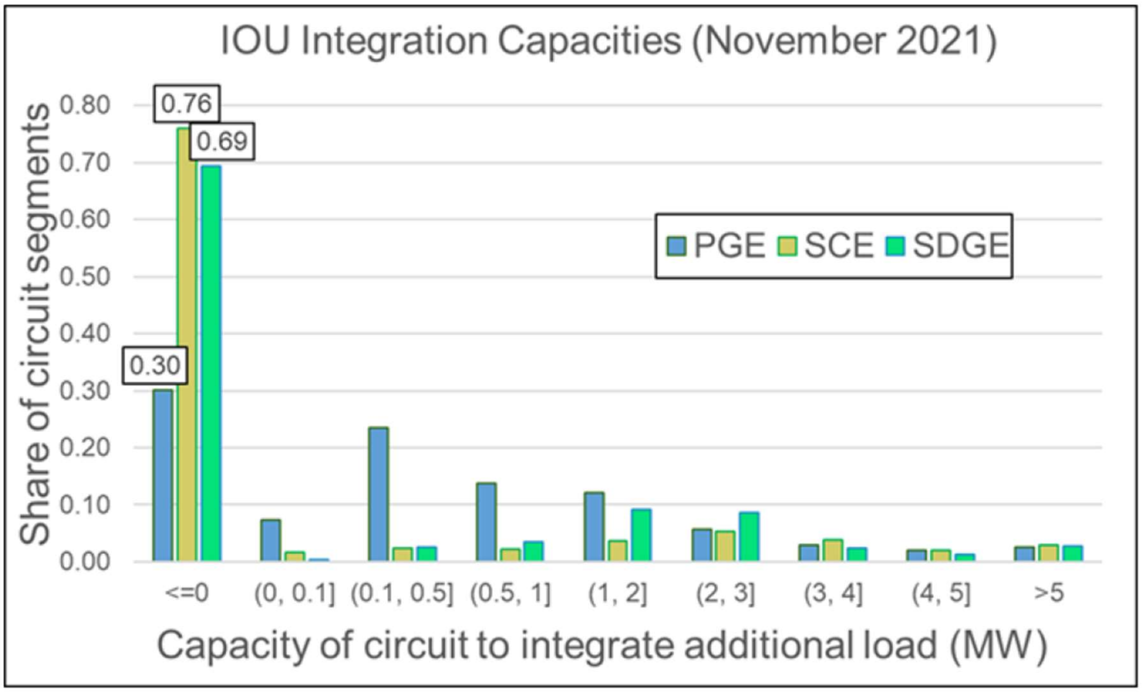


[47] Draft Environmental Analysis (EA) for the Proposed ACC II Program. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/appe1.pdf. Accessed: June 2022.

[48] Ibid.

You can see this in numerical terms in **Figure A-8** (obtained from Virtual Medium and Heavy-Duty Infrastructure Workgroup Meeting - Electricity and the Grid on January 12, 2022[49]), which details the capacity of circuits to integrate additional load. This figure illustrates that 30% to 76% of circuit segments have no capacity to integrate additional load. Thus, no appreciable charging capacity can be added to most of these circuits without the expenditure and time for additional construction of needed transmission and distribution infrastructure.

Figure A-8: Capacity of circuits to integrate additional loads[50]



While the economic analysis in the Draft 2022 Scoping Plan appears to account for the costs associated with increase of electric vehicle charging infrastructure, electrical generation and transmission and distribution infrastructure under "cost and savings from changing fuel expenditures" category,[51] the 2022 Scoping Plan documents do not provide sufficient detail for the public to understand the assumptions used in the economic analysis and the cumulative costs associated with these improvements from 2022 to 2035.

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49 Virtual Medium and Heavy-Duty Infrastructure Workgroup Meeting - 01/12/22. Available at: https://www.youtube.com/watch?v=_mr0TmwxGZQ. Accessed: June 2022.

50 Ibid.

51 CARB. Draft 2022 Scoping Plan Update. Appendix B Draft Environmental Assessment. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp-appendix-b-draft-environmental-analysis.pdf. Accessed: June 2022.

As noted in our September 7, 2021, comment letter,[52] Ramboll's meta-study of published literature on the Transportation Electrification Costs in California,[53] estimates that the cumulative transportation infrastructure costs (generation, transmission, distribution, maintenance, and electric vehicle chargers) from 2020 to 2050 as at least $2.1 to $3.3 trillion. While the economic analysis for the Draft 2022 Scoping Plan potentially estimates these cumulative costs, it was not disclosed as part of the Scoping Plan Documents. Therefore, we respectfully request CARB to release the details input and outputs of the economic analysis so the public and stakeholders can review and comment on it.

Carbon Capture & Sequestration in Proposed Scenario (Alternative 3)

A.23 CCS and CDR technologies are essential to achieving carbon neutrality, but adoption of these technologies must be driven by federal and state government and market-based mechanisms such as LCFS and Cap-and-Trade.

CARB appropriately acknowledges the role of engineered carbon removal, point source carbon capture, and geological sequestration in meeting California's carbon neutrality goal by 2045. We do want to caution the Board however, that the adoption of CCS technologies by any industrial emitter would be enhanced by the existing market--based mechanisms in place including Cap-and-Trade and the LCFS, rather than be subject to any statutory or regulatory mandate. Such a mandate could have the opposite intended effect and rather than drive adoption within California, instead would drive the exportation of emissions to other jurisdictions where a mandate to install CCS on industrial facilities does not exist.

The identified "Strategies for Achieving Success" for CDR and CCS[54] appropriately note the challenges facing wide scale adoption of this safe and reliable tool for California to meet 2045 goals, while simultaneously identifying the critical role that mechanical CDR and CCS can and should play in meeting these challenges.

There are also longstanding gaps in the accounting protocols of Mandatory Reporting of Greenhouse Gases Regulation (MRR) used in the Cap-and-Trade program, which makes it impossible to credit the avoidance of GHG emissions or negative emissions. Once this key aspect of the Cap-and-Trade program is addressed, stakeholders will more clearly be able to understand and quantify the emissions credits available through CCS and mechanical CDR, making both technologies much more economically viable.

Additionally, the LCFS CCS Protocol must be revisited and updated so changes necessary to enable development of CCS are operative before 2025. As noted in **Comment A.10**, CCS

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52 September 7, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/80-sp22-concepts-ws-AmNWJVA2VFgEM1Bn.pdf. Accessed: June 2022.

53 Attachment to the September 7, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/80-sp22-concepts-ws-AmNWJVA2VFgEM1Bn.pdf. Accessed: June 2022.

54 Draft 2022 Scoping Plan Update. Pages 177-178. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

projects have lengthy timelines for permitting and development,[55] and it is imperative that CCS protocol enhancements are in hand so that financial and approval barriers are mitigated and California CCS projects can obtain critical LCFS crediting. An unclear understanding of the value for such projects will present a significant market barrier. Indeed, without such clarity, financing for such projects, either internal or external, will be difficult to obtain.

Key areas within the CCS Protocol that should be further evaluated and revised, as they have significant impacts on CCS project economics, include buffer account requirements and fracture pressure gradient specifications. Specifically, CARB should evaluate its CCS Protocol to ensure alignment with the federal 45Q program and the U.S. EPA Class VI UIC program to ensure a project operator can comply with all relevant provisions without unnecessary conflicts. In addition, issues such as pore space rights and eminent domain, while not in CARB's direct control, must be acknowledged as critical barriers that need to be addressed for the state to achieve its ambitions for CCS/CDR.

A.24 California must streamline permitting for CCS and mechanical CDR projects to ensure that CEQA and other regulatory proceedings do not unjustly stall or halt technologies that are crucial to meeting the goals of the 2022 Scoping Plan Update.

CARB rightly identifies the challenging permitting environment currently present in California as numerous federal, state, regional, and local entities play key roles in approving a CCS project. Among these many agencies, delays with obtaining the otherwise simple approval required in sequence can lead to a cascade of delays and recycle of effort. The uncertainty in schedule that results from these delays can undermine the economics and financing for such opportunities. Further, the utilization of CEQA and the associated environmental impact report (EIR) to stall projects, even those that are broadly recognized as positive, is well-known. While a robust EIR process is important to ensure that all relevant community impacts are being evaluated, the process cannot be allowed to hold CCS and similar such projects hostage. Given that CARB have identified CCS and mechanical CDR among the critical technologies for the state to achieve its climate goals, California needs to consider how to ensure these projects can be permitted and implemented on a timely basis. Everything that CARB can do to support a broader effort within California to streamline permitting and approvals of such projects will be vitally important (See **Comment 5** for further details).

A.25 The proposed timeline to deploy CCS "on a majority of refinery operations by 2030" is likely infeasible given the current delays in processes and lack of economic incentives in California's market-based program to support these projects.

CARB's premise in its chosen scenario that CCS would be "on majority of refinery operations by 2030" [56] needs further discussion. The timeline for permitting and implementing such

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55 Lawrence Livermore National Laboratory (LLNL). 2021. Permitting Carbon Capture & Storage Projects in California. February. Available at: https://gs.llnl.gov/sites/gs/files/CA_CCS_PermittingReport.pdf. Accessed: June 2022.

56 Draft 2022 Scoping Plan Update. Table 2-2 on Page 59. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

projects, which will easily exceed 5 years, [57] would not permit such a comprehensive extent of CCS being installed by this time, particularly considering that most major refineries are in major metropolitan areas and the preferred sequestration locations[58] will be substantial distances away from the CO_2 sources.

WSPA agrees with CARB's assessment in its Draft 2022 Scoping Plan Update that CCS technology is currently focused on the capture of nearly pure CO_2 streams that arise from non-combustion processes. Indeed, the majority of CCS installations today are found at ethanol and fertilizer plants, [59] which have such streams available. Within or alongside refineries, operations that have a byproduct stream approaching such CO_2 purity are from hydrogen SMRs. These produce a CO_2 rich stream, the majority of which is also a normal, non--combustion process byproduct. Like ethanol and fertilizer plants, vents from hydrogen plants are strong candidates for early sequestration.

The extension of application of CCS to the remaining refinery operations, including combustion-intensive units, is an exciting longer-term prospect. Unlike streams from fertilizer, ethanol and hydrogen plants, the concentration of CO_2 in combustion streams is much lower, and it will be likely more costly to employ CCS. As acknowledged by CARB, the application of CCS for such streams today is very limited. The first tranche of such facilities is only expected to start up in the second half of the 2020s, even though they are being characterized as being in the "advanced development phase," with only two such plants in construction and only a single such facility (Boundary Dam, Saskatchewan, Canada) in operation today.[60] Timing for implementation of CCS on these streams in refining operations, or any other combustion activity, will have to be assessed for cost-effectiveness as this technology develops.

While WSPA does present some concerns related to the ***timing*** for CCS in the Scoping Plan as it relates to refinery operations, we want to be clear that we believe CCS is a critical technology to achieve carbon neutrality and we are excited to work towards its implementation in our sector.

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57 LLNL. 2021. Permitting Carbon Capture & Storage Projects in California. February. Available at: https://gs.llnl.gov/sites/gs/files/CA_CCS_PermittingReport.pdf. Accessed: June 2022.

58 LLNL. 2020. Getting to Neutral: Options for Negative Carbon Emissions in California. August. Available at: https://gs.llnl.gov/sites/gs/files/2021-08/getting_to_neutral.pdf. Accessed: June 2022.

59 Draft 2022 Scoping Plan Update. Page 176. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf. Accessed: June 2022.

60 Global CCS Institute. 2021. The Global Status of CCS 2021. Available at: https://www.globalccsinstitute.com/wp-content/uploads/2021/11/Global-Status-of-CCS-2021-Global-CCS-Institute-1121.pdf. Accessed: June 2022.

Alternative 4 Assumptions

A.26 Similar to the Proposed Scenario (Alternative 3), Alternative 4 is technologically infeasible given the unprecedented level of growth in solar, battery storage, and grid capacity required, the proposed ZEV mandates for the transportation sector, and phase down of oil and gas extraction and refining in line with demand.

While Alternative 4 represents a slightly more conservative timeline for the deployment of the aforementioned strategy, it does not address the key issues present within the Proposed Scenario. Although under Alternative 4 LDV and MDV)/HDV sales are **required to be ZEV five years later than the Proposed Scenario, the required annual deployment of solar technology and battery storage to complete this transition (6 GW and 2 GW) still dramatically outpace the historic maximum build rates for these technologies.**

Alternative 4 does not address any of the concerns regarding need for grid resiliency under an electrification-centric Scoping Plan, the impacts of global mineral mining, battery production, and battery recycling, nor does it address the feasibility of achieving these levels of electrification across the transportation, residential, and industrial sectors.

WSPA maintains that a technology-neutral, market-based approach to achieving California's GHG reduction goals is more technologically and economically feasible and CARB should make serious considerations as to what approach would best serve California.

WSPA

ATTACHMENT B
Legal Comments

B.1 CARB Does Not Have Unfettered Regulatory Authority.

CARB proposes to adopt a broad-sweeping Scoping Plan that "lays out the transformations needed across our society and economy to reduce emissions and reach our climate goals." The California Legislature, however, in directing CARB to adopt the Scoping Plan, set forth express requirements and limitations on CARB's authority in adopting and implementing the Scoping Plan. Importantly, CARB must consider technological feasibility, cost-effectiveness, total potential costs, and environmental impacts of the proposed Scoping Plan and avoid relying on policies it does not have the statutory authority to implement.

AB 32 requires CARB to prepare a scoping plan "for achieving the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions." Cal. Health & Safety Code § 38561(a). The statute also requires CARB to account for the plan's total potential costs and benefits "using the best available economic models, emission estimation techniques, and other scientific methods." Id. § 38561(d). Likewise, Executive Order N-79-20 requires that CARB, in developing zero-emission vehicle strategies, to "act consistently with technological feasibility and cost-effectiveness." Executive Order N-79-20(2).

Similarly, the California Environmental Quality Act ("CEQA") Guidelines require consideration of environmental impacts, as well as the mitigation of such impacts where feasible. See 14 C.C.R. § 15021(a). CARB should also evaluate a "range of reasonable alternatives" which would "feasibly attain" most of the Draft Scoping Plan proposals' basic objectives "but would avoid or substantially lessen any of the significant effects" of the proposals. *See id.* § 15126.6(a). Specifically, when considering the feasibility of alternatives, the CEQA Guidelines provide the following factors to consider: "site suitability, economic viability, availability of infrastructure, general plan consistency, other plans, or regulatory limitations, [and] jurisdictional boundaries." Id. § 15126.6(f)(1).

B.2 The Draft Scoping Fails To Adequately Consider Required Statutory Factors.

Currently, the Draft Scoping Plan does not meet CARB's obligation to consider the potential negative environmental and economic externalities associated with the proposals described in the plan. Accordingly, WSPA urges CARB to consider the following technological feasibility and economic and environmental impacts[61] before finalizing the Scoping Plan.

- The proposed technology mandates are not cost-effective or technically feasible. The Draft Scoping Plan's arbitrary exclusion of mature technologies contradicts AB32's mandate that the plan "achiev[e] the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions." The Draft Scoping Plan imposes limits on renewable fuels, direct air capture, and other applications for carbon capture, as well as certain vehicle technologies in pursuit of specific mandated technologies. These limits preclude other technologies that could achieve similar outcomes in a feasible and cost-effective manner. To maximize emission reductions all options must be on the table.
- CARB fails to adequately consider cumulative direct costs. The Health & Safety Code requires CARB to utilize "best available economic models." Health & Saf. Code § 38561(d).

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[61] See Attachment A, Technical Comments for further detail.

In evaluating the potential range of costs resulting from the Draft Scoping Plan, CARB limits this evaluation to a single cost value for calendar years 2035 and 2045. This formula does not accurately portray the vast cumulative direct costs associated with the proposed policies over the course of the multiple decades covered by this Scoping Plan.

- CARB fails to adequately evaluate, and minimize, leakage. Under AB 32, CARB has an obligation to minimize leakage resulting from its regulatory activities. Health & Saf. Code § 38562. While CARB acknowledges the risk of leakage resulting from policies such as those impacting electricity grid demand that may result in increased production of dirtier power outside of California, residual liquid fuel demand that may result in increased imports, or emissions associated with production of ZEVs (mining/processing of minerals critical to battery production), it fails to adequately calculate, evaluate, and set forth policies to minimize such leakage.
- CARB fails to consider the negative impacts of curtailing oil production and refining. Consistent with AB 32 and CEQA, CARB must carefully consider all of the social and environmental impacts, both positive and negative, associated with curtailing oil production in the Scoping Plan. See Cal. Health & Safety Code § 38561(a); 14 Cal. Code Regs., tit. 14 § 15021(a). The Draft Scoping Plan fails to consider the full scope of the negative consequences of its preferred Alternative. For example, the plan would require the reduction of petroleum use by 91 percent in 2045 from 2022 levels but does not evaluate whether this would inadvertently increase emissions by increasing fuel imports to California via marine vessels. Similarly, CARB does not meaningfully consider the social consequences of the preferred Alternative—merely acknowledging that there will be significant job losses is insufficient consideration and fails to represent the full scope of social impacts that will be experienced. By way of example, CARB does not consider the impact of increased marine vessels and distribution activities on nearby communities, nor does it consider the economic and environmental impacts of closing retail stations, many of which are owned by small businesses. CARB must also address the significant social and environmental effects of lost jobs, lost tax revenue, and increased costs associated with the loss of a major industry sector that is tightly integrated into myriad aspects of California's economy and into the daily lives of Californians.
- CARB fails to consider the negative impacts of increased vehicle electrification. Similarly, the Draft Scoping Plan emphasizes the anticipated benefits it hopes to gain from increased electrification of the vehicle fleet while glossing over negative impacts associated with increased electrical demand. These may include increased loading on power plants, which may result in increased localized emissions near power plants as well as increased fire risk due to strain on the electrical grid. Power shortages would endanger Californians' lives and property—especially during hot summer months when demand is at its peak in many areas. The Draft Scoping Plan also does not recognize the impacts on roadways resulting from loss of gas tax revenue to fund maintenance, nor does it acknowledge the consequences of increased loading on roadways attributable to the extremely heavy batteries required to power heavy-duty vehicles. Finally, and most significantly, CARB does not acknowledge the lifecycle emissions, social impacts, or national security considerations associated with minerals sourcing and battery production. CARB must grapple with both the positive and

negative social and environmental effects of vehicle electrification, as required by AB 32 and CEQA.

B.3 The Draft Scoping Plan Mandates Actions That Violate Constitutional Rights.

Before finalizing the Scoping Plan, CARB must consider that elimination of an entire industry likely would constitute a regulatory taking, a violation of the Contract Clause, and a deprivation of vested rights under the California and U.S. Constitutions. As such, the companies affected by such policies would be entitled to just compensation from the state. At a minimum, should CARB continue down this path, CARB must quantify and evaluate the cost burden this would place on the State.

First, both the federal Constitution and the California Constitution provide that property owners are entitled to "just compensation" when the government takes their property for public use. Cal. Const. art. I, § 19; U.S. Const. 5th Amend. Article 1, § 19(a) of the California Constitution states, "Private property may be taken or damaged for a public use and only when just compensation, ascertained by a jury unless waived, has first been paid to, or into court for, the owner." These constitutional provisions are "designed to bar [g]overnment from forcing some people alone to bear public burdens which, in all fairness and justice, should be borne by the public as a whole." Penn Central Transp. Co. v. New York City, 438 U.S. 104, 123 (1978) (citation and quotation marks omitted).

A per se taking occurs where a government regulation completely deprives an owner of all economically beneficial or productive use of the property. *Jefferson St. Ventures, LLC v. City of Indio*, 236 Cal. App. 4th 1175, 1193 (2015). Shutting down domestic oil facilities and petroleum refineries would constitute a per se taking under this standard. Such properties may have no other economical or productive use, resulting in stranded assets. Additionally, even if some sites can be redeveloped for some other economically productive use, the oil in the ground owned by WSPA members constitutes real property that the state would permanently prevent them from accessing. Forcing this oil to remain in the ground would deprive WSPA members of "all economically beneficial or productive use" of the oil, thereby constituting a per se taking. *See Lucas v. South Carolina Coastal Council*, 505 U.S. 1003, 1015 (1992).

Second, policies that would effectively shut down oil facilities violate the Contract Clause under the California and Federal Constitution, to the extent that such policies impair the obligations of companies under existing contracts. *See* Cal. Const. art. I, § 9 ("A law . . . impairing the obligation of contracts may not be passed."); U.S. Const. art. I, § 10, cl. 1; *Birkhofer v. Krumm*, 81 P.2d 609, 621 (Cal App. 1938) ("[I]t follows that such provisions of state constitutions as merely parallel and iterate provisions of the Federal Constitution must be so construed as to harmonize with the construction placed by the federal courts upon the latter.") If the state imposes production quotas or policies equivalent to this, fuel producers may not be able to meet existing contracts with fuel purchasers. In addition, such regulations would undoubtedly impair production leases, royalty agreements and transportation contracts between California residents and oil companies. Notably, the "severity of the impairment" increases the level of scrutiny which regulations are subject to, and "[t]otal destruction of contractual expectations is not necessary for a finding of substantial impairment." *Energy Reserves Grp., Inc. v. Kansas Power & Light Co.*, 459 U.S. 400, 411 (1983).

While courts have upheld state regulations that impair contracts but have a "significant and legitimate public purpose," id. at 411, the contracting parties in such cases are still entitled to just compensation from the state for any resulting impairment. *See Lynch v. United States*, 292 U.S. 571, 579 (1934) ("The Fifth Amendment commands that property be not taken without making just compensation. Valid contracts are property, whether the obligor be a private individual, a municipality, a state, or the United States."). As such, even if the aforementioned policies do not violate the Contract Clause, the state would still owe WSPA members, local business owners, and California families that lease their land to WSPA members just compensation for any existing contracts that such policies impair.

Finally, California courts have held that businesses have "the right to continue operating an established business in which he has made a substantial investment."[62] Vested rights are rights that are "already possessed" or "legitimately acquired."[63] California courts have recognized both vested rights in economic interests (ability to continue operation of a business) and as it relates to land use development (ability to develop land in accordance with a valid government authorization).[64] In addition, where the real property is legitimately acquired, the business activity is "undertaken in accordance with applicable statutory mandates," and the right has a "potentially massive economic aspect," then, "[c]ertainly, a fundamental vested right is at issue."[65] When these types of rights are at stake, they are considered too important to be relegated to "exclusive administrative extinction."[66]

While California courts have been careful to require more than economic burden by way of increasing the cost of doing business, the express goal of the Draft Scoping Plan is to phase out the petroleum industry through the rapid electrification of the transportation industry. While some facilities that serve the residual liquid-fueled fleet or export fuel outside of California may remain while likely operating at fraction of their prior production capacity, for other facilities, including small business owners of gas stations, the rule forecloses all business opportunities. These businesses have lawfully operated within in the state of California for decades and have invested heavily in their operations within the state. The shutting down of these businesses goes well beyond an additional costs of doing business and falls squarely within the scope of interests Courts have looked to protect—where a company will be driven out of business or

62 *Id.* at 1529.

63 *Harlow v. Carleson,* 16 Cal. 3d 731, 735 (1976).

64 *Goat Hill Tavern v. City of Costa Mesa*, 6 Cal. App. 4th 1519, 1526 (1992).

65 *The Termo Co. v. Luther*, 169 Cal. App. 4th 394, 407–08 (2008) (Finding a fundamental vested right where the Director of Conservation ordered the plugging of 28 oil wells that had been lawfully in operation for over 20 years).

66 *Id.* at 406 (citing *Goat Hill Tavern*, 6 Cal. App. 4th at 1526).

"forced to operate at a loss and close."[67] Like the cases described above, the interests at stake here are not purely economic privilege, but rather the extinction of an entire industry.

67 *Mobil Oil Corp. v. Superior Court*, 59 Cal. App. 3d 293, 305 (1976) (Determining a fundamental vested right was not impacted because "[w]e are not presented with the enforcement of a rule which effectively drives the Oil Companies out of business. At most it puts an economic burden on them increasing the cost of doing business"); *Standard Oil Co. v. Feldstein*, 105 Cal. App. 3d 590, 604 (1980) (Concluding that the action did not impact a fundamental vested right because "[t]here is no contention that Standard will be driven to financial ruin by the action of the District; there is not even a contention that this particular facility will be forced to operate at a loss and close."); *San Marcos Mobilehome Park Owners' Ass'n v. City of San Marcos*, 192 Cal. App. 3d 1492, 1502 (Holding that "there is no contention, nor does the evidence suggest, that if the Commission denied the requested rent increases, the park owners would be in such an unfavorable economic position they would go out of business.").

ATTACHMENT C
List of Previous WSPA Comments on the Draft 2022 Climate Change Scoping Plan

April 4, 2022 Comments[68]

1. CARB's modeling analysis unreasonably constrains the scope of decarbonization strategies in the transportation sector, to the detriment of the environment and consumers.
2. The scenarios in the E3 modeling presentation clearly show that an all-electrification option by itself will not reach the State's GHG reduction targets. WSPA maintains its position that CARB should conduct a multi-technology analysis to evaluate how a technology/fuel-neutral market-based approach, could achieve the emission reduction targets and do so faster and with more cost-effectiveness. Such a strategy could also reduce the significant systemic risks inherent to the all-electrification option.
3. AB 32 requires CARB to "ensure that activities undertaken pursuant to the regulations complement, and do not interfere with, efforts to achieve and maintain federal and state ambient air quality standards and to reduce toxic air contaminant emissions." The scenarios presented not only interfere with efforts to achieve the federal ozone standard, but actively impede near-term progress toward attainment.
4. CARB's scenarios all depend on unprecedented levels of growth within the solar energy and battery storage sectors. Inclusion of natural gas and RNG power plants with carbon capture, utilization, and storage (CCUS) to meet the State's electrical demand and reliability requirements and can help alleviate the infrastructure redundancy that would be necessary with an all-renewable electric grid.
5. CARB's scenarios and Scoping Plan should consider all options of hydrogen generation.
6. Trillions of dollars would be required for the electric infrastructure upgrades needed to sustain the all-sector transition to electrification contemplated in CARB's scenarios. Adopting technology-neutral, market-based approaches for GHG emissions reductions could be more cost-effective.
7. CARB's transportation energy demand projections for the E3 scenarios appear to assume VMT reductions ranging from 10% by 2030 for Alternative 4 to 30% by 2035 in Alternative 1 as compared to the 2020 VMT baseline. This is despite the State's previous failure to achieve VMT reductions under Senate Bill (SB) 375. The increased use of low carbon-intensity fuels could provide GHG reductions with much greater certainty than VMT reduction assumptions.
8. CARB is obligated under AB 32 to minimize the "leakage" potential of any of their regulatory activities. The presented scenarios appear to set an emissions inventory boundary that fails to account for California GHG emissions that would be caused outside the California border. Such emissions leakage would likely be a direct result of certain CARB policy concepts presented in these scenarios. CARB must estimate the emissions increases outside of California which result from leakage and policy-driven demand.

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[68] April 4, 2022 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/41-sp22-modelresults-ws-AWBUMF0DUjIGMgVa.pdf Accessed: June 2022.

9. WSPA agrees that carbon removal technologies including CCS critical tool for industries to choose to invest in and will be pivotal to the overall success of the Scoping Plan to achieve carbon neutrality by 2045. Each of the scenarios considered by E3 would require CCS technologies and/or CDR to reach carbon neutrality. CARB may be compromising the viability for these technologies by undercutting the very market tools on which they would depend, specifically the LCFS.

November 19, 2021 Electricity Sector Comments[69]

1. WSPA concurs with the position of both the CPUC and CEC with regard to the importance of natural gas in our energy future. As noted by more than one stakeholder during the Workshop, strategically-located natural gas power plants and the continuous improvements in facility efficiency and clean fuels are an important consideration in any strategic planning in the electricity sector for California.

2. WSPA is a strong supporter of CCS as a critical tool towards achieving deep carbon reductions in California and globally.

November 19, 2021 Technical Workshop Comments[70]

1. WSPA urges CARB to model an alternative that relies more heavily on market-based approaches, such as cap and trade, to achieve emission reductions. Specifically, WSPA requests the inclusion of an "Alternative 5" that prioritizes "least cost" emissions reductions across the economy, inclusive of certain policy constraints. "Alternative 5" would evaluate the potential roles (and additional benefits) that market mechanisms and a price on carbon could contribute (in place of bans and mandates) to pursuing carbon neutrality.

2. WSPA believes that biofuels should hold a more prominent role in the Scoping Plan (particularly beyond 2035), as a carbon emissions-reducing tool. We encourage CARB to include in the PATHWAYS modeling assumptions greater use of biofuels in multiple applications (e.g., light-duty vehicles, medium and heavy-duty vehicles, off-road engines, railroad, aviation, etc.), and that the volumetric use increase with time as supply grows and the LCFS CI targets become more stringent (as noted in previous WSPA comment letters).

3. WSPA strongly supports further education on the application of CCS and other carbon removal technologies such as DAC and their important role in the Scoping Plan and recommends that CARB consider in the PATHWAYS modeling different rates of implementation CCS over the time periods identified in CARB's Alternatives 1-4.

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69 November 19, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/24-sp22-electricity-ws-BVpQIVEjBCdQNwNc.pdf. Accessed: June 2022.

70 November 19, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/96-sp22-inputs-ws-VwhUJVwuV3RXMFMM.pdf. Accessed: June 2022.

<u>October 11, 2021 Comments</u>[71]

1. An alternative prioritizing the lowest cost of implementation should be included as part of CARB's modeling. WSPA believes that CARB should allow market and price signals to drive reductions in the oil and gas sectors to meet the carbon neutrality goals of the state, while minimizing impacts to the economy and consumers.
2. Market-based approaches will be critical to pursuing carbon neutrality in the most cost-effective manner. WSPA encourages CARB and the state's policymakers to focus on programs that will complement and allow for integration with the global economy, rather than a framework based on bans and mandates that could contribute to a patchwork of impractical policies across the world.
3. The impact of market mechanisms currently in place is still unclear. CARB should develop a new Alternative 5 to evaluate the potential roles (and additional benefits) that market mechanisms and a price on carbon could contribute (in place of bans and mandates) to pursuing carbon neutrality.
4. WSPA generally finds CARB's proposed Alternatives 3 and 4 to be more realistic and balanced approaches than Alternatives 1 and 2.
5. CARB should evaluate a wider range of alternatives, including a flat (0%) VMT per capita improvement over time as well as a middle value of 10% improvement.
6. CARB should assume continuing fuel economy improvements for internal combustion LDVs to 2035 and then beyond to 2045 in Alternative 4. WSPA believes that there is potential for efficiency gains above 2% depending on the level of hybridization there is in the fleet.
7. WSPA recommends that CARB include at least one alternative that does not evaluate a ban on the internal combustion engine, and instead models a more gradual increase in ZEV sales extending to 2045.
8. WSPA recommends review and use of the assumptions in the December 2020 Princeton University "Net Zero in America" study for MDV/HDV ZEV vehicle sales, stock inventory, and truck transportation within port operations in the "E-" case.
9. WSPA recommends that Alternatives 3 and 4, at a minimum, should assume some use of renewable SAF, consistent with expected SAF supply and per CARB's biofuels supply modeling assumptions.
10. Alternative 4 should model a majority of rail service using liquid fuels in 2045 to better bracket the assumptions of full or near-full adoption of electrification technologies in the other Alternatives. CARB should also consider how rail transportation originating outside the state or country is likely to be powered. Alternative 4 should assume consumption of

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[71] October 11, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/93-sp22-inputs-ws-AnUBdF0sWGoEXQFi.pdf. Accessed: June 2022.

biofuels consistent with expected annual production capacity of those fuels (for which CARB has assumed zero GHG emissions).

11. WSPA believes that CARB should include: 1) improved energy efficiency and electrification in the upstream O&G sector including the pre-combustion capture of carbon to increase combustion efficiency; 2) expanded application of and use of renewables (renewable power or renewable fuels or hydrogen) in the upstream O&G sector to power operations; and 3) the use of CCUS on upstream combustion sources similar to the manner in which CARB is applying CCUS for the refining industry in the Alternatives. This is especially critical to Alternative 4.
12. WSPA requests that CARB adjust its approach in Alternative 4 as to the relationship between oil production and fuel demand in the state. WSPA specifically requests that CARB use an in-state oil production decline rate in step with the long term (20+ years) oil production in California from data collected by government agencies such as the US Energy Information Administration (EIA) or the CEC.
13. WSPA believes CARB is underestimating the potential for emission reductions at refineries by only modeling the application of CCS for refinery emission reductions. Just like the O&G production sector, there is potential for continued emission reductions at refineries through improvements in energy efficiency and the use of renewables (renewable electricity and renewable fuel gas).
14. We urge CARB to: 1) model the amount of biofuels that can be cost-effectively put into the fuel supply system; 2) incorporate biofuels into the baselines of Alternatives 2, 3, and 4; and 3) model varying levels in each alternative, with a maximum in Alternative 4.
15. WSPA believes that it is suboptimal for CARB to dictate an order of emission reductions. A better approach would be to evaluate all potential options simultaneously to determine which can provide emissions reductions most efficiently, and with the least economic dislocation.
16. Alternative 4 should model the findings from the Lawrence Livermore National Laboratories report at 100 MMt/year at $200/tonne. Alternative 4 should further include an assumption for carbon removal from the atmosphere via DAC. Finally, if appropriate for the modeling, Alternative 4 should include reasonable assumptions for carbon removal from Natural and Working Lands.
17. WSPA recommends that CARB take a different approach to modeling in the commercial and residential buildings sector and suggests the modeling of a non-zero but increasing efficiency standard for sales in this sector in at least one of the modeled alternatives

September 22, 2021 Comments[72]

1. WSPA's members would like to request access to the emission reduction data by sub-sector to better inform our members' understanding of the calculations.

2. WSPA would like to ask CARB to clarify the approach to their scenario modeling conducted to evaluate how fugitive methane from oil and gas sources will change based on: 1) the Governor's directive to phase out in-state oil and gas production by 2045 or sooner; 2) Changes in natural gas demand; and 3) RNG utilization in existing fossil gas infrastructure.

September 7, 2021 Comments[73]

1. WPSA recommends that CARB expand the range of options and alternatives being considered for modeling decarbonization in multiple different sectors.

2. CARB should consult with more academic centers of excellence, national labs, and others to identify a stronger modeling construct. In particular, the model should be capable of evaluating the effects of a price on carbon to allow markets to determine the solutions rather than employing arbitrarily mandated targets and handpicked solutions.

3. CARB should include a peer review in the modeling process and broaden the range of assumed economic and technology assumptions

4. CARB should evaluate the potential role (and additional benefit) that market mechanisms and a price on carbon could contribute (in place of bans and mandates) to pursuing carbon neutrality.

5. CARB should make some additions to the concepts illustrated in slide 10 (Transition from Fossil Fuels to Alternatives). In addition to items already listed, CARB should add elements to the arrow diagram and "Alternatives" list such as low carbon petroleum fuels, low carbon petroleum fuels with CCS, and low carbon gasoline for the light-duty sector.

6. The Scoping Plan should include a detailed summary of the assumptions and forecasts related to achieving the 2030 goal. CARB should continue to support the science of a cumulative emissions approach to planning. We welcome CARB evaluating, as directed by Governor Newsom in 2021, an accelerated goal of achieving carbon net-neutrality by 2035, so long as that evaluation transparently identifies the technological and economic hurdles to full implementation and fairly recognizes that it will be exponentially more difficult to achieve that goal. CARB should also model options on the other end of the spectrum.

7. More specificity is needed regarding levels of engineered carbon removal to be evaluated. CARB should not only model deployment of engineered carbon removal as part of its

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72 September 22, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/28-sp22-slcp-ws-ViECd1cmU2ECWwJx.pdf. Accessed: June 2022.

73 September 7, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/80-sp22-concepts-ws-AmNWJVA2VFgEM1Bn.pdf. Accessed: June 2022.

scenarios, but it should also evaluate the trade-offs of not deploying significant negative emissions technologies as part of its modeling exercise. We believe evaluation of these trade-offs should include a look at cost-effectiveness as well as an evaluation of the impact to employment and labor income.

8. CARB should ensure that modeling scenarios include potential increasing electricity generation and increasing electricity consumption. WSPA strongly supports the inclusion of Scenarios C and D which use the widest possible range of technologies to meet the SB-100 goals. Of note, WSPA strongly believes that natural gas power plants equipped with CCS can play a large role in meeting our SB-100 goals while ensuring grid reliability. This should be included in the modeling.
9. CARB should evaluate a wider range of scenarios including a flat (0%) VMT per capita change over time as well as a middle value of 10%. If the assumptions for VMT are too optimistic and not achieved in practice, the state will fall short of achieving its goals.
10. CARB should include one or more scenario that account for and evaluates different EV adoption rates, including slower adoption than those shown in workshop slides. CARB should also model at least one scenario where renewable and low-carbon fuels are used in combination with higher efficiency vehicles to compete with ZEVs on a lifecycle emissions AND cost basis. CARB should assess the full range of emissions, impacts, and costs generated outside of California for electric vehicles (e.g., from mining, battery production, recycling, etc.) and incorporate those into the model for the transportation system. CARB should develop a ZEV supply chain analysis and incorporate those findings into the Scoping Plan modeling.
11. CARB should include multiple scenarios that allow market forces and a price on carbon to drive the emission reductions from this sector as there are many opportunities to reduce emissions (efficiency, fuel switching, CCS, use of renewable power and feedstocks, etc.) that are not directly related to a decrease in production. We believe that cost and feasibility should be the driving factors that determine what the reductions in this sector are over time.
12. WSPA supports CARB's modeling scenarios and appreciates that many allow all SLCP methane/woody/solid biomass waste to include fuels derived from those sources.
13. CARB should model scenarios where renewable and low-carbon fuels and energy efficiency improvements exist alongside electrification options.
14. CARB should revise Option A as any scenario which forces facilities or sectors to shut down is very likely to lead to leakage from that sector which is exactly the type of impact AB32 was written to avoid. Additionally, WSPA is concerned that the option to use CCS for the industrial sector is not specifically listed in the other options. WSPA strongly believes that CCS offers a significant opportunity for the state to decarbonize the industrial sector and believes it should be specifically called out in the options.

August 16, 2021 Comments[74]

1. Deployment of engineered carbon removal is essential to meeting carbon neutrality. CCUS can help the state significantly reduce carbon emissions from sectors such as crude production, refining, biofuels, cement manufacturing, power generation, agriculture, dairy, and others.
2. Deployment of CCUS technologies will lead to reduction in air quality impacts.
3. WSPA member companies are in the process of designing and permitting facilities that could benefit California through engineered carbon removal.

July 9, 2021 Comments[75]

1. CARB should approach the Scoping Plan with an open mind by looking at and leaving on the table all available options to achieve carbon neutrality. Doing so will increase the likelihood of meeting the state's goal.
2. We encourage CARB to clearly communicate the potential pros and cons (or risks) of electrification in the Scoping Plan.
3. CARB should remain cognizant of its obligations and boundaries under the relevant authorizing statutes as CARB develops the Scoping Plan.
4. Approaches that recognize the important impact of low carbon liquid fuels available today could allow the state to help meet its goals, particularly in the short-term, and foster technologies that could become a linchpin of California's low carbon future.
5. Ultimately the California energy system must work to foster an optimum outcome for the state. CARB, can help facilitate this via thoughtful approaches in the 2022 Scoping Plan. An approach that relies too heavily on a single approach, such as electrification, will lead to unreliability and unintended consequences.
6. It is important that this reality is acknowledged early in the 2022 Scoping Plan development process to allow for a robust discussion and evaluation. In defining carbon neutrality, we also encourage CARB to clearly define early in the Scoping Plan process the broadest range of sources and sinks and geographic boundaries possible.

74 August 16, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/41-sp22-co2-removal-ws-VyAFcFcmWGpVDFQy.pdf. Accessed: June 2022.

75 July 9, 2021 WSPA Comments on CARB 2022 Scoping Plan Update. Available at: https://www.arb.ca.gov/lists/com-attach/77-sp22-kickoff-ws-ViFSJwd2AzEGXwlq.pdf. Accessed: June 2022.

7. Given that GHGs are measured on a global basis, California should embrace the most cost-effective emission reductions or removals wherever they can be achieved. CARB should continue to lean into the cap-and-trade program and allow it to play a bigger role in the 2022 Scoping Plan.

8. CARB staff should evaluate and publicly vet multiple scenario analyses; then they should present a range of low-risk, cost-effective approaches for public comment before presenting to the CARB Board. All this should be done without prejudgment.

9. Liquid fuels will still be needed beyond 2045 and can provide early benefits. Some of our WSPA member companies are pursuing major projects in California to produce non-traditional lower-carbon liquid fuels such as renewable diesel and gasoline, RNG, lower carbon gasoline, and sustainable jet fuel. These must be a part of any Scoping Plan and should be included in the modeling of potential pathways.

10. The support of the technologies that would occur by valuing lower-carbon fuels could help ensure that there are fuel options ready for longer-distance modes of transportation that are even more difficult to decarbonize. These include fuels for the aviation industry as well as global shipping.

11. Forcing in-state crude oil production decline through policy and tax approaches only serves to prop up jurisdictions who do not share California's values. Preserving the capabilities of this industry allows for production of lower carbon crudes that will be needed for California to meet its climate goals.

12. WSPA encourages CARB to consider the synergy between farming practices and biofuels. Recognition of sustainable farming practices in a biofuel lifecycle will connect the farmer to a market-based incentive program and drive this behavior while at the same time providing substantial near-term emission reductions.

13. The Scoping Plan process will fall short if it does not utilize a fully transparent approach that provides multiple opportunities for public meetings to discuss data and assumptions for CARB's modeling work. The modeling work should exhaustively consider a range of scenarios by which the state can reach carbon neutrality.

14. WSPA implores CARB to hold multiple workshops regarding the model work performed to support the 2022 Scoping Plan. We also suggest that California consider modeling scenarios where critical technologies do not advance at the pace predicted by CARB as well as where critical technologies advance much faster than CARB predicts.

15. Modeling work should consider the costs and risks of the full supply chain. We encourage CARB to not ignore these environmental costs, outsourcing the environmental impacts that result. CARB should seek to understand these impacts and model those emissions.

16. Negative emissions opportunities should be supported for optimal outcomes. As GHGs are a global challenge, progressing technology that supports negative emissions should be appropriately valued.

17. CARB should remain cognizant of its obligations and boundaries under relevant authorizing statutes.

18. WSPA emphasizes that CARB must consider technological feasibility, cost-effectiveness, total potential costs, and environmental impacts of proposals and cautions CARB against relying on policies it lacks the current statutory authority to implement.

19. Consistent with its obligations under AB 32 and CEQA, as CARB evaluates proposals, it should consider the following: 1) the environmental impacts of ZEV manufacturing; 2) a full-life cycle analysis of mass scale BEV battery production, including end-of-life battery recycling and disposal; 3) the environmental impacts of an increased statewide fleet inventory; 4) the environmental impacts and health and safety issues associated with the transport of hazardous materials in ZEVs; 5) the changes in non-exhaust particulate matter (PM) emissions from increased ZEV operation; 6) the near-term air quality benefits of low- and ultra-low NOx technologies; 7) an assessment of the impacts resulting from updates and improvements to existing infrastructure; 8) the effects of increased ZEV use on the reliability of the electricity grid; and 9) the impact of energy price increases as a result of fuel production restrictions.

20. Consistent with AB 32 and CEQA, CARB must carefully consider all of the social and environmental impacts, both positive and negative, associated with such proposals. CARB must fully evaluate the detrimental social and environmental impacts of proposals to shut down domestic oil production.

21. When considering the total potential impacts of transportation sector policies for inclusion in the Scoping Plan, CARB should evaluate the constitutional implications of shutting down California oil production via production quotas, burdensome excise taxes, or restrictive setbacks.

22. CARB lacks statutory authority to unilaterally impose policies that shut down oil facilities. Until the legislature passes a bill that imposes production quotas, additional excise taxes, or setbacks on fuel companies, CARB cannot do so unilaterally. Because the California legislature has already rejected such bills, WSPA cautions CARB about relying on policies that may never ultimately pass to meet Scoping Plan goals.

ATTACHMENT D
Economic Impacts of Achieving California's 2022 Draft Scoping Plan's "Proposed Scenario" by NERA Economic Consulting dated June 2022

NERA
ECONOMIC CONSULTING

Economic Impact Analysis of California's 2022 Draft Scoping Plan's "Proposed Scenario"
Volume I: *Scenario Modeling and Key Study Results*

Prepared for:

Western States Petroleum Association

June 2022

Project Team

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About NERA

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EXECUTIVE SUMMARY

SYNOPSIS

This report compares the relative economic impacts of two different approaches that attain a similar amount of cumulative economy-wide CO_2 emissions reductions in California from 2024 through 2045. They are: (1) a set of "regulatory" policies that promote carbon-reducing actions on a sector-specific basis without a unifying price signal., and (2) the application of an economy-wide CO_2 emissions limit or cap that has a trajectory similar to what is attained in the regulatory approach. The first scenario contains the key sector-specific mandates that are part of the California Air Resources Board's (CARB) 2022 Draft Scoping Plan's "Proposed Scenario" which we refer to as the "Regulatory scenario".[1] In the second scenario, carbon reductions are achieved through the imposition of an economy-wide emission cap, an approach typically proposed as an alternative to a regulatory approach, which we refer to as the "Market scenario."[2] Both scenarios also achieve net-zero emissions by 2045. The economic impacts of each scenario on the California economy have been projected using NERA's macroeconomic model of the U.S. economy, which contains substantial detail on economic sectors, regions, and available and projected future energy technologies. The impacts from each of these scenarios are compared to a business-as-usual (or "BAU") case which reflects a continuation of existing policies.

Because both scenarios attain a similar level of cumulative CO_2 emissions reductions from 2024 to 2045 and net-zero emissions by 2045, their economic impacts can be compared to each other to assess their relative cost-effectiveness. In brief, our analysis finds a very wide gap in cost-effectiveness between the Regulatory and the Market scenarios. The Market scenario is projected to be far less costly than the Regulatory scenario, whether assessed in terms of gross domestic product (GDP) or consumer-focused metrics such as consumption per household. The gap in economic costs is projected to widen over time as both policies achieve deeper emissions cuts. For example, by 2045:

- The reduction in annual GDP relative to the BAU is projected to be about $23 billion in the Market scenario compared to about $44 billion in the Regulatory scenario,[3] and
- The reduction in annual consumption per household relative to the BAU is projected to be about $820 in the Market scenario compared to about $1,890 in the Regulatory scenario.

The greater cost-effectiveness of a uniform emissions price signal over a patchwork of sector-specific regulatory measures is not a surprising result for policy analysts. This study, however, is able to illustrate why this result is reasonable to expect via multiple, specific examples of how the Regulatory scenario's

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[1] The Regulatory scenario that is modeled in this study is based on key elements of the "Proposed Scenario."

[2] We also consider two sets of sensitivity scenarios (referred to as the "High Alternative Vehicle Cost" and "Low Alternative Vehicle Cost" scenarios) whose impacts are used to bound the range of results from the two core scenarios. These sensitivity scenarios differ from the core scenarios in the vehicle purchase cost trajectories assumed for battery-electric vehicles in the personal transportation sector and for battery-electric and fuel-cell electric vehicles in the commercial trucking sector. The inputs for these sensitivity scenarios are outlined in Appendix II of Volume II: Technical Appendices.

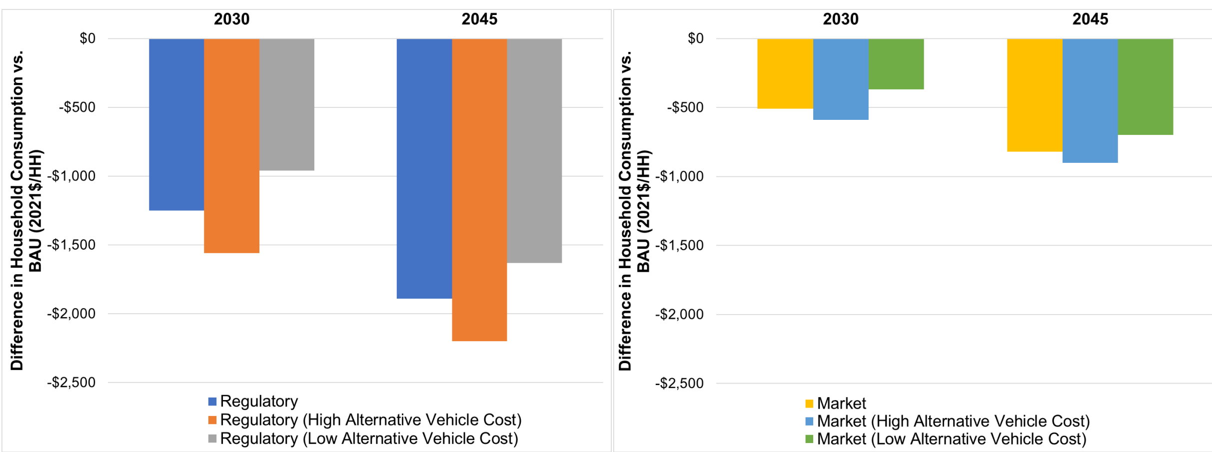
[3] All impacts are stated in 2021$, unless otherwise noted.

lack of ability to equalize marginal cost of reducing emissions across all sectors distorts incentives for selecting the most cost-effective reduction actions from an economy-wide perspective.

SUMMARY OF KEY RESULTS

The central question addressed in this analysis is how the projected economic impacts of a purely regulatory approach compare to those of a market-based approach that would achieve similar cumulative CO_2 emission reductions by 2045 across the California economy. Our analysis finds that the Regulatory scenario would likely have higher economic costs, whether assessed in terms of household consumption[4], or gross domestic product (GDP). As Figure1 illustrates the projected difference in annual household consumption (relative to the BAU) is projected to be larger in the Regulatory scenario than in the Market scenario. In 2030, the difference in per-household consumption (relative to the BAU) is projected to be about $1,250 in the Regulatory scenario compared to about $510 in the Market scenario. The gap is projected to widen over time as both policies achieve deeper emission cuts such that by 2045, per-household consumption is $1,890 lower than the BAU in the Regulatory scenario compared to $820 in the Market scenario. In 2045, the range of impacts for this metric for the Low Alternative Vehicle Cost cases are projected to range between $700 and $1,630 for the Market and Regulatory scenarios respectively and between $900 and $2,200 for the corresponding High Alternative Vehicle Cost cases.

Figure 1: Projected Differences in Annual Household Consumption Cost per Household in 2030 and 2045 (Relative to the BAU (2021$/Household)



As Figure 2 illustrates, the difference in GDP (relative to the BAU) is projected to be about $16 billion in the Regulatory scenario compared to about $10 billion in the Market scenario in 2030. By 2045, the difference in GDP (relative to the BAU) is projected to be about $44 billion in the Regulatory scenario compared to about $23 billion in the Market scenario. For the same time period, the GDP impacts range between 0.5% (about $20 billion) and 0.8% (about $35 billion) in the Low Alternative Vehicle Cost cases

[4] Consumption is the market value of all goods and services that households are projected to be able to purchase, after accounting for their income, government taxes, and savings decisions in each time period covered by the model. It is equal to economic welfare without inclusion of the utility-value of leisure. Annual consumption cost per household is the loss in consumption value divided by the number of households in each model year.

for the Market and Regulatory scenarios respectively. The corresponding impacts for the High Alternative Vehicle Cost cases range between 0.6% (about $26 billion) and 1.1% (about $49 billion).

Figure 2: Projected Differences in GDP in 2030 and 2045 (Relative to the BAU) (2021$, Billions)

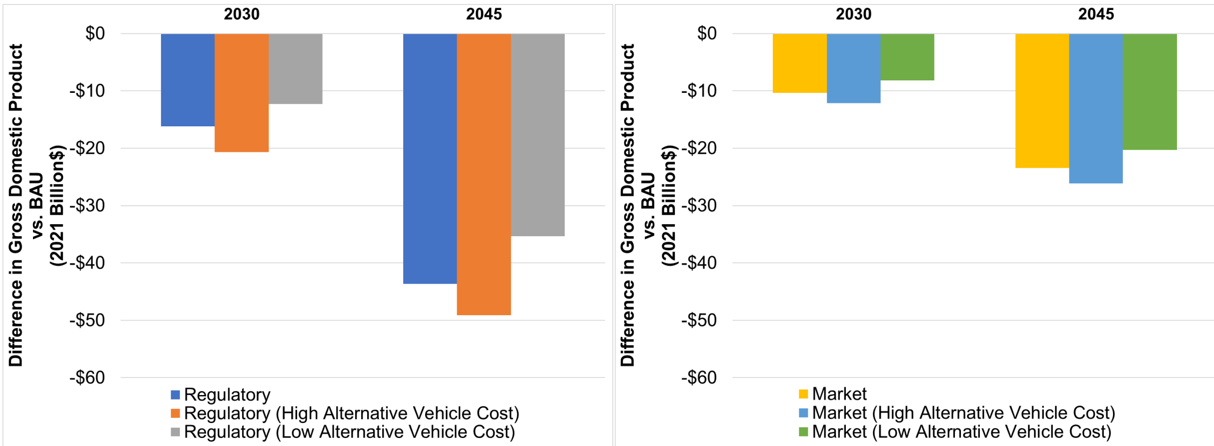


Figure 3 shows the projected economy-wide CO_2 emissions in California under each scenario. Although the total reductions under the Regulatory and Market scenarios differ somewhat from year to year (with the Regulatory scenario achieving greater reductions in emissions in the long run as the stringencies of the mandates increase over time; while in the Market scenario the carbon prices induce greater emissions reductions in the short run), both scenarios achieve about a 50% reduction in CO_2 emissions relative to the BAU by 2045. The CO_2 emission reductions (relative to the BAU) for the Low Alternative Vehicle Cost and High Alternative Vehicle Cost cases for the Market and Regulatory scenarios are also projected to be similar to each other in 2045. Figure 4 illustrates the projected CO_2 emissions in California by sector in 2030 and 2045 while Figure 5 shows the CO_2 emissions by sector on a cumulative basis from 2024 to 2045 for the different scenarios. A higher level of emission reductions (relative to the BAU) are projected in the residential, commercial, and industrial sectors in the Market scenario while for the electric and transportation sectors, the emission reductions are projected to be higher in the Regulatory scenario. Figure 4 also shows the amount of DAC deployed in California in 2045 in the various scenarios to offset the economy-wide CO_2 emissions.

Figure 3: Projected Economy-wide CO_2 Emissions in California

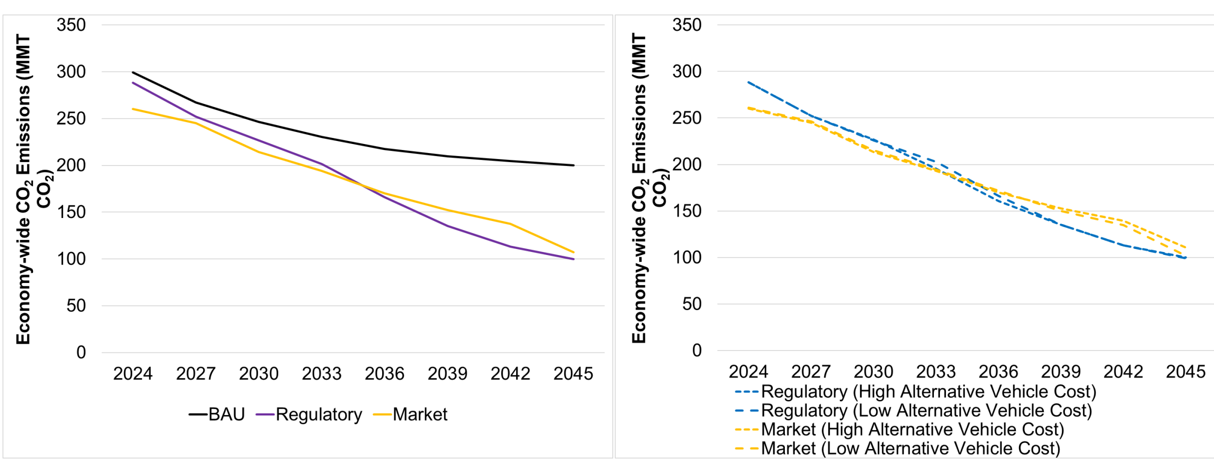


Figure 4: Projected CO_2 Emissions in California by Sector

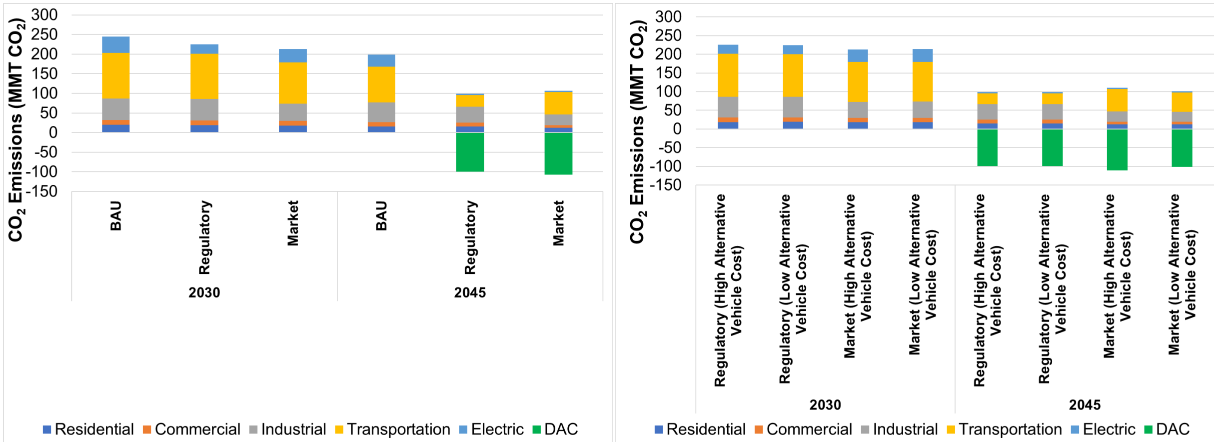
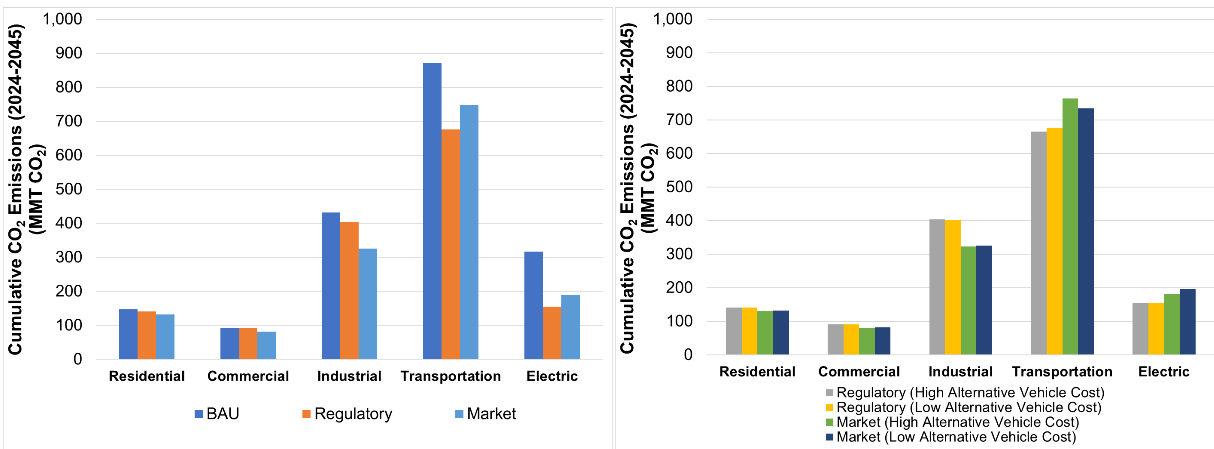


Figure 5: Cumulative CO_2 Emissions in California by Sector (2024-2045)



CONCLUSION

Our study has modeled the economic and energy market impacts of two different policy approaches - the first approach which we refer to as the "Regulatory" scenario containing certain key sector-specific mandates that are part of CARB's 2022 Draft Scoping Plan's Proposed Scenario and a second approach in which a similar level cumulative emission reductions are achieved by 2045 modeled using a cap-and-trade approach which we refer to as the "Market" scenario. Under both policy scenarios, a net-zero emission target is achieved in 2045 by deploying DAC as a carbon dioxide removal technology.

For this study, we also modeled two sets of sensitivities around the Regulatory and Market scenarios to bound the range of impacts from these approaches. These sensitivity scenarios (which we refer to as Low Alternative Vehicle Cost and High Alternative Vehicle Cost scenarios) take into account uncertainties that are associated with the technology costs in the transportation sector. Specifically, for these scenarios we employ a range of costs assumptions that relate to the vehicle purchase costs of battery electric vehicles in the personal transportation sector and battery-electric and fuel-cell electric vehicles in the commercial trucking sector.

We use a CGE model of the U.S. economy called NewERA with regional disaggregation (where California is represented as a separate region) and sectoral disaggregation (containing 12 economic sectors) to estimate the economic impacts of these scenarios. The costs of each of these scenarios are reported relative to a business-as-usual (or a "BAU") case which reflects a continuation of existing policies.

The results indicate a trade-off between reducing carbon emissions and the costs that households would incur under these policy approaches in California. In both scenarios, California's carbon emissions are reduced to about 100 MMT CO_2 by 2045 (a reduction of about 75% relative to 2005 levels) with a similar level of cumulative emissions reduction from 2024 to 2045. Both scenarios also achieve net-zero emissions by 2045 by deploying DAC. In 2045, the reduction in annual consumption per household relative to the BAU is projected to be about $820 in the Market scenario compared to about $1,890 in the Regulatory scenario. The underlying driver behind the difference in costs between the two scenarios is that businesses and consumers would face higher energy and transportation costs under the Regulatory scenario, from prescriptive regulations, which would in turn would lead to increased costs of other goods and services throughout the California economy. As a consequence, household disposable income and household consumption would fall. In addition, capital would be diverted to sectors that are affected by the regulations and away from rest of the economy. Wages and returns on investment would also fall, resulting in lower growth in productivity. Thus, the results imply that that the Market approach is more cost effective in reducing emissions than the Regulatory approach for similar levels of cumulative emissions reductions.

At the sectoral level, the Regulatory scenario is projected to result in a larger reduction in emissions from the transportation sector than the Market scenario while a larger reduction in emissions is projected from the industrial sector – the implication of this being that it is more cost-effective to achieve emission reductions in the industrial sector than from the transportation sector in California. The results also imply that there are trade-offs in how carbon reduction policy is designed i.e., emissions reductions have a net cost and that sector specific mandates that target deeper emissions cuts are costlier than a market-based approach.

I. INTRODUCTION

This study evaluates the economic impacts of representative regulations and mandates that are based on the Proposed Scenario from CARB's 2022 Draft Scoping Plan's (collectively referred to as the "Regulatory" scenario) on the California economy and energy sectors.[5] The study also evaluates the economic impacts of a cap-and-trade scenario (referred to as the "Market" scenario) that achieves the same level of cumulative emissions and net-zero emissions by 2045.

A. Background

Under a regulatory approach, mandates are imposed on sectors, and in particular energy intensive sectors, to reduce greenhouse gas emissions directly or indirectly by encouraging fuel substitution from high to low carbon content fuels or by substituting technologies that are less carbon intensive. Greenhouse gas emissions largely arise due to the combustion of fossil fuels in transportation, heating, various industrial and commercial processes, and electricity production. Sector specific technology specific mandates implicitly subsidize clean technology while taxing carbon intensive technology, which leads to emission reductions. These sector specific mandates limit sectoral output thereby increasing the cost of production. Mandates that target fuels directly would increase the cost of fossil fuels, leading to increases in costs to consumers and businesses as well as other economic impacts. The marginal cost of reducing emissions would vary across sectors and will depend upon the stringency of the mandate on the sectors. The cap-and-trade scenario, on the other hand, will still impose costs on emissions but will ensure that the marginal costs of reducing emissions are equalized across all sectors and that emissions are reduced in the most cost-effective manner.

The increased costs from mandates or from an emissions cap under the cap-and-trade scenario would encourage companies to switch to lower-emitting fuels and would result in households and companies reducing their energy use. The net effect of these changes whether from a purely regulatory or market-based approach would be to reduce CO_2 emissions.

B. Objectives of This Study

The principal objective of this study is to provide estimates of the economic impacts of certain key mandates that are part of the Proposed Scenario from CARB's 2022 Draft Scoping Plan on the California economy. We compare the economic impacts from these mandates (which we refer to collectively in our modeling as the Regulatory scenario) and a corresponding market-based scenario (which we refer to as the Market scenario) on California GDP and other measures of economic activity, on CO_2 emissions across sectors, and the adoption of technologies in the transportation sector compared to a business-as-usual case that does include policies or mandates that reduce emissions. We use a state-of-the-art integrated energy and economic model, the NewERA model, to estimate these effects. The NewERA

[5] CARB released their Draft 2022 Scoping Plan Update in May 2022 whose objective is to assess progress towards achieving the SB 32 target (reducing GHG emissions by at least 40% below 1990 levels by 2030) and lay out a path to achieve carbon neutrality no later than 2045. The Scoping Plan's Proposed Scenario (also referred to as "Alternative 3") incorporates a goal for carbon neutrality by 2045 and includes deployment of a broad portfolio of existing and emerging fossil fuel alternatives and clean technologies. *See* Draft 2022 Scoping Plan Update, May 10, 2022, California Air Resources Board (available at https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf).

model allows us to estimate detailed effects on energy markets as well as impacts on different sectors and the California economy. We consider two core scenarios and sensitivities around these scenarios. These scenarios are described in greater detail in Section III.

A. **Regulatory Scenario**: This scenario incorporates regulations to increase fuel economy and increase electric vehicle penetration in the transportation sector, regulation to phase out oil and gas extraction, mandates to promote the uptake of clean technologies in the electric sector as well as energy efficiency targets in various sectors of the economy. The scenario also incorporates a constraint to achieve a net-zero emission target in California by 2045.

B. **Market Scenario**: This scenario incorporates an emissions limit or cap that is similar to the CO_2 emission trajectory in the Regulatory scenario and is modeled as a cap-and-trade scenario with banking and a net-zero emissions target in California by 2045.

C. Outline of the Report

The remainder of the report is organized as follows. Section II provides an overview of the N$_{ew}$ERA model that is used to analyze these scenarios. Section III describes the two core scenarios and sensitivities around these core scenarios that we modeled. Section IV discusses some key results of the analyses. The technical appendices provide details on the NewERA model and the modeling assumptions for the baseline and the scenarios.

II. OVERVIEW OF THE NEWERA MODEL

A. General Features of the NewERA Framework

NERA's NewERA model is an energy-economy modeling framework that integrates a bottom-up representation of the U.S. electricity sector with a top-down representation of the production, consumption, and investment decisions across the rest of the U.S, economy, including household decisions that affect overall energy use and related GHG emissions[6]. The modeling framework assesses the economic impacts from policies by accounting for important sectoral and regional interactions that take place in the economy in addition to the direct costs or other effects of the policy.

The top-down portion of NewERA is a forward-looking dynamic computable general equilibrium (CGE) model of the U.S. economy regions including California as a separate region. It simulates all key economic interactions in the regional economy including those among industries, households, and the government. Industries and households maximize profits and utility, respectively, with foresight about future economic conditions. The theoretical construct behind the model is based on the circular flow of goods, services, and payments in the economy—every economic transaction has a buyer and a seller whereby goods and services go from a seller to a buyer and payment goes from the buyer to the seller.

The CGE model is centered around the decisions of a representative household that characterizes the economic behavior of an average consumer. Households provide labor and capital to businesses, taxes to the government, and savings to the financial markets, while also consuming goods and services and receiving government subsidies. One of the services decided upon by households is how to meet personal transportation needs. In addition to deciding on the quantity of personal vehicle miles traveled (VMT), households in NewERA choose between two different types of vehicles - internal combustion engine vehicles (ICEs) and battery-operated Electric vehicles (BEVs). The household's vehicle choice depends upon relative vehicle life-cycle cost differences and consumers' preferences for different vehicles.[7]

The economic sectors in the model, in aggregate, account for all of the production and commercial activities of the economy. Each economic sector uses labor, capital, energy resources, other sector's outputs, and imported inputs to produce their own specific category of goods or services. Economic sectors pay their share of FICA and health insurance, and corporate taxes to the government. Industries are both consumers and producers of capital for investment in the rest of the economy.

[6] The model accounts for carbon dioxide (CO_2) emissions from fossil fuel combustion and emissions from industrial processes (e.g., cement production, ammonia production) involving chemical or physical transformations other than fuel combustion. Non-CO_2 GHG including methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) are not modeled.

[7] Consumers choose to buy a certain vehicle over another considering the level of satisfaction they receive from the vehicle attributes and the vehicle life-cycle cost differences between the vehicle types. In our model, consumers are assumed to have the same preference over ICE vehicles and BEVs in the long-term, that is, the elasticity of substitution between the two types of vehicles is infinite. However, we restrict consumer's desire to completely shift from ICE vehicles to BEVs in the short-term if the cost advantage shifts toward BEVs by including an elasticity of substitution between BEV costs and a market constraint. The market constraint is included to capture the buildup of electric vehicle infrastructure and equipment markets. A higher elasticity value allows for higher degree of deployment of BEVs at any given level of cost advantage of BEVs over ICE.

One of the sectors in N_{ew}ERA is the electricity sector. This sector is modeled in a bottom-up (i.e., technology-specific) manner that is fully integrated with the rest of the economy (which is simulated in the CGE framework described above). The model includes all existing electric generating units, while future capacity investment and economic retirement decisions are represented simultaneously with dispatch decisions.[8] The model dispatches electricity to load duration curves. Long-term investment and retirement decisions and short-term unit dispatch decisions are projected by solving a dynamic, non-linear program with an objective function that minimizes the present value of total system costs, while complying with all system constraints, such as meeting demand, renewable portfolio standards, reserve margin requirements, emissions limits, transmission limits, clean energy standards, and other environmental and electric specific policy mandates.

Lastly, the CGE portion of N_{ew}ERA represents the government. In the model, the government collects revenues from taxes imposed on labor and capital. Revenues are used to pay for government services. The model also holds overall government debt the same in all scenarios by either returning excess revenues to the consumers, or by increasing taxes . The rebates or revenue-raising actions may be performed on a lump-sum basis (e.g., by changing the standard deduction) or by altering tax rates. Unless otherwise stated, the model uses the lump-sum transfer assumption.

Within the circular flow of the above macroeconomy, an equilibrium is found whereby demand for goods and services equals their supply, and investments are optimized for the long term. Thus, supply equals demand in all markets for all time periods.

The model produces integrated projections of the energy sector and other economic activities for future years and estimates the energy market and macroeconomic impacts of a potential policy by comparing projections of the future with and without the policy's requirements included in the model's input assumptions. More details on the structure of N_{ew}ERA are provided in Appendix I of Volume II: Technical Appendices.

B. Model Details Specific to This Study

The version of the macroeconomic model used in each analysis is produced by calibrating the N_{ew}ERA computations framework to reflect a specific set of baseline projections (trends) over the policy impact time period of concern. This analysis estimates economic impacts for the period from 2024 through 2045 with estimates for every third year in that time period.

The model also includes sectoral disaggregation tailored to match policy implementation and impact considerations. The version of the N_{ew}ERA model used in this analysis includes 12 economic sectors. Five of these are energy sectors, which include coal mining (COL), natural gas extraction and gathering (GAS), crude oil (CRU), petroleum refining (OIL), and the electricity sector (ELE). (The labels used to

[8] The electricity sector represents, with extensive disaggregation, over 17,000 existing units in the U.S. electricity generation system. It also disaggregates its projections of new capacity builds by type (which differ endogenously in each policy scenario). The new technology options included in this analysis are: onshore wind, offshore wind, photovoltaic solar, concentrated solar thermal, onshore wind-with-storage, photovoltaic solar-with-storage, nuclear, hydro, natural gas combined cycle (CC), natural gas CC with carbon capture and sequestration (CCS), natural gas combustion turbine (CT), coal with CCS, biomass, and biomass with CCS.

identify each sector in the model are indicated in parentheses.) The seven non-energy sectors[9] represented in this analysis are as follows:

- Motor vehicle manufacturing (M_V)
- Energy-intensive sectors (EIS)[10]
- Other manufacturing (MAN)[11]
- Agriculture (AGR)
- Commercial trucking (TRK)
- Commercial transportation other than trucking (TRN)
- Services (SRV)

This study has been conducted to produce national average energy and macroeconomic outcomes for two core policy scenarios that produce comparable CO_2 emissions reductions through 2045 while achieving net-zero emissions by 2045.[12] The first of these scenarios reflects key sector-specific mandates that are part of the California Air Resources Board's (CARB) 2022 Draft Scoping Plan's "Proposed Scenario"[13] (which we hereafter refer to as the "Regulatory scenario"). In the second scenario (which we hereafter refer to as the "Market scenario"), an emissions limit or cap equal to the CO_2 emissions trajectory in the Regulatory scenario is imposed which, in aggregate, achieve about the same cumulative emissions through 2045 and reductions *in* 2045 as is projected for the Regulatory scenario. We also consider two sets of sensitivity scenarios (referred to as High Alternative Vehicle Cost and Low Alternative Vehicle Cost scenarios) whose impacts are used to bound the range of results from the two core scenarios. These sensitivity scenarios differ from the core scenarios in the vehicle purchase cost trajectories assumed for BEVs in the personal transportation sector and for BEVs and fuel-cell electric vehicles (FCEVs) in the commercial trucking sector. We provide a more detailed description of the scenarios modeled in Section III below. The differences in the economic impact of these scenarios relative to the BAU are characterized by comparing the estimated changes for several model outputs that are commonly considered to be relevant measures of economic and energy market impact:

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[9] The non-energy manufacturing sub-sectors are aggregated to 3-digit NAICS code and are consistent with U.S. Energy Information Administration's (EIA) Manufacturing Energy Consumption Survey (MECS) sectors.

[10] This comprises pulp and paper, chemicals, glass, cement, iron and steel, alumina and aluminum and mining.

[11] This comprises construction, food, beverage, and tobacco products, fabricated metal products, machinery, computer and electronic products, transportation equipment, electrical equipment, appliances, and components, wood and furniture, plastics, and other manufacturing sectors.

[12] Direct Air Capture (DAC) is employed as a carbon dioxide removal technology to achieve net-zero emissions by 2045.

[13] Draft 2022 Scoping Plan Update, May 10, 2022, California Air Resources Board (available at https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf).

- California gross domestic product,
- Household consumption,
- Economy-wide electricity generation mix, and
- Sectoral emissions by fossil fuel.

Because the two core scenarios are constructed to have comparable emissions reductions and are analyzed under identical assumptions about technological, behavioral, and other baseline conditions, the differences in the above metrics for the two scenarios relative to the BAU provide an indication of how different the cost of compliance and market impacts of carbon-reduction policies may be due to differences in policy design choices. We also report here a variety of other model outputs of interest that are associated with the above economic impacts for each policy scenario. These include the projected mix of electricity generation, the mix of personal vehicles on the road (internal combustion vs. electric), the projected mix of vehicle types in the commercial trucking sector, and CO_2 emissions over time. More detailed documentation of the N_{ew}ERA modeling framework is provided in Appendix I while a description of the baseline conditions for this analysis are provided in Appendix II of Volume II: Technical Appendices.

III. SCENARIO DESCRIPTION

The following are the specifications that relate to the baseline scenario, the core Market and Regulatory scenarios and the sensitivity cases around these scenarios that were modeled.

Baseline: The baseline (which we hereafter refer to as the "BAU") contains projected fuel prices, CO_2 emissions and economic output that is largely consistent with the Energy Information Administration's *Annual Energy Outlook 2021's* "Reference" case. The baseline includes compliance with all existing national and state rules and regulations on energy and environmental outcomes. A description of the baseline conditions for this analysis are provided in Appendix II of Volume II: Technical Appendices.

Regulatory Scenario: The Regulatory scenario incorporates the following sector-specific mandates that are part of CARB's 2022 Draft Scoping Plan's "Proposed Scenario".

- Personal Transportation Sector
    - Advanced Clean Cars I (ACC I) GHG standards for model year (MY) 2017-2025 and 2% annual fuel improvement for 2026-2035.
    - 100% of light-duty vehicle (LDV) sales are zero-emission vehicles (ZEVs) by 2035.
- Commercial Trucking Sector
    - 100% of medium-duty (MD)/heavy-duty (HD) vehicle sales are ZEVs by 2040.
- Electric Sector
    - RPS: 60% of electric retail sales comes from renewable resources by 2030.
    - SB 100: 100% of retail sales to end-use customers by 2045 to come from renewable and zero-carbon resources.
- Energy Efficiency
    - Energy efficiency targets for electricity and natural gas use in the residential, commercial, and industrial sectors.
- Oil and Gas Extraction
    - Phasing out of resource extraction operations by 2045.

A description of the assumptions that relate to each of these mandates are provided in Appendix II of Volume II: Technical Appendices.

Market Scenario: In this scenario, an emissions limit or cap was modeled which was set approximately equal to the emissions trajectory projected in the Regulatory scenario.

Sensitivity Scenarios: For the Low Alternative Vehicle Cost and High Alternative Vehicle Cost sensitivity scenarios, the following assumptions were employed.[14] The same set of assumptions were employed for the sensitivity scenarios around the Market and Regulatory cases.

[14] The default cost markups for BEVs relative to the cost of a typical ICE vehcile in the personal transportation sector were 1.28 in 2024 declining to 1.15 by 2045. In the commercial trucking sector, the default cost markups for BEVs were 1.78 in 2024 declining to 1.23 by 2045 while for FCEVs they were 1.48 in 2024 declining to 1.16 in 2045. These are the cost markups employed in the modeling of the BAU case.

- **Low Alternative Vehicle Cost:** A lower cost markup ratio for BEVs in the personal transportation sector relative to gasoline internal combustion vehicles (ICEVs)[15] and for BEVs and FCEVs in the commercial trucking sector relative to diesel ICEVs was employed.[16]
- **High Alternative Vehicle Cost:** A higher cost markup ratio for BEVs in the personal transportation sector relative to gasoline internal combustion vehicles (ICEVs)[17] and for BEVs and FCEVs in the commercial trucking sector relative to diesel ICEVs employed.[18]

A description of the assumptions that relate to each of these cost markup ratios are provided in Appendix II of Volume II: Technical Appendices.

[15] The cost markup declines from 1.32 in 2024 to 0.96 by 2045.

[16] For BEVs, the cost markup declines from 1.34 in 2024 to 1.05 by 2045. For FCEVs, the cost markups decline from 1.58 in 2024 to 1.02 by 2045.

[17] The cost markup declines from 1.89 in 2024 to 1.27 by 2045.

[18] For BEVs, the cost markup declines from 3.80 in 2024 to 1.76 by 2045. For FCEVs, the cost markups decline from 1.63 in 2024 to 1.20 by 2045.

IV. STUDY RESULTS

A. Projected Impacts on the California Economy and California Households

Consumption and gross domestic product (GDP) are two of the most commonly reported metrics of economic impact models. Consumption is the market value of all goods and services that households are projected to purchase, after accounting for their income, government taxes, and savings decisions in each time period covered by the model while the GDP in any year is defined as the sum of consumption, investment, government spending, and net exports in that specific year. Table 1 shows the projected difference in the impacts on GDP for the different scenarios relative to the BAU. By 2045, the GDP in the Regulatory scenario is about $44 billion lower than in the BAU while in the Market scenario, the GDP is about $23 billion lower than in the BAU. In 2045, the GDP impacts are projected to be $35 million and $20 million lower than in the BAU for the Low Alternative Vehicle Cost cases in the Regulatory and Market scenarios respectively while for the High Alternative Vehicle Cost cases, they are projected to be $49 million and $26 million lower in the BAU for the Regulatory and Market scenarios respectively.

Table 1: Projected Differences in GDP by Year (Relative to the BAU) (2021$, Billions)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory	-$13	-$13	-$16	-$23	-$28	-$34	-$40	-$44
Regulatory (High Alternative Vehicle Cost)	-$16	-$16	-$21	-$28	-$34	-$41	-$47	-$49
Regulatory (Low Alternative Vehicle Cost)	-$10	-$10	-$12	-$17	-$21	-$25	-$31	-$35
Market	-$8	-$10	-$10	-$12	-$13	-$13	-$14	-$23
Market (High Alternative Vehicle Cost)	-$10	-$12	-$12	-$14	-$15	-$16	-$19	-$26
Market (Low Alternative Vehicle Cost)	-$7	-$8	-$8	-$9	-$9	-$9	-$10	-$20

Table 2 shows the projected difference in percentage impacts on GDP for the different scenarios relative to the BAU. By 2045, the GDP in the Regulatory scenario is about 1% lower than in the BAU while in the Market scenario, it is about 0.5% lower than the BAU. In 2045, the GDP impacts are projected to be about 0.8% and 0.5% lower than in the BAU for the Low Alternative Vehicle Cost cases in the Regulatory and Market scenarios respectively while for the High Alternative Vehicle Cost cases, they are projected to be 1.1% and 0.6% lower in the BAU for the Regulatory and Market scenarios respectively.

Table 2: Projected Differences in GDP by Year (Relative to the BAU) (%)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory	-0.4%	-0.4%	-0.5%	-0.7%	-0.8%	-0.9%	-1.0%	-1.0%
Regulatory (High Alternative Vehicle Cost)	-0.5%	-0.5%	-0.6%	-0.8%	-0.9%	-1.1%	-1.2%	-1.1%
Regulatory (Low Alternative Vehicle Cost)	-0.3%	-0.3%	-0.4%	-0.5%	-0.6%	-0.6%	-0.7%	-0.8%

Market	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.5%
Market (High Alternative Vehicle Cost)	-0.3%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.5%	-0.6%
Market (Low Alternative Vehicle Cost)	-0.2%	-0.3%	-0.2%	-0.3%	-0.3%	-0.2%	-0.2%	-0.5%

Table 3 shows the projected difference in percentage impacts on household consumption for the different scenarios relative to the BAU. By 2045, the consumption in the Regulatory scenario is about 1.2% lower than in the BAU while in the Market scenario, it is about 0.5% lower than the BAU. In 2045, the consumption impacts are projected to be about 1.1% and 0.5% lower than in the BAU for the Low Alternative Vehicle Cost cases in the Regulatory and Market scenarios respectively while for the High Alternative Vehicle Cost cases, they are projected to be 1.4% and 0.6% lower in the BAU for the Regulatory and Market scenarios respectively.

Table 3: Projected Differences in Household Consumption by Year (Relative to the BAU) (%)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory	-0.9%	-0.8%	-0.8%	-0.9%	-0.9%	-1.0%	-1.1%	-1.2%
Regulatory (High Alternative Vehicle Cost)	-1.1%	-1.0%	-1.0%	-1.1%	-1.2%	-1.3%	-1.3%	-1.4%
Regulatory (Low Alternative Vehicle Cost)	-0.7%	-0.6%	-0.6%	-0.6%	-0.7%	-0.8%	-0.9%	-1.1%
Market	-0.3%	-0.3%	-0.3%	-0.3%	-0.4%	-0.4%	-0.4%	-0.5%
Market (High Alternative Vehicle Cost)	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.6%
Market (Low Alternative Vehicle Cost)	-0.2%	-0.3%	-0.2%	-0.3%	-0.3%	-0.3%	-0.3%	-0.5%

As consumption has a direct implication for household dollar spending, in Table 4 we also report the projected difference in spending on goods and services on a dollars per household basis under the different scenarios relative to the BAU. By 2045, the Regulatory scenario is projected to reduce household consumption per household by about $1,890 while in the Market scenario, household consumption is projected to decline by about $820. In 2045 in the Low Alternative Vehicle Cost cases, the household consumption impacts are projected to be about $1,630 and $700 lower than the BAU in the Regulatory and Market scenarios respectively while in the High Alternative Vehicle Cost cases, they are projected to be $2,200 and $900 lower than the BAU.[19] The Market scenario allows for the most cost-effective reduction of emissions. The Regulatory approach on the other hand, incorporates sector-specific targeted mandates which may not necessarily be the least cost-way of reducing emissions since it could force in technologies that would otherwise not be adopted. The stringency of the specific mandates determine the costs of the Regulatory scenario and how it compares to the costs of the Market scenario..

[19] These changes in consumption are relative to an average current baseline household consumption of $133,000 in California. It is important to note that this is significantly larger than the more commonly-reported figure of median household consumption of $79,000 because of the impact of very high-income households in California.

Table 4: Projected Dollar Difference in Annual Consumption per Household (Relative to the BAU) (2021$/HH)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory	-$1,300	-$1,260	-$1,250	-$1,310	-$1,430	-$1,580	-$1,710	-$1,890
Regulatory (High Alternative Vehicle Cost)	-$1,600	-$1,550	-$1,560	-$1,650	-$1,770	-$1,920	-$2,040	-$2,200
Regulatory (Low Alternative Vehicle Cost)	-$1,010	-$960	-$960	-$980	-$1,110	-$1,260	-$1,410	-$1,630
Market	-$480	-$520	-$510	-$530	-$550	-$560	-$540	-$820
Market (High Alternative Vehicle Cost)	-$550	-$590	-$590	-$610	-$630	-$640	-$660	-$900
Market (Low Alternative Vehicle Cost)	-$340	-$380	-$370	-$380	-$400	-$400	-$400	-$700

B. Projected Changes in the California Transportation Sector

There are opportunities for changes in the introduction of two very different types of LDVs: internal combustion engines (ICEs) and battery electric vehicles (BEVs) in the transportation sector. There are also flexibilities to alter the fuel efficiency of vehicles, and to decide on the amount of income to spend on personal transportation services or VMT. The assumptions about changing technology costs and consumer preferences for the two types of vehicles are the same in both scenarios, but the two scenarios create different economic and regulatory pressures on these consumer decisions, resulting in different amounts of adoption of BEVs, vehicle mileage, and VMT. In the Market scenario, the amount of response to any of these is determined entirely by the cost implications of the allowance price on uses of each alternative vehicle type. In the Regulatory scenario, the light-duty vehicles ZEV mandate applied determines the penetration of the two vehicle types.

Table 5 reports the projected VMT in each scenario, disaggregated by vehicle type. Total VMT decreases in the Market scenario in response to the carbon price signal that leads to a higher cost of compliance of transportation fuels and electricity prices while in the Regulatory scenario, the decline in VMT is a consequence of an increase in the cost-per-mile derived coupled together with the increase in electricity prices in response to the light-duty vehicles ZEV mandate. Table 6 shows the differences in the projected VMT in the Regulatory and Market scenarios relative to the BAU. By 2045, the decrease in the Total VMT in both the Regulatory and Market scenarios are about the same while the BEV VMT levels are higher in the Regulatory scenario compared to the Market scenario. Conversely, in 2045 the ICE VMT levels are higher in the Market scenario compared to the Regulatory scenario.

Table 5: Projected VMT by Vehicle Type by Year (Billions of Miles)

	2024	2027	2030	2033	2036	2039	2042	2045
BAU								
All ICE Vehicles	322	314	297	268	257	254	254	270
All BEVs	5	10	19	33	48	58	63	70
Total	327	324	316	301	305	312	317	339

Regulatory								
All ICE Vehicles	312	306	293	249	190	140	98	70
All BEVs	11	15	19	47	106	159	202	246
Total	324	321	313	296	296	299	300	316
Regulatory (High Alternative Vehicle Cost)								
All ICE Vehicles	312	305	294	249	190	140	98	70
All BEVs	11	15	18	47	105	159	201	245
Total	323	320	312	296	295	299	299	315
Regulatory (Low Alternative Vehicle Cost)								
All ICE Vehicles	313	306	292	250	191	140	98	70
All BEVs	11	15	21	47	106	160	202	246
Total	324	322	313	297	297	300	300	316
Market								
All ICE Vehicles	318	309	291	258	244	236	232	217
All BEVs	5	11	20	37	54	67	75	99
Total	323	320	311	295	298	304	307	316
Market (High Alternative Vehicle Cost)								
All ICE Vehicles	323	315	298	267	253	248	243	232
All BEVs	0	5	13	29	44	55	63	85
Total	323	320	311	295	298	303	307	317
Market (Low Alternative Vehicle Cost)								
All ICE Vehicles	319	309	289	254	236	225	215	192
All BEVs	5	11	22	42	62	79	92	123
Total	324	321	312	296	298	304	307	315

Table 6: Differences in the Projected VMTs by Year (Relative to the BAU) (%)

	2024	**2027**	**2030**	**2033**	**2036**	**2039**	**2042**	**2045**
Regulatory	-0.9%	-1.0%	-1.0%	-1.6%	-2.9%	-4.2%	-5.6%	-7.0%
Regulatory (High Alternative Vehicle Cost)	-1.2%	-1.2%	-1.3%	-1.8%	-3.1%	-4.4%	-5.8%	-7.2%
Regulatory (Low Alternative Vehicle Cost)	-0.8%	-0.8%	-0.9%	-1.4%	-2.7%	-4.0%	-5.4%	-6.8%
Market	-1.1%	-1.3%	-1.5%	-2.0%	-2.4%	-2.8%	-3.3%	-6.8%
Market (High Alternative Vehicle Cost)	-1.1%	-1.3%	-1.5%	-2.0%	-2.4%	-2.8%	-3.4%	-6.6%
Market (Low Alternative Vehicle Cost)	-0.9%	-1.2%	-1.4%	-1.9%	-2.3%	-2.8%	-3.4%	-7.1%

Table 7 presents the percentage share of VMT of the total stock for the different vehicle types. In the Market scenario (where there is no BEV mandate), the share of the VMT from electric vehicles (of the total stock vehicles) rises to 31% in 2045 purely due to the economic incentives created by the allowance price. However, the more stringent light-duty vehicle ZEV mandate imposed in the Regulatory scenario results in a greater penetration of electric vehicles, with the share of VMT from electric vehicles rising to 78% in 2045. In 2045, it can be seen that for both the Low Alternative Vehicle Cost and High Alternative Vehicle Cost Regulatory scenario cases, the share of VMT from electric vehicles are about the same as in the core scenario (as per as the mandate) while they are about 27% and 39% in the High Alternative Vehicle Cost and Low Alternative Vehicle Cost cases for the Market scenario respectively.

Table 7: Share of Vehicle Miles Traveled per Year by Type of Vehicle (%)

	2024	2027	2030	2033	2036	2039	2042	2045
BAU								
All ICE Vehicles	98%	97%	94%	89%	84%	81%	80%	79%
All BEVs	2%	3%	6%	11%	16%	19%	20%	21%
Regulatory								
All ICE Vehicles	97%	95%	94%	84%	64%	47%	33%	22%
All BEVs	3%	5%	6%	16%	36%	53%	67%	78%
Regulatory (High Alternative Vehicle Cost)								
All ICE Vehicles	97%	95%	94%	84%	64%	47%	33%	22%
All BEVs	3%	5%	6%	16%	36%	53%	67%	78%
Regulatory (Low Alternative Vehicle Cost)								
All ICE Vehicles	97%	95%	93%	84%	64%	47%	33%	22%
All BEVs	3%	5%	7%	16%	36%	53%	67%	78%
Market								
All ICE Vehicles	98%	97%	93%	87%	82%	78%	76%	69%
All BEVs	2%	3%	7%	13%	18%	22%	24%	31%
Market (High Alternative Vehicle Cost)								
All ICE Vehicles	100%	99%	96%	90%	85%	82%	79%	73%
All BEVs	0%	1%	4%	10%	15%	18%	21%	27%
Market (Low Alternative Vehicle Cost)								
All ICE Vehicles	98%	96%	93%	86%	79%	74%	70%	61%
All BEVs	2%	4%	7%	14%	21%	26%	30%	39%

Unlike the light-duty vehicles in the personal transportation sector, the NewERA model does not simulate the vehicles miles traveled by these truck vehicle types. Instead, these vehicle types provides value-added services in the model. Table 8 presents the projected change in output from the commercial trucking sector disaggregated by vehicle type. In 2045, a greater reduction in the output (relative to the BAU) from diesel trucks is projected in the Regulatory scenario compared to the Market scenario while the increase in the output from battery-electric and fuel-cell trucks relative to the BAU are projected to be about the same in both scenarios. In 2045, for both the Low Alternative Vehicle Cost and High Alternative Vehicle Cost Regulatory scenario cases, the output impacts are projected to be about the same as in the core scenario. For the Market scenario, a larger increase in the total output from battery-electric and fuel-cell trucks are projected in the Low Alternative Vehicle Cost case than in the High Alternative Vehicle Cost case in 2045.

Table 8: Projected Change in Output from the Commercial Trucking Sector by Vehicle Type and Year (Relative to the BAU) (2021$, Billions)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory								
Diesel	0	0	0	-1	-8	-18	-24	-27
Battery-Electric	0	0	0	1	2	3	4	5
Fuel-Cell	0	0	0	0	1	2	3	4
Regulatory (High Alternative Vehicle Cost)								
Diesel	0	0	0	-12	-19	-18	-24	-27
Battery-Electric	0	0	0	0	1	3	4	5
Fuel-Cell	0	0	0	1	1	2	3	4
Regulatory (Low Alternative Vehicle Cost)								
Diesel	0	0	0	0	-8	-18	-24	-27
Battery-Electric	0	0	0	1	2	3	4	5
Fuel-Cell	0	0	0	0	1	2	3	4
Market								
Diesel	-1	-1	-1	-1	-1	-2	-2	-4
Battery-Electric	0	0	0	0	0	0	4	5
Fuel-Cell	0	0	0	0	0	2	3	4
Market (High Alternative Vehicle Cost)								
Diesel	-1	-1	-1	-1	-2	-2	-2	-4
Battery-Electric	0	0	0	0	0	0	0	0
Fuel-Cell	0	0	0	0	0	0	0	4
Market (Low Alternative Vehicle Cost)								
Diesel	-1	-1	-1	-1	-1	-2	-2	-4
Battery-Electric	0	0	0	1	2	3	4	5
Fuel-Cell	0	0	0	0	0	2	3	4

C. Projected Changes in the California Energy System

The purpose of both scenarios is to reduce CO_2 emissions, most of which come from fossil fuel combustion. Although both scenarios achieve comparable carbon emissions reductions by 2045, they have somewhat different impacts with respect to the electricity demand, delivered electricity prices and electricity generation. Table 9 reports the percentage changes in projected electricity consumption for the different scenarios relative to the BAU. By 2045, the electricity demand in the Regulatory scenario is projected to about 8.6% greater than in the BAU while in the Market scenario, it is projected to be only about 0.1% higher than in the BAU. This is a consequence of the significantly high levels of BEV penetration in the Regulatory scenario, a direct result of the more stringent light-duty vehicle ZEV mandate. This also results in significantly higher delivered electricity prices to households by 2045 in the Regulatory scenario compared to the Market scenario as shown in Table 10.

Table 9: Projected Change in California Retail Electricity Consumption (Relative to the BAU) (%)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory	-0.7%	0.2%	1.1%	3.2%	7.1%	8.1%	9.6%	8.6%
Regulatory (High Alternative Vehicle Cost)	-0.7%	0.1%	1.0%	3.1%	7.3%	8.2%	9.3%	8.7%
Regulatory (Low Alternative Vehicle Cost)	-0.7%	0.2%	1.2%	3.8%	7.7%	8.6%	9.3%	7.8%
Market	-2.4%	-2.7%	-2.9%	-2.0%	-2.6%	-2.5%	-0.6%	0.1%
Market (High Alternative Vehicle Cost)	-3.3%	-3.5%	-4.1%	-3.5%	-4.2%	-3.7%	-3.7%	-3.0%
Market (Low Alternative Vehicle Cost)	-2.4%	-2.4%	-2.4%	-0.7%	-0.7%	-0.1%	0.9%	2.3%

Table 10: Projected Change in Delivered Electricity Price to Residential Customers (Relative to the BAU (%)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory	4%	0%	-4%	-3%	3%	13%	21%	37%
Regulatory (High Alternative Vehicle Cost)	3%	0%	-4%	-5%	1%	14%	23%	38%
Regulatory (Low Alternative Vehicle Cost)	4%	0%	-3%	-4%	1%	12%	23%	42%
Market	5%	5%	6%	4%	6%	7%	7%	9%
Market (High Alternative Vehicle Cost)	5%	5%	7%	5%	7%	6%	7%	8%
Market (Low Alternative Vehicle Cost)	5%	5%	5%	4%	6%	7%	7%	10%

Table 11 shows the projected electricity generation by asset type over time in terms of levels of TWh for the different scenarios. It can be seen that natural gas generation levels are lower until 2042 in the Regulatory scenario compared to the Market scenario. This is a consequence of the more stringent RPS and SB100 targets in the Regulatory scenario that mandates significant amounts of renewables or zero-carbon resources. The economic incentives created by the allowance price motivates natural gas with CCS generation in the long-run and higher nuclear generation in 2024 in the Market scenario compared to the Regulatory scenario. The RPS and SB100 mandates in the Regulatory scenario also motivates higher generation from renewable resources leading to higher renewable penetration levels in the Regulatory scenario compared to the Market scenario.

Table 11: Projected Gross Electricity Generation in California by Year and Type of Energy Source (TWh)

	2024	2027	2030	2033	2036	2039	2042	2045
Natural Gas (No CCS)								
BAU	117	116	108	100	93	94	95	86
Regulatory	95	84	63	53	36	23	12	11
Regulatory (High Alternative Vehicle Cost)	95	84	63	53	37	23	12	10
Regulatory (Low Alternative Vehicle Cost)	95	84	63	53	36	23	13	9
Market	102	110	90	73	51	35	20	8
Market (High Alternative Vehicle Cost)	101	108	87	70	49	31	16	7
Market (Low Alternative Vehicle Cost)	103	110	91	77	61	38	22	9
CCS*								
BAU	0	0	0	0	0	0	0	0
Regulatory	0	0	0	0	0	0	0	0
Regulatory (High Alternative Vehicle Cost)	0	0	0	0	0	0	0	0
Regulatory (Low Alternative Vehicle Cost)	0	0	0	0	0	0	0	0
Market	0	0	0	0	0	1	11	26
Market (High Alternative Vehicle Cost)	0	0	0	0	0	4	11	25
Market (Low Alternative Vehicle Cost)	0	0	0	0	0	1	11	28
Nuclear								
BAU	0	0	0	0	0	0	0	0
Regulatory	0	0	0	0	0	0	0	0
Regulatory (High Alternative Vehicle Cost)	0	0	0	0	0	0	0	0
Regulatory (Low Alternative Vehicle Cost)	0	0	0	0	0	0	0	0
Market	18	0	0	0	0	0	0	0
Market (High Alternative Vehicle Cost)	18	0	0	0	0	0	0	0
Market (Low Alternative Vehicle Cost)	18	0	0	0	0	0	0	0
Solar								

BAU	46	65	83	104	129	158	187	220
Regulatory	78	119	160	202	239	271	310	344
Regulatory (High Alternative Vehicle Cost)	78	119	160	202	239	271	310	338
Regulatory (Low Alternative Vehicle Cost)	78	119	160	202	239	271	311	341
Market	42	59	100	141	183	223	255	293
Market (High Alternative Vehicle Cost)	40	58	98	140	182	222	254	292
Market (Low Alternative Vehicle Cost)	42	60	100	142	184	223	256	294
Wind**								
BAU	29	41	52	63	74	85	96	107
Regulatory	29	41	54	67	80	93	106	119
Regulatory (High Alternative Vehicle Cost)	29	41	54	67	80	93	106	119
Regulatory (Low Alternative Vehicle Cost)	29	41	54	67	80	93	107	120
Market	29	41	52	63	74	87	100	114
Market (High Alternative Vehicle Cost)	29	41	52	63	74	87	100	113
Market (Low Alternative Vehicle Cost)	29	41	52	63	76	89	102	115
Storage***								
BAU	0	0	0	0	0	0	0	0
Regulatory	0	0	0	0	28	54	82	107
Regulatory (High Alternative Vehicle Cost)	0	0	0	0	29	55	82	106
Regulatory (Low Alternative Vehicle Cost)	0	0	0	0	28	55	83	107
Market	0	0	0	0	10	20	35	37
Market (High Alternative Vehicle Cost)	0	0	0	0	7	18	25	26
Market (Low Alternative Vehicle Cost)	0	0	0	0	2	25	38	41
Other Renewables****								
BAU	87	83	83	83	83	82	82	87
Regulatory	87	81	70	71	72	72	72	72
Regulatory (High Alternative Vehicle Cost)	87	81	70	71	72	72	72	72

Regulatory (Low Alternative Vehicle Cost)	87	81	70	71	72	72	72	72
Market	87	81	76	74	70	70	71	74
Market (High Alternative Vehicle Cost)	87	81	74	72	70	70	74	76
Market (Low Alternative Vehicle Cost)	87	81	76	76	76	70	70	74

** Includes generation from coal with CCS, natural gas with CCS and biomass with CCS resources. We disallow coal with CCS builds in California in the model. The model does not project any biomass with CCS generation over the model horizon*

*** Includes generation from onshore and offshore wind resources. The model however does not project any offshore wind generation over the model horizon.*

**** Includes generation from solar with co-located storage and wind with co-located storage.*

***** Includes generation from pumped storage hydro, conventional hydro, biomass, landfill gas, municipal solid waste and geothermal resources.*

D. Projected Reductions in the California CO_2 Emissions

Table 12 reports the projected percentage changes in economy-wide CO_2 emissions for each scenario relative to the BAU. In the Regulatory scenario, CO_2 emissions from the electric and non-electric sectors are projected to be reduced by 88% and 43% by 2045 respectively. This results in a reduction in economy-wide CO_2 emissions by about 50% by 2045 relative to the BAU. In the Market scenario by 2045, the projected reductions in electric sector CO_2 emissions are about the same (88%) while those from the non-electric sector are slightly lower (39%). This results in the projected economy-wide CO_2 emissions in 2045 for the Market scenario to be slightly lower than in the Market scenario (47%). Larger reductions in CO_2 emissions are projected in the residential, commercial, and industrial sector CO_2 emissions in the Market scenario by 2045 relative to the BAU while the same is true for the transportation sector in the Regulatory scenario. Table 13 reports the projected percentage changes in economy-wide CO_2 emissions for each scenario relative to 2005 levels.[20] By 2045, similar levels of reductions in CO_2 emissions are projected for both scenarios.

The sectoral reductions in CO_2 emissions projected in the Regulatory scenario is a reflection of the mandate design and its stringency. Since the mandates in the Regulatory scenario are more targeted towards the transportation sector, there are greater emission reductions achieved in this sector compared to other sectors in the economy (such as the industrial sector). Under the Market scenario, however, the industrial sector is subject to allowance prices under the emissions cap. Under this approach (as shown in Table 12), it is relatively cost-effective to achieve emission reductions from the industrial sector than from the transportation sector.

[20] Based on the CARB's 2014 Edition of California's Greenhouse Gas Emission Inventory (2000-2012), the CO_2 Emissions in California in 2005 was reported to be 425.3 MMT CO_2 (available at https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2012/ghg_inventory_00-12_report.pdf).

Table 12: Projected Change in California CO_2 Emissions by Sector and Year (Relative to the BAU) (%)

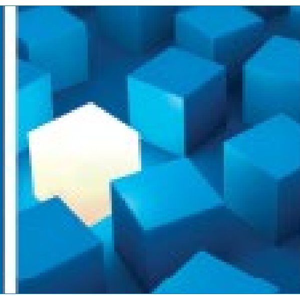
	2024	2027	2030	2033	2036	2039	2042	2045
Residential								
Regulatory	-4%	-4%	-4%	-4%	-4%	-4%	-5%	-5%
Regulatory (High Alternative Vehicle Cost)	-4%	-4%	-4%	-4%	-4%	-5%	-5%	-5%
Regulatory (Low Alternative Vehicle Cost)	-3%	-4%	-4%	-4%	-4%	-4%	-4%	-4%
Market	-5%	-6%	-7%	-8%	-10%	-12%	-14%	-25%
Market (High Alternative Vehicle Cost)	-5%	-6%	-8%	-9%	-11%	-13%	-15%	-25%
Market (Low Alternative Vehicle Cost)	-4%	-6%	-7%	-8%	-10%	-11%	-13%	-25%
Commercial								
Regulatory	-1%	-1%	-1%	-1%	-1%	-2%	-2%	-2%
Regulatory (High Alternative Vehicle Cost)	-1%	-1%	-1%	-1%	-1%	-2%	-2%	-2%
Regulatory (Low Alternative Vehicle Cost)	-1%	-1%	-1%	-1%	-1%	-2%	-2%	-2%
Market	-5%	-7%	-9%	-10%	-12%	-14%	-17%	-29%
Market (High Alternative Vehicle Cost)	-6%	-7%	-9%	-11%	-13%	-15%	-18%	-29%
Market (Low Alternative Vehicle Cost)	-5%	-7%	-8%	-10%	-12%	-14%	-16%	-30%
Industrial								
Regulatory	0%	0%	1%	-2%	-7%	-12%	-15%	-19%
Regulatory (High Alternative Vehicle Cost)	0%	1%	1%	-3%	-7%	-12%	-15%	-18%
Regulatory (Low Alternative Vehicle Cost)	0%	0%	0%	-2%	-7%	-12%	-16%	-19%
Market	-14%	-16%	-20%	-21%	-25%	-28%	-30%	-46%
Market (High Alternative Vehicle Cost)	-14%	-17%	-21%	-22%	-26%	-29%	-31%	-45%
Market (Low Alternative Vehicle Cost)	-13%	-16%	-20%	-21%	-25%	-28%	-31%	-47%
Transportation								
Regulatory	-2%	-1%	-1%	-8%	-26%	-44%	-58%	-68%

Regulatory (High Alternative Vehicle Cost)	-2%	-1%	-1%	-13%	-31%	-44%	-58%	-68%
Regulatory (Low Alternative Vehicle Cost)	-1%	-1%	-2%	-7%	-25%	-44%	-58%	-68%
Market	-5%	-6%	-9%	-11%	-15%	-19%	-22%	-38%
Market (High Alternative Vehicle Cost)	-4%	-5%	-9%	-9%	-13%	-16%	-18%	-34%
Market (Low Alternative Vehicle Cost)	-4%	-6%	-9%	-12%	-17%	-22%	-26%	-43%
Electric								
Regulatory	-15%	-28%	-42%	-47%	-60%	-74%	-86%	-88%
Regulatory (High Alternative Vehicle Cost)	-15%	-28%	-42%	-47%	-60%	-74%	-86%	-88%
Regulatory (Low Alternative Vehicle Cost)	-15%	-28%	-42%	-47%	-60%	-74%	-86%	-90%
Market	-27%	-6%	-18%	-28%	-46%	-61%	-77%	-88%
Market (High Alternative Vehicle Cost)	-28%	-8%	-20%	-31%	-48%	-65%	-81%	-90%
Market (Low Alternative Vehicle Cost)	-27%	-6%	-17%	-24%	-35%	-58%	-76%	-87%
Non-Electric								
Regulatory	-1%	-1%	-1%	-5%	-16%	-28%	-36%	-43%
Regulatory (High Alternative Vehicle Cost)	-1%	-1%	-1%	-9%	-19%	-28%	-36%	-43%
Regulatory (Low Alternative Vehicle Cost)	-1%	-1%	-1%	-5%	-16%	-28%	-36%	-43%
Market	-7%	-9%	-12%	-13%	-17%	-21%	-23%	-39%
Market (High Alternative Vehicle Cost)	-7%	-9%	-12%	-13%	-17%	-19%	-22%	-36%
Market (Low Alternative Vehicle Cost)	-6%	-8%	-12%	-14%	-18%	-22%	-25%	-42%

Table 13: Projected Change in Total California CO_2 Emissions Relative to 2005 Levels by Year (%)

	2024	2027	2030	2033	2036	2039	2042	2045
Regulatory	-32%	-41%	-47%	-53%	-61%	-68%	-73%	-76%
Regulatory (High Alternative Vehicle Cost)	-32%	-41%	-47%	-54%	-62%	-68%	-73%	-77%
Regulatory (Low Alternative Vehicle Cost)	-32%	-41%	-47%	-52%	-61%	-68%	-73%	-77%

Market	-39%	-42%	-50%	-54%	-60%	-64%	-68%	-75%
Market (High Alternative Vehicle Cost)	-39%	-42%	-50%	-55%	-60%	-64%	-67%	-74%
Market (Low Alternative Vehicle Cost)	-39%	-42%	-49%	-54%	-60%	-65%	-68%	-76%



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Economic Impact Analysis of California's 2022 Draft Scoping Plan's "Proposed Scenario"
Volume II: *Technical Appendices*

Prepared for:

Western States Petroleum Association

June 2022

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APPENDIX I. NEWERA MODELING FRAMEWORK

A. Introduction

NERA's NewERA model evaluates impacts of policy and regulatory shocks to the U.S. economy, with emphasis on the energy sector. The NewERA model couples a multi-sector macroeconomic model with a detailed electricity sector model that characterizes electricity production at the generation asset level. This coupling allows for a comprehensive understanding of the direct and indirect policy impacts to all aspects of the economy, including the complex interdependencies between energy consumption, electricity supply, and macroeconomic growth.

The main benefit of this separate, yet integrated framework, is that the electric sector can be modeled with full technological detail in a multi-sector macroeconomic setting, while maintaining solution tractability. The electric sector model is a nonlinear program characterizing electricity production. Each electricity generating asset, which amounts to more than 17,000 units in the United States, is represented in the model. The model also provides a detailed account of technologies available to produce electricity, according to realistic engineering specifications. To obtain a solution, the model minimizes costs while meeting all specified operational constraints, such as demand, peak demand, emissions limits, and transmission limits. The electricity model outputs generation resource planning and unit dispatch decisions, along with overall supply and consumption of electricity in the U.S. economy.

The macroeconomic model, a computable general equilibrium (CGE) model of the U.S. economy, takes from the electricity model, information regarding supply and demand for electricity, and the resource inputs used to produce electricity. The macroeconomic model in turn, creates price responses of electricity and electricity sector inputs that are consistent with the rest of the economy.

The integrated NewERA model hence outputs demand, supply and prices of all goods and services, and trade effects; i.e., changes in imports and exports. Model outputs also include gross regional or state product, aggregate consumption, sectoral output and investment levels, and changes in "job equivalents" based on labor wage income.[1]

B. Overview

NERA's NewERA modeling system is an integrated energy-economy model that consists of a multi-sector macroeconomic model and a detailed electric sector model. The electric sector model includes unit-level details of power generation to assess the sector's response to economic shocks that can affect major investment or unit operations decisions. The macroeconomic model represents all other sectors of the economy to provide a comprehensive impact assessment of such shocks. The time horizon used in model projections can be flexibly adapted to the analysis, with typical model time horizons running between

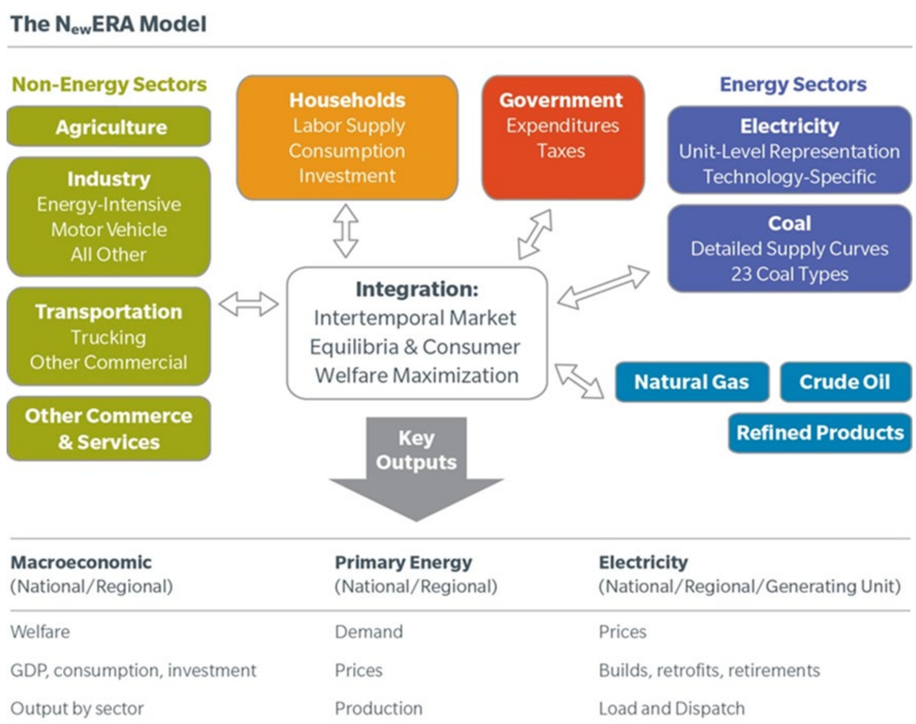
[1] NewERA assumes full employment given the supply of labor and does not model for involuntary unemployment.

fifteen and thirty years[2]. The model produces a standard set of reports that includes the following information:

- *Unit-level investments in the electric sector*: Retrofits in response to environmental policies; new builds and retirements based on economic resource planning; and a full range of power generating technologies is represented in the model.
- *Prices*: Wholesale electricity prices for each of the 64 U.S. electricity regions, capacity prices for each U.S. electricity region, delivered electricity prices to sectors of the economy, Henry Hub natural gas prices and delivered natural gas prices, mine-mouth coal prices for 23 different coals, delivered coal prices by coal generation unit, refined oil product prices (gasoline and diesel fuel), renewable energy credit (REC) prices for each state/regional renewable portfolio standard (RPS), and emissions prices for all national programs with tradable credits.
- *Macroeconomic results:* Gross domestic product (and gross regional/state product for each macroeconomic region), changes in household consumption, changes in labor income and wage rates (used to estimate labor market changes in terms of an equivalent number of jobs), economy-wide energy usages, fuel prices, economy-wide CO_2 emissions by sector.

Figure 1 provides a simplified representation of the key elements of the N$_{ew}$ERA modeling system.

Figure 1: N$_{ew}$ERA Modeling System Representation



[2] As noted in the report body, we set N$_{ew}$ERA to begin in year 2024 and model every third year thereafter until 2048. We extend the model beyond 2045 (the final year of interest for the analysis) to capture the full life of the electric and non-electric capital.

C. Electric Sector Model

The N_{ew}ERA modeling system's electric sector model is a detailed bottom-up model of the electric and coal sectors. The model is fully dynamic and includes perfect foresight (under the assumption that future conditions are known). Thus, all decisions within the model are based on minimizing the present value of costs over the entire time horizon of the model while meeting all specified constraints, regarding demand, peak demand, emissions limits, transmission limits, RPS regulations, CES regulations, fuel availability and costs, new build limits and CCS retrofit build or retire requirements for coal units. The model set-up is intended to mimic decisions made by electric sector investors and system operators. In determining the least-cost method of satisfying specified constraints, the model determines the following:

1. Investment decisions (*e.g.*, addition of retrofits, build new capacity, repower unit, add fuel switching capacity, or retire units);

2. Unit operations decisions (*e.g.*, unit dispatch by fuel and technology and optimal power generation mix); and

3. Demand response – the model assesses the trade-off between the amount of demand-side management (DSM) to be undertaken and the level of electricity usage.

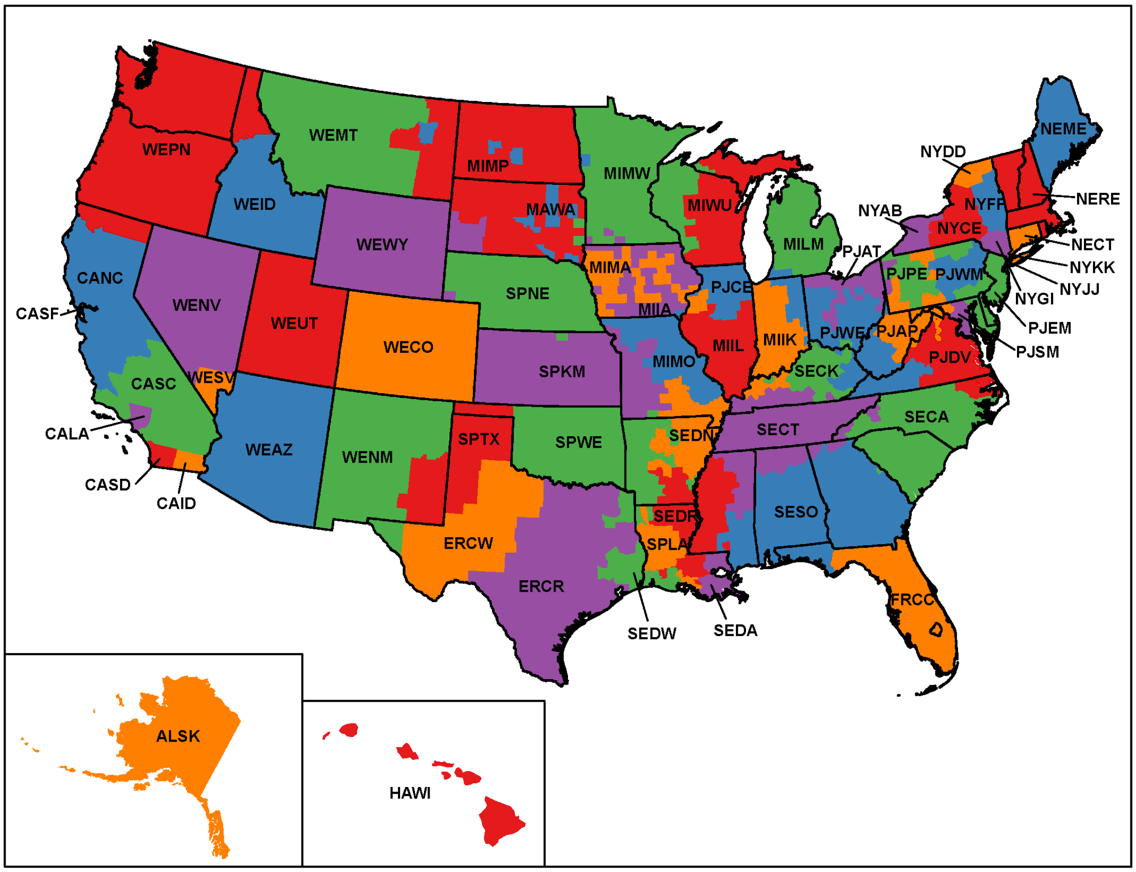
Each unit in the model has certain number of actions it can take. For example, all units can retire, and most can undergo retrofits. Any publicly-announced actions, such as planned retirements, planned retrofits (for existing units), or new units under construction can be specified. Coal units have more potential actions than other types of units. These include retrofits to reduce emissions of SO_2, NO_X, mercury, and CO_2. The costs, timing, and need for retrofits may be specified as scenario inputs or left for the model to endogenously determine. Coal units can also switch the type of coal they burn (with realistic unit-specific limitations). Coal units may choose to retire when it is no longer economic to operate, given net profits from generation and capacity services.

In the model, coal units in particular are responsive to environmental limits specified in the model. Such limits include emission caps (for SO_2, NO_X, Hg, and CO_2) that can be applied at the national, regional, state or unit level. The user can also specify allowance prices for emissions, emission rates (especially for toxics such as Hg), and heat rate levels that must be met by assets.

Similar to investment decisions, the operation of each unit in a given year depends on the policies in place (*e.g.*, unit-level standards), electricity demand, and operating costs – especially energy prices. The model accounts for these conditions in determining dispatch decisions of each unit. On top of unit-level regulations, the model also considers system-wide operational issues such as environmental regulations, limits on the share of generation from intermittent resources, transmission limits, and operational reserve margin requirements in addition to annual reserve margin constraints.

To meet increasing electricity demand and reserve margin requirements over time, the electric sector must build new generating capacity. Future environmental regulations and forecasted energy prices influence decisions on technology type and location of asset. For example, if a national CES policy is to take effect, some share of new generating capacity will need to come from "clean" power. On the other hand, if there is a policy to address emissions, it might elicit a response to retrofit existing fossil-fired units with pollution control technology or enhance existing coal-fired units to burn different types of coals, biomass, or natural gas. Policies that call for improved heat rates may lead to capital expenditure spent on repowering existing units. Policies will also likely affect retirement decisions – an asset will be retired if the model deems it uneconomic to keep that asset operating given future regulatory, technological, and economic constraints. All model decisions hence optimize over all current and future assumptions that may impact resource planning. The model contains 64 U.S. electricity regions (and 11 Canadian electricity regions).[3] Figure 2 shows the U.S. electricity regions in the electric sector model.

Figure 2: N$_{ew}$ERA Electric Sector Model – U.S. Regions



1. Generator Representation

In the model, we represent over 17,000 electricity generating units in the United States. Larger coal units (greater than 200 MW) are individually represented in the model and smaller units are aggregated based on region, size, and existing controls for ease of computation[4]. All other types of units are included in different regional aggregates based on their operating characteristics.

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[3] The N$_{ew}$ERA electric sector model regions are based on the model regions in EPA's Integrated Planning Model (IPM) and are designed to be approximately consistent with the configuration of the NERC assessment regions in the NERC Long-Term Reliability Assessments (available at https://www.epa.gov/airmarkets/clean-air-markets-power-sector-modeling).

[4] The system of non-linear equations become increasingly difficult to solve in the dimensionality of the model.

Table 1 shows the existing generating technologies in the electric sector model.

Table 1: Existing Generating Technologies in the Electric Sector Model

Coal	Pumped Storage Hydroelectric
Natural Gas Combined Cycle	Biomass
Natural Gas Combustion Turbine	Geothermal
Gas/Oil Steam	Landfill Gas
Oil Combustion Turbine	Municipal Solid Waste
Onshore Wind	Solar Photovoltaic
Hydroelectric (Run-of-River)	Concentrated Solar Thermal

New technology types that the model can build, in addition to existing types, include advanced coal with carbon capture and storage (CCS), natural gas combined cycle with CCS, offshore wind, onshore wind with storage, photovoltaic solar with storage, and biomass with CCS. Annual build limits can be specified to reflect real world constraints. The model can also accommodate joint build limits that apply to multiple new technology types.

For this study, NERA incorporated two additional electricity generating technologies – photovoltaic solar co-located with storage ("Solar with Storage") and onshore wind co-located with storage ("Wind with Storage"). The representative technology that formed the basis for each of these technologies was a Solar PV module of 100 MW co-located with 60 MW Li-Ion battery storage system with a 4-hour discharge duration and a round-trip efficiency of 87%.[5] This translates to a capacity factor of 60% at full discharge for the battery storage system. We also assumed that the battery storage system would discharge during the top 25% of the peak hours in each season (summer, spring, fall, winter).[6] We developed technology cost estimates and an adjusted capacity factor for these combined technologies as follows:

- **Obtaining the Number of Hours to Apply Storage Discharge.** Based on our assumption that the battery storage system would only discharge during the top 25% of the peak hours in each season, we first obtained both the number of hours and the percentage of total number of hours in each seasonal load block in which discharge takes place.

- **Obtaining Unadjusted and Adjusted Daily Generation by Season.** We obtained the total unadjusted daily generation for each season, based on the default capacity factor for each of the standalone technologies, and the number of hours present in each seasonal load block. An adjusted daily generation was computed for each season by subtracting the generation losses that occur during discharge of the battery storage system from the unadjusted daily generation.

- **Obtaining the Adjusted Capacity Factor.** A maximum capacity factor of 60% for the combined technology with storage was assigned to each of the hours in a seasonal load block, in

[5] Fu, Ran, Timothy Remo, and Robert Margolis. 2018. "2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark," National Renewable Energy Laboratory (available at https://www.nrel.gov/docs/fy19osti/71714.pdf).

[6] Storage Discharge Duration (4 hours)/Number of Daily Peak Hours (16) = 25%.

which the battery storage system discharges completely. We then computed an adjustment factor to be applied to the capacity factor in all other hours of the season to make total daily generation (that considers the storage discharge) consistent with the adjusted daily capacity factor. An adjusted capacity factor was calculated for these hours by multiplying the adjustment factor with the unadjusted capacity factor in each of the hours. In a seasonal load block that requires the storage system to discharge only a portion of the hours, the adjusted capacity factor was computed as the weighted average of two elements: the capacity factor during complete discharge (60%) and the adjusted capacity factor corresponding to non-discharge hours. The two elements were weighted using the fraction of hours in the load block that the discharge applies to.

2. Electricity Demand

Electricity demand within the model is represented by load duration curves.[7] These region-specific curves are created by sorting the hourly demand by load within a season, and then aggregating the hours into a load block based on load characteristics.[8] The model has four seasons and a total of 25 load blocks (ten in the summer and five each in winter, spring, and fall).[9] Four seasons are used to better capture differences between hydroelectric generation in the spring and fall. Peak demand is also a model input and is used in conjunction with reserve margins to determine capacity prices within the model.[10]

The electric sector model is a non-linear program that is linked with the macroeconomic model, so electricity demand can respond to changes in equilibrium conditions affecting all sectors of the economy and model inputs. Furthermore, the electric sector model's demand constraint allows demand to be satisfied either through electricity production or demand-side management programs. Therefore, in the face of a policy such as a nationwide cap or carbon tax on greenhouse gas emissions, the model can choose between meeting demand as forecasted, meeting a lower level of demand (which results in lower values of consumer wellbeing), or implementing DSM programs.

3. Coal Representation

The steam coal sector is represented within the electric sector model of the N_{ew}ERA modeling system. The model includes 23 steam coals types. Existing coal units each have an initial coal type specified and a maximum percentage of PRB coal that the unit can burn (based on recent historical percentages). Units can switch to burn more PRB coal than they currently burn, but they would incur capital costs as well as heat rate and capacity penalties in order to make the switch. Moreover, units can switch to burning other coals if the coal type can be delivered to the unit (and if the unit can be reasonably expected to be able to

[7] Baseline assumptions relating to electricity demand for the different N_{ew}ERA electric sector regions are drawn from the total net energy for load projections for the various electricity market module regions from the AEO 2021 Reference case.

[8] Hourly demand for each of the N_{ew}ERA electric sector regions are aggregated into load blocks based on a mapping of hours to load blocks based on EPA's IPM assumptions.

[9] There are in aggregate about 3,672 hours across the ten load blocks in the summer, 1,464 hours across the five load blocks each in the spring and fall and 2,160 hours across the five load blocks in the winter.

[10] Baseline assumptions relating to peak demand for the different N_{ew}ERA electric sector regions are drawn from the North American Electric Reliability Corporation's (NERC) 2018 Electricity Supply and Demand Projections (available at https://www.nerc.com/pa/RAPA/ESD/Pages/default.aspx).

burn such a coal). In the near term, the model limits excessive switching in the first few years of the analysis to reflect realistic coal market conditions. Coal exports, and coal use in non-electric sectors are exogenous inputs to the model, although this can be changed depending on the study.

The model utilizes coal supply curves that are paired with inputs for non-electric demand, export demand, and endogenously-determined electric sector demand to produce coal prices for each coal type available in the model.[11] The supply curves are built up from mine-level data and include prices at each step of the curve, along with annual production levels and total reserves at each price step. Demand in prior years depletes the total reserves going forward, which would generally lead to higher coal prices if total reserves at a price step are fully depleted.

There is a complete coal transportation matrix within the model that maps each generating unit to the coals that can be delivered to it.[12] The matrix assigns a transportation cost for each of the deliverable coals. More specifically, the matrix accounts for costs associated with the different modes of transportation that can be used to deliver the coal, along with the distance that the coal must travel.

D. Macroeconomic Model

1. Overview

The N_{ew}ERA macroeconomic model is a forward-looking, dynamic, computable general equilibrium (CGE) model of the United States. The model simulates all economic interactions in the U.S. economy, including those among industry, households, and the government. Additional background information on CGE models can be found in Burfisher (2011).[13]

The N_{ew}ERA CGE framework uses a standard theoretical macroeconomic structure to capture the flow of goods and factors of production within the economy. A simplified version of these interdependent macroeconomic flows is shown in Figure 3. The model solution assumes an Arrow-Debreu general equilibrium. This general equilibrium is characterized by three principles – i. zero-profit, which states any economic activity must earn zero profit as the value of inputs equal the value of outputs; ii. market clearance, which states supply must equal demand for all positively priced goods; and iii. income balance, which states all agents' income must equal its factor endowments plus any net transfers received.

Accordingly, in the model, households supply factors of production, including labor and capital, to firms. Firms provide households with payments for the factors of production in return. Firm output is produced from a combination of production factors and intermediate inputs of goods and services supplied by other sectors of the economy (both domestic and foreign). Similarly, each firm's final output is either consumed within the United States or exported abroad. In addition to consuming goods and services,

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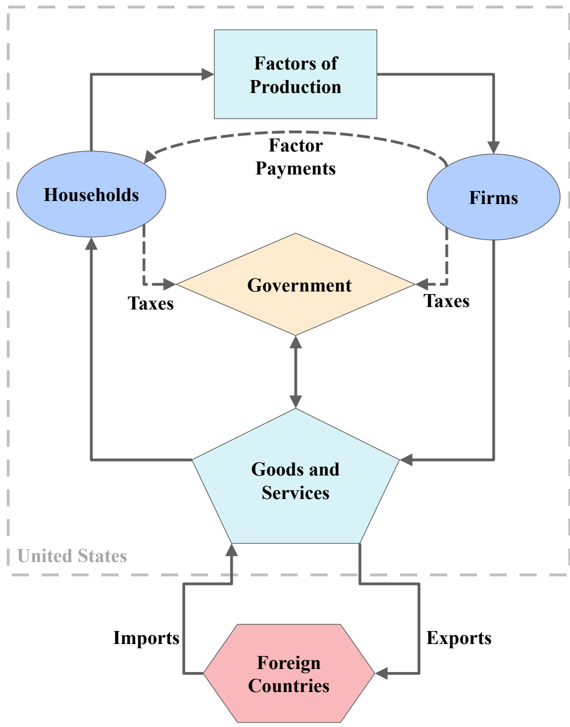
[11] The coal supply curves were developed by NERA based on the coal supply regions and associated coal types in EPA's IPM model documentation.

[12] NERA engaged Hellerworx to create a coal transportation matrix going out in time with the mapping of available coals to the coal-fired power plants based on coal deliverability, the total cost of the delivered coal (commodity plus delivery costs), the heat content of the coal, the rank of the coal, and the emissions contents of the coal.

[13] Burfisher ME. 2011. *Introduction to Computable General Equilibrium Models*. New York: Cambridge University Press.

households can accumulate savings, which they provide to firms for investments in new production capacity. The government agent receives taxes from both households and firms, contributes to the production of goods and services, and purchases goods and services. Although the model assumes equilibrium, there exist capital flow within regions as they run deficits or surpluses. In aggregate, the value of firm output must equal the sum of its production inputs (zero-profit), the sum of regional commodities and factors of production must equal their demands (market clearance), and household income must equal its factor endowments plus any tax revenue received (income balance).

Figure 3: Interdependent Economic Flows in N$_{ew}$ERA's Macroeconomic Model



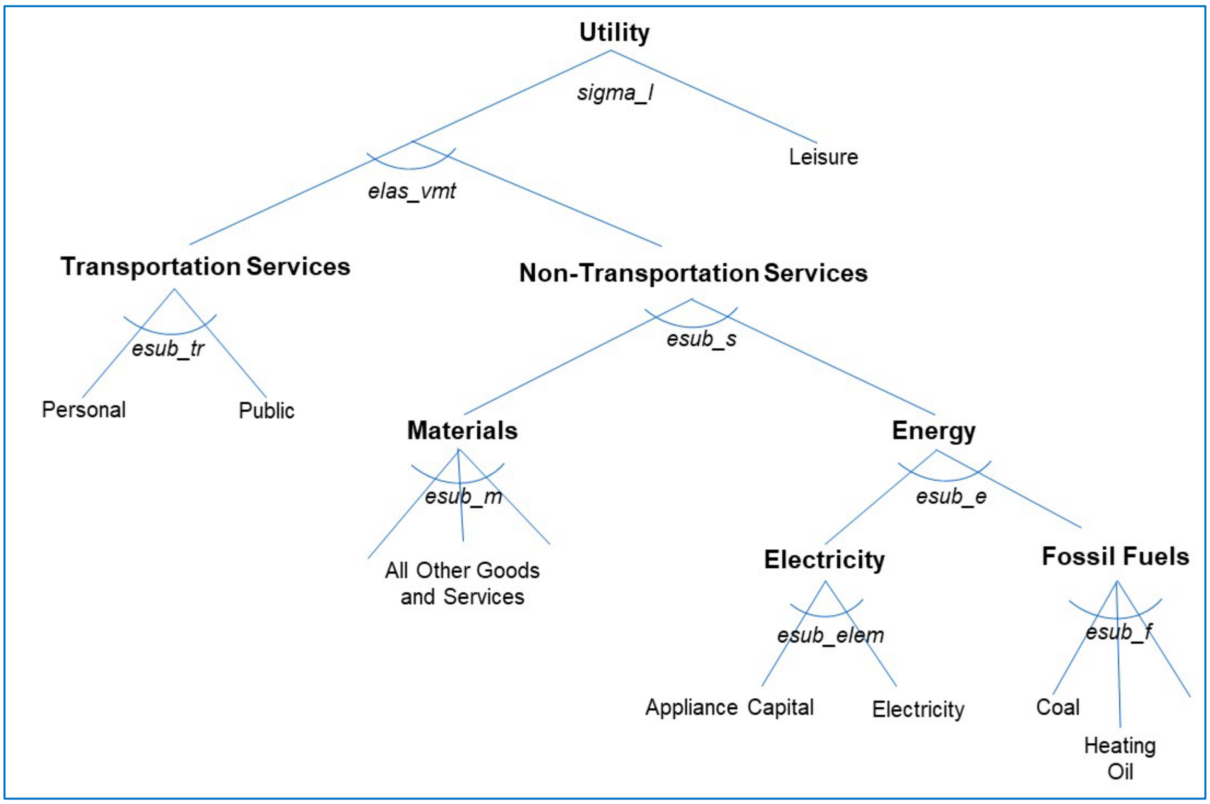
2. Household Behavior Representation

The model assumes that households seek to maximize their overall welfare, or utility, across time periods. Households have utility functions that reflect trade-offs between leisure (which reduces the amount of time available for earning income) and an aggregate consumption good. Households in the model demand leisure, personal transportation, energy inputs, and other intermediate goods and services inputs. Household utility is represented by a nested CES utility function where the trade-off between inputs to the utility function are optimized. The trade-offs between inputs are determined by the elasticities of substitution among goods in utility input nests. For example, if the elasticity of substitution between goods is greater than unity (substitution is elastic), then substitution between goods in response to relative price changes would take place relatively easily. Similarly, if the elasticity of substitution is small (substitution is inelastic), scope for substitution would be limited and the household will likely reduce its overall consumption as a result of reducing demand for the good for which the relative price has risen. The elasticity parameter values are drawn from MIT's USREP and EPPA models.[14,15]

Households maximize their utility over all time periods, subject to lifetime budget constraints based on their income from supplying labor and capital to firms, and owning initial capital stock and economic resources. In each time period, household income is used to consume goods and services, or saved to fund investment. Within consumption, households distinguish between energy goods (including electricity, coal, natural gas, and petroleum), transportation, and other goods and services.

Figure 4 illustrates the nesting structure of the household utility function, while Table 2 displays the elasticity values used in the structure.

Figure 4: Consumption Structure in N$_{ew}$ERA's Macroeconomic Model



[14] Mei Yuan, Sebastian Rausch, Justin Caron, Sergey Paltsev and John Reilly, 2019, The MIT U.S. Regional Energy Policy (USREP) Model: The Base Model and Revisions. Joint Program Technical Note TN #18, August 2019. (available at http://globalchange.mit.edu/publication/17331).

[15] Paltsev, S., J.M. Reilly, H.D. Jacoby, R.S. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005, The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4. Joint Program Report Series Report 125, August 2005 (available at http://globalchange.mit.edu/publication/14578).

Table 2: Elasticity of Substitution Values for Consumption

Elasticity	Description	Short-run	Long-Run
sigmal_l	Elasticity based on compensated labor supply of 0.32		
elas_vmt	Elasticity between transportation and other goods	0.40	0.80
elas_tr	Elasticity between transportation services	0.20	0.20
elas_s	Elasticity between energy and materials	0.00	0.00
elas_m	Elasticity between materials	0.20	0.50
elas_e	Elasticity between energy goods	0.20	0.50
elas_elem	Elasticity between electricity and appliance capital	0.20	0.20
elas_f	Elasticity between electricity fuels	1.00	1.00

3. Transportation Sector Representation

The NewERA model explicitly models personal transportation services, which are represented by vehicle miles traveled, namely from light duty vehicles and the trucking transportations services.

We categorize personal travel into two main types of technologies, ICE and BEV vehicles. Under a partial putty-clay structure, the model differentiates the extant – vehicles that have been built prior to the initial model time period (2020) – from the new – vehicles that are newly built during the model horizon. We assume that these pre-2020 vintage vehicles (clay vehicles) are assumed to maintain the same technology going forward and depreciate at a fixed rate of 10%. Inputs for personal transportation services from vehicles include fuel (gasoline or electricity), vehicle specific capital, and maintenance and insurance costs. We assume that clay vehicles, which are already built, cannot substitute between inputs since the technology is fixed. In contrast, consumers of putty ICE and BEV vehicles can flexibly substitute between fuel and capital. That is, if the relative price of fuel to capital increases (as a consequence of a carbon tax or fuel economy standards), the representative consumer will substitute away from fuel to capital or reduce vehicle miles travelled.

The structure of inputs for the personal transportation sector that characterize the use of ICE and BEV vehicles follows the structure presented in Karplus et al. (2013), Paltsev et al. (2005), and Gandhi et al. (2019).[16,17,18] The model calibration procedure regarding vehicle usage also follows the procedure outlined in these studies. Assumptions on gasoline input for ICE vehicles are taken from EIA's AEO 2021 Reference case, while electricity input assumptions are described in the baseline assumptions section of Appendix II. Cost assumptions relating to vehicle services and maintenance are based on

[16] Karplus, V., S. Paltsev, M. Babiker & J. Reilly, 2013, Applying engineering and fleet detail to represent passenger vehicle transport in a computable general equilibrium model, *Economic Modelling* 30, 295–305.

[17] Paltsev, S., J.M. Reilly, H.D. Jacoby, R.S. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005, The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4. Joint Program Report Series Report 125, August 2005 (available at http://globalchange.mit.edu/publication/14578).

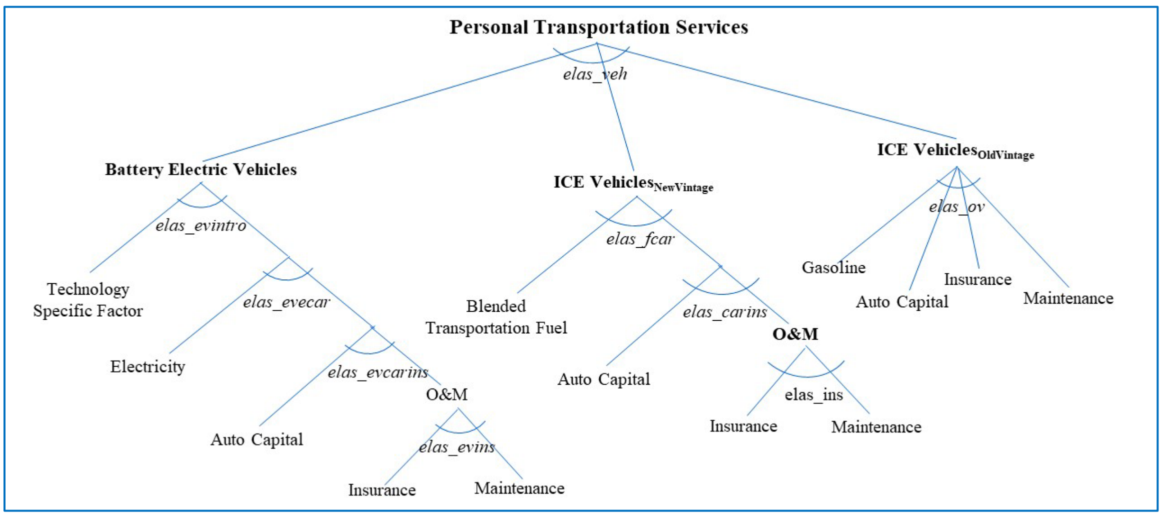
[18] Ghandi, A. and S. Paltsev, 2019, Representing a Deployment of Light-Duty Internal Combustion and Electric Vehicles in Economy-Wide Models, February 2019 (available at https://globalchange.mit.edu/publication/17199).

estimates from the 2018 Consumer Expenditure Survey.[19] Figure 5 illustrates the nesting structure in the production of personal transportation services within households, and

Table 3 displays the elasticity parameters used in the structure.

To capture the deployment of new vehicle technologies, we have adopted an approach in the NewERA model that is different from the approach typically adopted in a technology-based bottom-up model. In a bottom-up model, the extent of penetration of new technologies are restricted by capacity limits and cost assumptions that embed learning-by-doing. Top-down economic models (such as NewERA) tend to use technology-specific fixed factors. The fixed factor represents the adoption dynamics of the new vehicle technology[20] and is modeled as an input to the cost structure. The fixed factor assumption is a function of supply and grows as the potential for the new technology grows. It also grows as the inputs to the technology becomes competitive with respect to its alternatives (Paltsev et al 2005).[21]

Figure 5: **Household Personal Transportation Services in N_{ew}ERA's Macroeconomic Model**



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[19] Based on the Consumer Expenditure Survey 2018, about 4.7% of consumer expenditure is attributed towards repair/maintenance, insurance and other finance charges. This amounts to about $585 million which is comprised of $398 billion towards insurance and repair and the rest towards finance and insurance charges. This forms the basis for calibrating insurance and maintenance costs in the model. (available at https://www.bls.gov/cex/2018/combined/cucomp.pdf).

[20] J.F. Morris, J.M. Reilly, Y.H. Henry Chen, 2019, Advanced technologies in energy-economy models for climate change assessment, *Energy Economics* 80, 476-490.

[21] Paltsev, S., J.M. Reilly, H.D. Jacoby, R.S. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005, The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4. Joint Program Report Series Report 125, August 2005 (available at http://globalchange.mit.edu/publication/14578).

Table 3: Elasticity of Substitution Values for Personal Transportation

Vehicle Type	Elasticity	Description	Short-run	Long-Run
Diesel Vehicles	**elas_veh**	Elasticity between vehicle types	Perfect Substitute	
	elas_s	Elasticity between energy and other goods	0.30	0.50
	elas_m	Elasticity between materials	0.00	0.00
	elas_eva	Elasticity between energy and value added	0.50	0.50
	elas_e	Elasticity between energy goods	0.20	0.50
	elas_va	Elasticity between value added inputs	0.80	0.80
Battery Electric Vehicles	**elas_evintro**	Elasticity between vehicle types	0.40	1.00
	elas_evcar	Elasticity between fuel and vehicle	0.40	0.40
	elas_evcarins	Elasticity between vehicle and insurance/maintenance	1.00	1.00
	elas_evins	Elasticity between insurance and maintenance	0.00	0.00

The trucking transportation services sector is also characterized in a manner similar to the personal transportation sector. Trucking sector services are provided by diesel-fueled trucks, battery-electric trucks, and hydrogen based fuel-cell trucks. These vehicle types are used to represent the medium and heavy-duty trucking sector in the NewERA model. Unlike the light-duty vehicles in the personal transportation sector, the NewERA model does not simulate the vehicles miles traveled by these truck vehicle types. Instead, these vehicle types provides value-added services in the model. Figure 6 illustrates the nesting structure in the production of trucking transportation services, and

Table 4 displays the elasticity parameters used in the structure.

Figure 6: **Trucking Transportation Services in N$_{ew}$ERA's Macroeconomic Model**

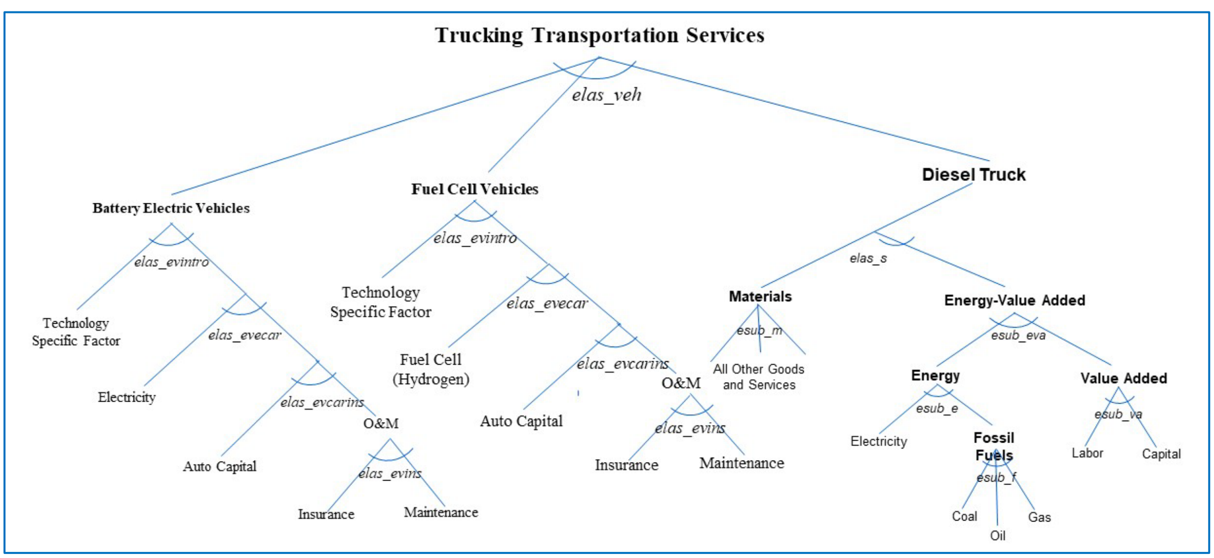


Table 4: Elasticity of Substitution Values for Trucking Transportation

Vehicle Type	Elasticity	Description	Short-run	Long-Run
Diesel Vehicles	**elas_veh**	Elasticity between vehicle types	Perfect Substitute	
	elas_s	Elasticity between energy and other goods	0.30	0.50
	elas_m	Elasticity between materials	0.00	0.00
	elas_eva	Elasticity between energy and value added	0.50	0.50
	elas_e	Elasticity between energy goods	0.20	0.50
	elas_va	Elasticity between value added inputs	0.80	0.80
Battery Electric Vehicles and Fuel Cell Vehicles	**elas_evintro**	Elasticity between vehicle types	0.40	1.00
	elas_evcar	Elasticity between fuel and vehicle	0.40	0.40
	elas_evcarins	Elasticity between vehicle and insurance/maintenance	1.00	1.00
	elas_evins	Elasticity between insurance and maintenance	0.00	0.00

4. Production Sectors Representation

Production sectors are characterized by a nested Constant Elasticity of substitution (CES) production function, in which inputs can be substituted as shown in Figure 7. The model assumes that all industries maximize profits subject to technological constraints. Inputs to production are energy (including the same four types noted above for household consumption), capital, and labor. Production also uses inputs from intermediate products provided by other firms. The N_{ew}ERA model allows producers to change the technology and the energy source they use to manufacture goods. If, for example, petroleum prices rise, an industry can shift to a cheaper energy source. It can also choose to use more capital or labor in place of petroleum, increasing energy efficiency and maximizing profits with respect to industry constraints.

For the bulk chemicals and iron and steel sectors – sectors that produce process emissions from feedstock use – we employ specialized production structures that incorporate energy feedstock inputs in the production process. Using assumptions from the AEO 2021 Reference case, we model natural gas and petroleum product feedstock as inputs to the bulk chemicals sector, and metallurgical coal feedstock as input to the iron and steel sector. We assume that these feedstocks are consumed in fixed proportion to the respective sectoral output. Figure 7 illustrates the nesting structure for industrial sector production while Table 5 shows the elasticity parameters used in the structure.

Figure 7: Production Structure for Manufacturing and Energy-Intensive Sectors in NewERA's Macroeconomic Model

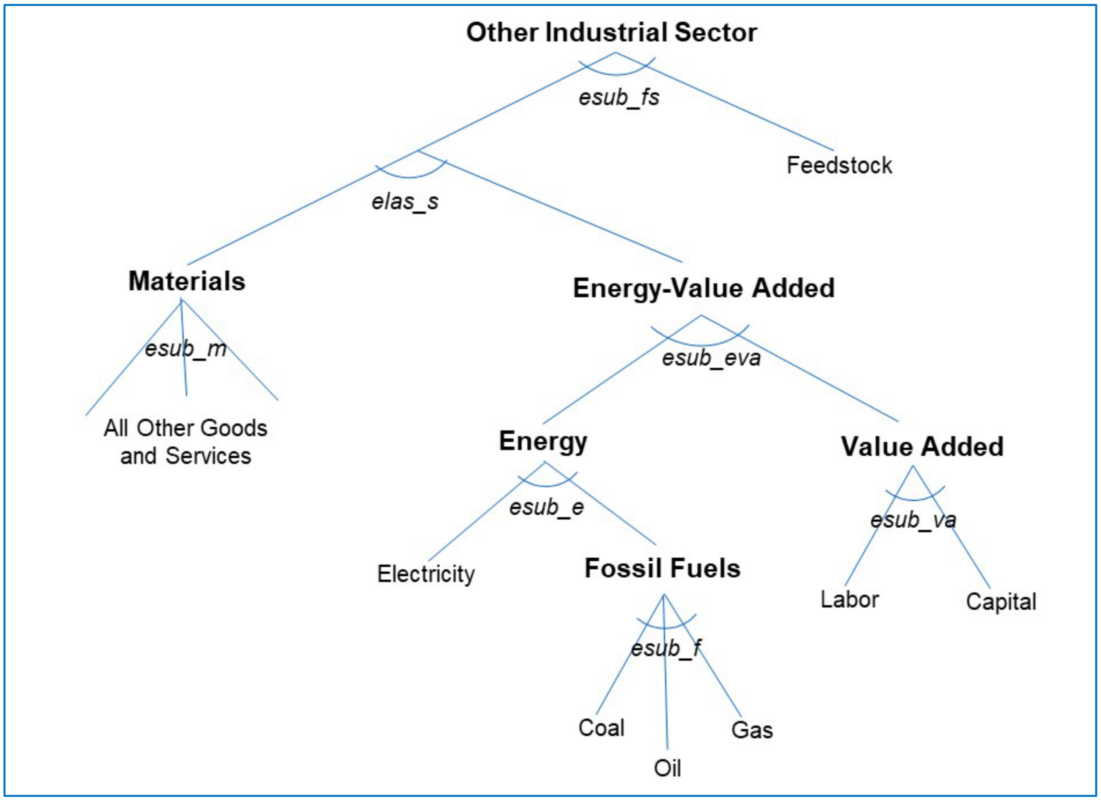


Table 5: Elasticity of Substitution Values for Industrial Sector Production

Elasticity	Description	Short-run	Long-Run
elas_fs	Elasticity between crude and other inputs	0.00	0.00
elas_s	Elasticity between energy and other goods	0.30	0.50
elas_m	Elasticity between materials	0.00	0.00
elas_eva	Elasticity between energy and value added	0.50	0.50
elas_e	Elasticity between energy goods	0.20	0.50
elas_va	Elasticity between value added inputs	0.80	0.80

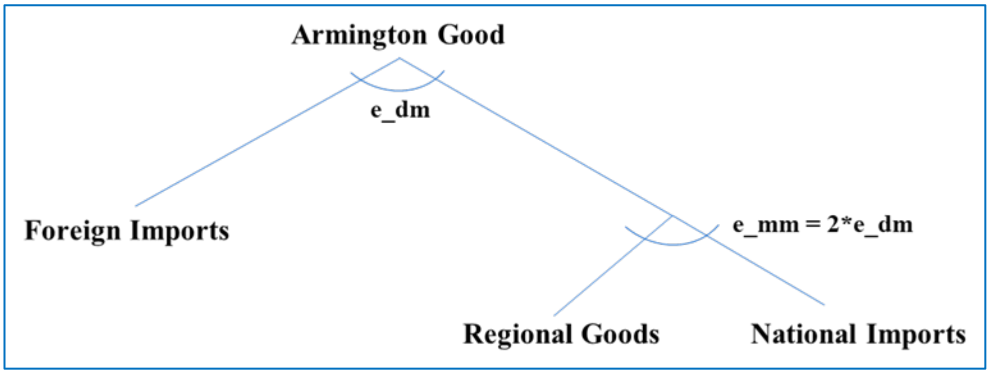
5. Trade Representation

All goods and services, except crude oil, are treated as Armington goods, which means domestic and foreign goods are differentiated and are thus imperfect substitutes.[22] As shown in Figure 8, these goods are either produced domestically or imported from foreign countries. The level of imports depends upon the elasticity of substitution between the imported and domestic goods. Using the "rule of two" discussed

[22] Armington P. 1969. "A Theory of Demand for Products Distinguished by Place of Production." *International Monetary Fund Staff Papers*, XVI: 159-78.

in Jomini et al. (1991),[23] the Armington elasticity among imported goods is assumed to be twice as that between the domestic and foreign imported goods, indicating greater substitutability among imported goods. The elasticity value at the top of the trade nest is assumed to be 2, based on the elasticity assumptions in MIT's EPPA modeling framework,[24] while the elasticity value between local goods and domestic imports is set at 4.

Figure 8: Trade Representation in NewERA's Macroeconomic Model



6. Exhaustible Resource Sector Representation

Crude oil, natural gas, and coal production are also characterized by a nested CES production function as shown in Figure 9. The N_{ew}ERA model does not explicitly model resource depletion. However, the resource constraints that arise from limited availability of the natural resource is represented by a fixed factor input, to mimic decreasing returns to scale in non-renewable resources. This implies that additional exhaustible resources can be harvested with rising marginal costs of production over time. Following model documentation on MIT's EPPA model and the EPA's EMPAX-CGE model,[25] we assume that the share of total production costs attributed to resource factors are 10% for coal, 33% for crude oil, and 25% for natural gas.

The top-level elasticity of substitution parameter that governs substitution between the natural resource and the materials - value added composite good, is calibrated to be consistent with each resource's short and long-run supply elasticity.

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[23] Jomini, P., Zeitsch, J. F., McDougall, R., Welsh, A., Brown, S., Hambley, J., & Kelly, J. (1991). SALTER: A General Equilibrium Model of the World Economy, vol. 1, Model Structure. Database and Parameters, Industry Commission, Canberra.

[24] Paltsev, S., J.M. Reilly, H.D. Jacoby, R.S. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005, The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4. Joint Program Report Series Report 125, August 2005 (available at http://globalchange.mit.edu/publication/14578).

[25] RTI International (2008). 'EMPAX-CGE Model Documentation (Interim Report), March 2008, North Carolina, USA: Research Triangle Park.

A literature review of natural gas elasticity estimates included in a 2018 NERA report on LNG exports[26] suggests that the short-run supply elasticity for natural gas ranges between 0.25 and 0.4, while the long-run elasticity ranges from 0.7 to 2. We use 0.25 as the short-run elasticity which is consistent with the implied supply elasticity used in a 2012 study on LNG exports commissioned by the Department of Energy.[27] We assume that the long-run supply elasticity of natural gas is equal to unity, consistent with a study conducted by Medlock et al. (2015).[28] From this study we take the implied elasticity value in 2035 scenario in which U.S. LNG exports amounts to 12 billion cubic feet per day (Bcf/d).

For crude oil, we use 0.3 as the short-run and 1 as the long-run elasticity, which is in line with the 0.3-0.9 range presented in Bjørnland et al. (2019).[29] Lastly, we assume an elasticity value (both short and long-run) of 5 for the non-electric sector coal supply (note that we model coal supplied to the electric sector explicitly via coal supply curves). This elasticity value is supported by a literature survey conducted by Dahl and Duggan (1996),[30] which finds a wide range of coal supply elasticity estimates between 0.05 and 7.9.

The short and long-run elasticity parameters are used to construct a time-varying elasticity parameter for each resource that initially takes the short-run and converges logarithmically over time to the long-run elasticity value.

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[26] "Macroeconomic Outcomes of Market Determined Levels of U.S. LNG Exports," Prepared by: NERA Economic Consulting, June 7, 2018 (available at https://www.energy.gov/sites/prod/files/2018/06/f52/Macroeconomic%20LNG%20Export%20Study%202018.pdf)

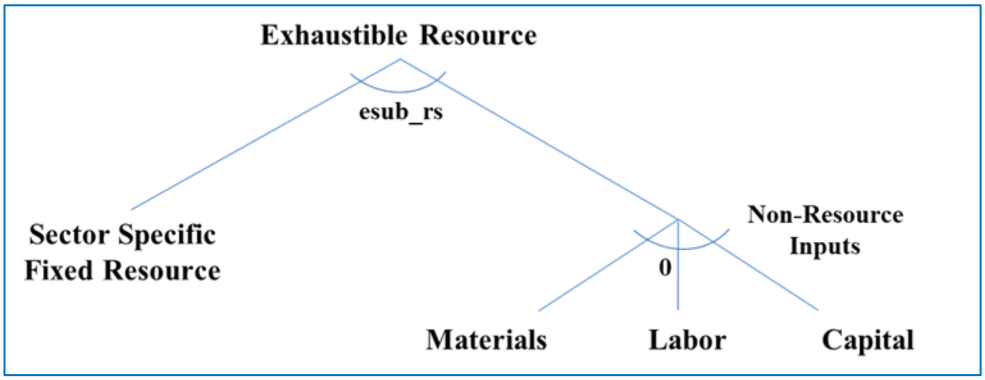
[27] "Effects of Increased Natural Gas Exports on Domestic Energy Markets, as requested by the Office of Fossil Energy," January 2012 (available at https://www.energy.gov/sites/prod/files/2013/04/f0/fe_eia_lng.pdf).

[28] Cooper, Adrian, Michael Kleiman, Scott Livermore, and Kenneth B. Medlock III. "The Macroeconomic Impact of Increasing US LNG Exports." (2015). (available at https://www.energy.gov/sites/prod/files/2015/12/f27/20151113_macro_impact_of_lng_exports_0.pdf).

[29] Hilde C. Bjørnland & Frode Martin Nordvik & Maximilian Rohrer, 2019."Supply flexibility in the shale patch: Evidence from North Dakota," CAMA Working Papers 2019-56, Centre for Applied Macroeconomic Analysis, Crawford School of Public Policy, The Australian National University. (available at https://cama.crawford.anu.edu.au/sites/default/files/publication/cama_crawford_anu_edu_au/2019-08/56_2019_bjornland_nordvik_rohrer.pdf).

[30] Dahl, C. and Duggan, T. E. (1996). US energy product supply elasticities: A survey and application to the US oil market. *Resource and Energy Economics*, 18(3):243-263.

Figure 9: Resources Sector Representation in NewERA's Macroeconomic Model



For each resource, we can construct the elasticity of substitution (*esub_rs* in Figure 9) between the resource and non-resource inputs using the value share of each component (resource and non-resource) in the resource production function, and the supply elasticity. Following Rutherford's method of benchmarking decreasing returns to scale production functions, presented in his documentation of MPSGE (1998),[31] we use the following expression to obtain elasticities of substitution between resource and non-resource inputs:

$$esub_{rs} = \frac{\theta\eta}{(1-\theta)},$$

where θ denotes the benchmark value share of the sector specific resource factor, and η, the time-varying supply elasticity parameter. The elasticity of substitution between the resource-specific resource and other goods in the production of fossil fuel is based on the supply elasticity of the resource. For natural gas and crude oil, we assume the supply elasticity to vary from 0.5 to 1.5 and 0.3 to 1.0, respectively. The values of the computed elasticities of substitution are displayed in Table 6.

Table 6: Elasticities of Substitution between Resource and Non-Resource Inputs in the Resource Sector

esub_rs	**2024**	**2027**	**2030**	**2033**	**2036**	**2039**	**2042**	**2045**
Natural Gas	0.393	0.660	0.980	1.220	1.386	1.505	1.578	1.633
Crude Oil	0.413	0.673	0.928	1.143	1.320	1.488	1.687	1.792

In terms of trade, production from the crude oil and natural gas sectors is either supplied to the domestic market or exported abroad. The N_{ew}ERA model represents the domestic and international crude oil and refined petroleum markets. The international markets are represented by flat supply curves with exogenously specified prices. Because crude oil is treated as a homogeneous good, the international price for crude oil sets the U.S. price for crude oil. Crude oil that is supplied to the domestic market is mixed with imported crude oil and is supplied to the domestic refinery sectors.

[31] Rutherford, Thomas F. "Economic equilibrium modeling with GAMS." Washington: GAMS Development Corporation (1998).

The natural gas module also accounts for foreign imports (as opposed to national imports) and U.S. exports of natural gas, by using a supply (demand) curve for U.S. imports (exports) that represents how the global LNG market price would react to changes in U.S. imports or exports. This makes it possible to provide a consistent analysis of the linkages between U.S. import levels, export policy, and the domestic price of natural gas.

We note that in the model, consumption of electricity as a transportation fuel can also affect the natural gas market. Along with alternative transportation fuels (including biofuels), the model also includes different vehicle choices that consumers can employ in response to changes in the fuel prices.

7. Investment Dynamics

Business investment decisions are informed by future policies and outlook. The forward-looking characteristic of the model enables businesses and consumers to determine optimal savings and investment levels through anticipation of future economic conditions. Intertemporal decisions are also linked through capital and investment dynamics. Capital turnover in the model is represented by a standard process that assumes capital in the next time period equals extant capital (minus the depreciated value of capital) plus investment. Such capital accumulation dynamics along with assumptions on perfect foresight allows for intertemporal decisions to optimize the tradeoff between present and future welfare.

8. Sectoral Aggregation

The N_{ew}ERA model for this study includes a standard set of 12 economic sectors: five energy (coal, natural gas, crude oil, electricity, and refined petroleum products) and seven non-energy sectors (motor vehicle manufacturing, energy-intensive sectors,[32] other manufacturing,[33] agriculture, commercial transportation other than trucking, trucking, and services). These sectors are aggregated up from 440 IMPLAN sectors. The model has the flexibility to represent sectors at different levels of aggregation, when warranted, to better meet the needs of specific analyses.

9. Tax Rates

The model accounts for personal income taxes on capital and labor, payroll taxes collected for Social Security under the Federal Insurance Contributions Act (FICA) and Medicare hospital insurance (HI), and the corporate income tax. The corporate income tax rates in the model are consistent with the Tax Cuts and Jobs Act (TCJA) which created as single corporate tax rate of 20%. We take tax rates from NBER's TAXSIM model[34] and other secondary sources. Based on TAXSIM data, we apply personal income tax rates to reflect the average marginal rate on labor income and the capital gains rate on capital income. A

[32] This comprises pulp and paper, chemicals, glass, cement, iron and steel, alumina and aluminum and mining.

[33] This comprises construction, food, beverage, and tobacco products, fabricated metal products, machinery, computer and electronic products, transportation equipment, electrical equipment, appliances, and components, wood and furniture, plastics, and other manufacturing sectors.

[34] Feenberg, Daniel, and Elisabeth Coutts. "An introduction to the TAXSIM model." *Journal of Policy Analysis and Management* 12.1 (1993): 189-194.

combined state and federal corporate income tax rate of 20%, consistent with TCJA[35] is applied to the corporate profit component of the total capital income. In addition, we apply a payroll tax rate of 12.4% to reflect Social Security's Old-age, Survivors, and Disability Insurance program and an additional 2.9% to reflect Medicare's Hospital Insurance (HI) program.

We differentiate tax rates at the state level in the database and hold the benchmark tax rates constant over the model horizon. These rates vary somewhat from state to state, as estimated by the NBER and Tax Foundation, due to differences in state income distributions. For 2013-2022, the baseline average marginal federal personal income (PIT) tax rate is 25% on labor earnings and 12% to 15% (depending on the state) on capital earnings. The Baseline average marginal corporate income tax rate is 19% to 21% depending on the state. The model estimates a weighted average of the state-specific levels to obtain a single rate for the U.S. as a whole.

10. Macroeconomic Outputs

As with other CGE models, the N_{ew}ERA macroeconomic model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include gross regional product, consumption, investment, cost of living or burden on consumers, and changes in "full-time job equivalents" based on changes in labor wage income. All model outputs are indexed by time, sector, and region.

11. Economic Database and Model Calibration

To model the inter-relationships of sectors in the economy, the model relies on a social accounting matrix (SAM), an economic database that portrays a snapshot of the economy in equilibrium. The N_{ew}ERA macroeconomic model uses the IMPLAN 2008 database as the benchmark data, which includes regional detail on economic interactions among 440 economic sectors.

The benchmark data is used to simulate forward a balanced dynamic equilibrium over the model time horizon. To calibrate the dynamic equilibrium, we adjust the benchmark data each year to incorporate forecasts in macroeconomic indices including GDP, sector output, population, energy use and carbon emissions. In this study, forecasts are drawn from the EIA's AEO 2021 Reference case.

E. Integrated NewERA Model

The N_{ew}ERA modeling framework fully integrates the macroeconomic model and the electric sector model so that the final solution is a consistent equilibrium for both models and thus for the entire U.S. economy.

We solve the integrated N_{ew}ERA model iteratively using a block decomposition method developed by Böhringer and Rutherford[36] using the Mathematical Programming System for General Equilibrium

[35] "The United States' Corporate Income Tax Rate is Now More in Line with Those Levied by Other Major Nations," February 12, 2018 (available at https://taxfoundation.org/us-corporate-income-tax-more-competitive/).

[36] Böhringer, Christoph, and Thomas F. Rutherford. "Combining top-down and bottom-up in energy policy analysis: a decomposition approach." ZEW-Centre for European Economic Research Discussion Paper 06-007 (2006).

(MPSGE) modeling framework[37] in GAMS.[38] The top-down macroeconomic model solves for equilibrium prices throughout all sectors, while the bottom-up model solves for equilibrium quantities in the electricity sector. The solution process is iterated until key prices and quantities converge.

To analyze a policy scenario, the system first solves for a consistent baseline solution between the two models. To obtain the baseline solution, the electric sector model is solved first under projections on electricity demand and energy prices. The equilibrium solution provides baseline electricity demand and supply by region, as well as the inputs—capital, labor, energy, and materials— used for production in the electric sector. These solution values are saved and passed on to the macroeconomic model.

Holding fixed electricity supply and intermediate goods consumption obtained from the electric sector model, the macroeconomic model solves for its baseline solution under the same energy price forecasts used to solve the electric sector baseline. In addition to energy price forecasts, the macroeconomic model's non-electric energy sectors are calibrated to exogenous target forecasts (e.g., EIA's latest AEO forecast) that include projections on energy consumption, energy production, and macroeconomic growth. The macroeconomic model solves for equilibrium prices and quantities in all model markets, subject to these exogenous forecasts.

After establishing baseline results, the integrated N_{ew}ERA modeling system solves for the counterfactual scenario. First the electric sector model reads in the scenario definition (often relative to the baseline) and solves for the equilibrium level of electricity demand, electricity supply, and inputs used by the electric sector (i.e., capital, labor, energy, emissions permits). Again, the electric sector model passes these equilibrium solution quantities to the macroeconomic model, which solves for the equilibrium prices and quantities in all markets. In turn, the macroeconomic model passes on to the electric sector model the following elements:

- Electricity prices by region;
- Prices of non-coal fuels used by the electric sector (*e.g.*, natural gas and oil); and
- Prices of any permits that are tradable between the non-electric and electric sectors (*e.g.*, carbon permits under a nationwide greenhouse gas cap-and-trade program).

The electric sector model then solves for the new electric sector equilibrium, taking the prices from the macroeconomic model as exogenous inputs. The models iterate—prices being sent from the macroeconomic model to the electric sector model, and quantities being sent from the electric sector model to the macroeconomic model—until the prices and quantities in the two models differ by less than a fraction of a percent.

This decomposition algorithm allows the N_{ew}ERA model to retain high-dimensional model details of the electricity model, while also considering impacts – to and from – the rest of the economy. N_{ew}ERA's

[37] Rutherford, Thomas F. "Applied general equilibrium modeling with MPSGE as a GAMS subsystem: An overview of the modeling framework and syntax." *Computational Economics* 14.1-2 (1999): 1-46.

[38] Brooke, A., Kendrick, D., Meeraus, A., Raman, R., & America, U. (1998). The general algebraic modeling system. GAMS Development Corporation, 1050.

detailed electricity sector model allows for the simulation and analysis of current regulatory policies imposed on the electricity sector at the generation unit level.

APPENDIX II. BASELINE AND SCENARIO INPUT ASSUMPTIONS

A. Baseline Modeling Assumptions

The NewERA baseline for this analysis was calibrated to match projections developed by Federal government agencies, notably those of the EIA as defined in its *Annual Energy Outlook 2021* (hereafter referred to as *AEO 2021*) Reference case.[39] This baseline includes the effects of continuing implementation of energy and environmental regulations that have already been promulgated (e.g., the Regional Greenhouse Gas Initiative (RGGI), the California GHG cap-and-trade program, federal vehicle fuel economy standards, federal appliance energy efficiency standards, and state renewable portfolio standards).

1. Fuel Prices

The references for assumptions related to fuel prices are presented in Table 7 below.

Table 7: References for Fuel Price Assumptions

Assumption	Description
Natural gas (Henry Hub), Distillate fuel oil price and Biomass trajectories	AEO 2021, EIA, Reference Case[40]
Natural gas basis differentials	EPA IPM Power Sector Modeling Platform Reference Case [41]

2. Technology Cost Assumptions

The references for assumptions related to technology capital costs are presented in Table 8 below.

Table 8: References for Technology Capital Costs

Assumption	Description
Cost characteristics of existing generating units	S&P Capital IQ Pro, S&P Global Market Intelligence[42]
Cost characteristics of new fossil, nuclear, and renewable electric generating units	Cost and Performance Characteristics of New Central Station Generating Technologies, AEO 2021, EIA [43,44]

[39] U.S. Energy Information Administration, *Annual Energy Outlook 2021*, February 2021 (available at https://www.eia.gov/outlooks/aeo/).

[40] U.S. Energy Information Administration, *Annual Energy Outlook 2021*, February 2021 (available at https://www.eia.gov/outlooks/aeo/).

[41] EPA's Power Sector Modeling Platform v6 using IPM January 2020 Reference Case (available at https://www.epa.gov/airmarkets/epas-power-sector-modeling-platform-v6-using-ipm-january-2020-reference-case).

[42] S&P Capital IQ Pro, S&P Global Market Intelligence (available at https://www.spglobal.com/marketintelligence/en/solutions/sp-capital-iq-pro).

[43] Cost and Performance Characteristics of New Generating Technologies, *Annual Energy Outlook 2021*, February 2021 (available at https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf).

[44] Except for new Biomass with CCS (BECCS) generating units in California and for new geothermal units in California and the rest of the U.S.

Regional cost factors for new fossil, nuclear, and renewable electric generating units	Total Overnight Capital Costs of New Electricity Generating Technologies by Region, AEO 2021, EIA[45]
Cost characteristics of new biomass with CCS generating units in California	Morris et al. (2019) [46]
Cost characteristics of new geothermal generating units in California	EPA IPM Power Sector Modeling Platform Reference Case[47]
Cost characteristics of direct air capture (DAC) units in California	Low: Pradhan et al. (2021) [48]; High: Keith et al. (2018) [49]

3. CO_2 Emissions

The references related to the assumptions for the baseline CO_2 emission inputs are presented in Table 9 below

Table 9: References for Baseline CO_2 Emissions

Assumption	Description
Baseline non-electric sector CO_2 emissions forecast for California	California 2000-2019 GHG Inventory (2021 Edition), CARB[50]; BAU Reference GHG Emission Projections, Draft 2022 Scoping Plan, CARB[51]
Baseline non-electric sector CO_2 emissions forecast for Rest of the U.S.	AEO 2021, EIA, Reference Case [52,53]

[45] Total Overnight Capital Costs of New Electricity Generating Technologies by Region, Assumptions to the Annual Energy Outlook 2021: Electricity Market Module, *Annual Energy Outlook 2021*, February 2021 (available at https://www.eia.gov/outlooks/archive/aeo21/assumptions/pdf/electricity.pdf).

[46] Morris et al. (2019). Representing the costs of low-carbon power generation in multi-region multi-sector energy-economic models. *International Journal of Greenhouse Gas Control*, *87*, 170-187.

[47] EPA's Power Sector Modeling Platform v6 using IPM January 2020 Reference Case (available at https://www.epa.gov/airmarkets/epas-power-sector-modeling-platform-v6-using-ipm-january-2020-reference-case).

[48] Pradhan et al. (2021). Effects of Direct Air Capture Technology Availability on Stranded Assets and Committed Emissions in the Power Sector. *Frontiers in Climate, 3:660787*.

[49] Keith et al. (2018). A Process for Capturing CO_2 from the Atmosphere. *Joule*, *2*(8), 1573-1594.

[50] California Greenhouse Gas Emissions for 2000 to 2019, California Air Resources Board (available at https://ww2.arb.ca.gov/ghg-inventory-data).

[51] 2022 Scoping Plan Documents, California Air Resources Board (available at https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents).

[52] U.S. Energy Information Administration, *Annual Energy Outlook 2021*, February 2021 (available at https://www.eia.gov/outlooks/aeo/).

[53] The non-electric CO_2 emissions represented in the NewERA model includes CO_2 emissions from fossil fuel combustion and process CO_2 emissions from the industrial sector (which relate to emissions from the chemical transformation of raw materials). Non-CO_2 emissions as well as CO_2 emissions that relate to fugitive emissions from oil and gas production and processing, emissions from flaring and feedstock emissions are not explicitly modeled in the NewERA modeling framework.

The baseline CO_2 emissions forecast for the electric sector in California and for the rest of the U.S. are exogenous outcomes of the NewERA electricity sector model.

4. Renewable Portfolio Standards

For the baseline, we assume the RPS specification in California to be 60% by 2045 consistent with the assumption for the reference baseline per the SB100 Joint Agency Report.[54] For other regions in the electricity model, the baseline RPS specifications are based on the Lawrence Berkeley National Laboratory's RPS Annual Status Update publication.[55]

5. Electricity and Peak Demand

The references related to the assumptions for the baseline electricity and peak demand are presented in Table 10 below

Table 10: References for Baseline Electricity and Peak Demand

Assumption	Description
Baseline electricity demand	Net Energy for Load Projections, AEO 2021, EIA, Reference Case [56]
Baseline peak demand	Electricity Supply and Demand (2020 Update), NERC [57]

6. Capacity Potential and Build Limits

The references related to the assumptions for capacity potential and annual build limits in the electricity sector model are presented in Table 11 below.

Table 11: References for Capacity Potential and Annual Build Limits

Assumption	Description
Capacity potential	EPA IPM Power Sector Modeling Platform Reference Case [58]

[54] SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future, California Energy Commission, March 2021 (available at https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity). The following resources in California are included under the RPS in the NewERA electricity sector model: Solar Photovoltaic, Concentrated Solar Thermal (Existing only), Onshore Wind, Offshore wind, Solar Photovoltaic with Storage, Onshore Wind with Storage, Geothermal and Small Hydro (Existing facilities smaller than 30 MW).

[55] Lawrence Berkeley National Laboratory, U.S. Renewable Portfolio Standards: 2021 Annual Status Update, Electricity Markets and Policy Group, February 2021 (available at: https://emp.lbl.gov/projects/renewables-portfolio).

[56] U.S. Energy Information Administration, *Annual Energy Outlook 2021*, February 2021 (available at https://www.eia.gov/outlooks/aeo/).

[57] North American Electric Reliability Corporation, *Electricity Supply and Demand (ES&D, 2020* (available at https://www.nerc.com/pa/RAPA/ESD/Pages/default.aspx).

[58] EPA's Power Sector Modeling Platform v6 using IPM January 2020 Reference Case (available at https://www.epa.gov/airmarkets/epas-power-sector-modeling-platform-v6-using-ipm-january-2020-reference-case).

Annual build limits (Natural gas with CCS generating units in California)	An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions, October 2020 [59]; Baik et al. (2022) [60]
Annual build limits (Renewable generating units in California)	CAISO 20-Year Transmission Outlook [61]
Annual build limits (DAC in California)	Getting to Neutral: Options for Negative Carbon Emissions in California, January, LLNL (2020) [62]

7. Transmission Flow Limits and Costs

The assumptions relating to the flow limits and costs associated with electricity transmission between the various regions in the U.S. are drawn from the EPA IPM Power Sector Modeling Platform's Reference Case.[63]

8. Carbon Capture and Storage (CCS) Transport and Storage Costs

The assumptions relating to the transport and storage costs of CO_2 captured at new coal and natural gas plants equipped with CCS are drawn from the EPA IPM Power Sector Modeling Platform's Reference Case.[64]

9. Biofuel Characteristics

The relative cost of biofuels relative to conventional fuels (motor gasoline and diesel) and the assumptions relating to the carbon intensity of biofuels, conversion efficiencies and blend wall assumptions are drawn from CARB's Biofuel Scenario model.[65] The biofuels that can be substituted for gasoline in the model include imported sugar ethanol, corn ethanol, cellulosic ethanol, biomass-to-liquid (BTL) fuel and compressed natural gas (CNG). For the diesel market, we include bio-diesel from waste grease and corn, CNG and BTL diesel.

10. Low Carbon Fuel Standard (LCFS)

The LCFS sets annual carbon intensity (CI) standards or benchmarks for gasoline, diesel, and the fuels that replace them.[66] Under the current LCFS regulation, the benchmarks for gasoline and

[59] Energy Futures Initiative and Stanford University. An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions, October 2020 (available at https://sccs.stanford.edu/california-projects/opportunities-and-challenges-for-CCS-in-California).

[60] Baik et al. (2022). California's approach to decarbonizing the electricity sector and the role of dispatchable, low-carbon technologies. *International Journal of Greenhouse Gas Control*, 113: 103527.

[61] 20-Year Transmission Outlook, CAISO, January 2022 (available at http://www.caiso.com/InitiativeDocuments/Draft20-YearTransmissionOutlook.pdf).

[62] Lawrence Berkeley National Laboratory, U.S. Renewable Portfolio Standards: 2021 Annual Status Update, Electricity Markets and Policy Group, February 2021 (available at: https://emp.lbl.gov/projects/renewables-portfolio).

[63] EPA's Power Sector Modeling Platform v6 using IPM January 2020 Reference Case (available at https://www.epa.gov/airmarkets/epas-power-sector-modeling-platform-v6-using-ipm-january-2020-reference-case).

[64] *Ibid*

[65] The Biofuel Scenario Model (Draft Version 0.91 BETA), California Air Resources Board (available at https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2017-scoping-plan-documents).

[66] The carbon intensity is expressed in grams of carbon dioxide equivalent per megajoule of energy provided by that fuel. The CI takes into account the GHG emissions associated with all steps of producing, transporting, and

diesel CI are equal to a 6.5 percent reduction relative to 2010, increasing to 20 percent to 2030 and then stays flat post-2030.[67] The data on the initial endowment of LCFS permits are drawn from CARB's LCFS quarterly reports. The most recent data for the endowment of LCFS permits is for Q4 2021 and was reported to be about 9.45 MMT (and is the sum of the previous quarter's banked credits, that quarter's total credits minus any deficits).[68]

11. Combined Heat and Power (CHP) Capacity and Technology Costs

The references for assumptions related to CHP capacity and technology costs are presented in Table 12 below.

Table 12: References for California CHP Capacity and Technology Costs

Assumption	Description
Capacity of existing CHP installations in California	U.S. DOE CHP and Microgrid Installation Database [69]
Cost characteristics of CHP installations	U.S. DOE CHP Technology Fact Sheet Series [70]

12. Transportation Sector Vehicle Cost Markups

Table 13: References for Cost Markups for Electric Vehicles

Assumption	Description
Cost markups for battery-electric vehicles relative to gasoline ICE vehicles (Personal transportation sector)	AEO 2021, EIA, Reference Case [71]
Cost markups for battery-electric and fuel-cell electric H_2 vehicles (Trucking sector)	UC Davis Research Report on Zero-Emissions Medium and Heavy-Duty Vehicle Technologies

consuming a fuel. The LCFS lets the market determine which mix of fuels will be used to reach the program targets. The fuels and fuel blendstocks introduced into the California fuel system that have a CI higher than the benchmark generate deficits. Similarly, fuels and fuel blendstocks with CIs below the benchmark generate credits. Annual compliance is achieved when a regulated party uses credits to match its deficits.

[67] LCFS Basics, Low Carbon Fuel Standard, California Air Resources Board (available at https://ww2.arb.ca.gov/resources/documents/lcfs-basics); California Climate Policy Fact Sheet: Low Carbon Fuel Standard, Center for Law, Energy and the Environment, Berkeley Law (available at https://www.law.berkeley.edu/wp-content/uploads/2019/12/Fact-Sheet-LCFS.pdf).

[68] Low Carbon Fuel Standard Reporting Tool Quarterly Summaries, California Air Resources Board (available at https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries).

[69] Full CHP data set, U.S. Department of Energy Combined Heat and Power and Microgrid Installation Databases, U.S. Department of Energy (available at https://doe.icfwebservices.com/downloads/chp).

[70] Combined Heat and Power Technology, Fact Sheet Series, U.S. Department of Energy (available at https://www.energy.gov/sites/default/files/2017/12/f46/CHP%20Overview-120817_compliant_0.pdf).

[71] U.S. Energy Information Administration, *Annual Energy Outlook 2021*, February 2021 (available at https://www.eia.gov/outlooks/aeo/).

13. Vehicles Miles Traveled and Fuel Economy

The references that relate to vehicle fuel economy and miles traveled are presented in Table 14 below.

Table 14: References for Vehicle Fuel Economy

Assumption	Description
Fuel Economy (Electric Vehicles)	MIT U.S. Regional Energy Policy (USREP) Model [72]
Vehicle Miles Traveled and Fuel Economy (Stock)	EMFAC 2021, April 2021, CARB [73]

14. Generator Retirements and Planned Capacity Additions

The NewERA electricity sector model incorporates the most up-to-date data on the retirement of electric generators and planned capacity additions per the monthly electric generator EIA-860M form.[74] It is assumed that natural gas generators in California remain online for the entirety of the model horizon to meet reliability requirements. [75]

B. Scenario Modeling Assumptions

The following assumptions were incorporated in NewERA to model some of the key elements of the Proposed Scenario (also referred to as "Alternative 3") from CARB's 2022 draft scoping plan.[76]

1. Personal Transportation Sector

- Fuel Economy Standards –ACC I GHG standards for 2017-2025 model years and a 2% annual fuel economy improvement for 2026-2035 model years.[77]

[72] The MIT U.S. Regional Energy Policy (USREP) Model: The Base Model and Revisions (available at https://globalchange.mit.edu/publication/17331).

[73] Emission Factor (EMFAC) Model, California Air Resources Board, Updated April 2021 (available https://arb.ca.gov/emfac/).

[74] Monthly Electric Generator Inventory (based on Form EIA-860M as a supplement to Form EIA-860) (available at: https://www.eia.gov/electricity/data/eia860m/).

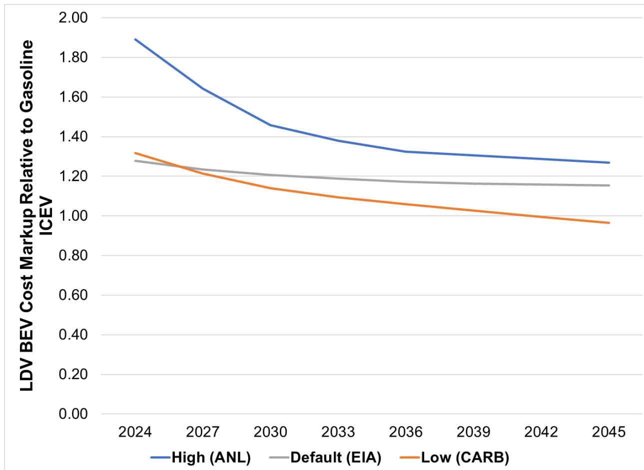
[75] This is consistent with the assumptions that underlie the 38 MMT GHG target for the electricity sector in 2030 in the CARB draft 2022 scoping plan and based on CPUC's 2021 IRP planning cycle. *See* Sections 4.1.4 and 4.1.5, Decision Adopting 2021 Preferred System Plan, February 10, 2022 (available at https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M449/K173/449173804.PDF).

[76] Draft 2022 Scoping Plan Update, California Air Resources Board, May 10, 2022 (available at https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf).

[77] Using data from the April 2021 version of the California Air Resources Board's EMFAC model (available at https://arb.ca.gov/emfac/), the percentage improvement in fuel economy for the LDV stock was calculated to be about 15% by 2050.

- Zero Emission Vehicle (ZEVs) Mandate – 100% of LDV sales are ZEVs by 2035[78, 79]
- Cost markups of BEVs (relative to Gasoline ICE vehicles): Low - ZEV Cost Modeling Workbook, ACC II workshop, CARB, May 2021[80]; High - Argonne National Laboratory (ANL) Total Cost of Ownership Study[81]. Figure 10 presents these LDV sector cost markups for the default, high, and low cases.[82]

Figure 10: Cost Markups of BEVs in the LDV Sector Relative to Gasoline ICE Vehicles



2. Commercial Trucking Sector

- Zero Emission Vehicle (ZEVs) Mandate – 100% of MD/HDV sales are ZEV by 2040[83,84]
- Cost markups of BEVs and FCEVs (relative to Diesel ICE vehicles): Low – CARB Draft Advanced Clean Fleets Total Cost of Ownership Discussion Document[85]; High – NREL

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[78] Governor Newsom's Zero-Emission by 2035 Executive Order (N-79-20) (available at https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf).

[79] Using data from the April 2021 version of the California Air Resources Board's EMFAC model (available at https://arb.ca.gov/emfac/), it was determined that the mandate of 100% ZEV sales by 2035 translates to a share of ZEVs in the LDV vehicle stock of about 92% by 2050. This was the target that was imposed in the NewERA model to implement the ZEV mandate.

[80] "ZEV Cost Modeling Workbook, ACC II workshop, CARB, May 2021", Public Workshop on Advanced Clean Cars II (available at https://ww2.arb.ca.gov/events/public-workshop-advanced-clean-cars-ii-1).

[81] Burnham et al., Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains, April 2021 (available at https://www.osti.gov/biblio/1780970-comprehensive-total-cost-ownership-quantification-vehicles-different-size-classes-powertrains).

[82] The default assumptions are used in the BAU case while the low and the high assumptions are used in the "High Alternative Vehicle Cost" and "Low Alternative Vehicle Cost" sensitivity cases.

[83] AB-74 Budget Act of 2019 (available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200AB74); AB 74 ITS Report (available at https://www.ucits.org/research-project/2179/).

[84] Using data from the April 2021 version of the California Air Resources Board's EMFAC model (available at https://arb.ca.gov/emfac/), it was determined that the mandate of 100% ZEV sales by 2040 translates to a share of ZEVs in the trucking vehicle stock of about 90% by 2050. This was the target that was imposed in the NewERA model to implement the ZEV mandate.

[85] Draft Advanced Clean Fleets Total Cost of Ownership Discussion Document, Advanced Clean Fleets Workshop, September 9, 2021 (available at https://ww2.arb.ca.gov/sites/default/files/2021-08/210909costdoc_ADA.pdf).

Market Segmentation Analysis of Medium and Heavy Duty Trucks with a Fuel Cell Emphasis.[86] Figure 11 and Figure 12 presents these commercial trucking sector cost markups for the default, high, and low cases.[87]

Figure 11: Cost Markups of BEVs in the Commercial Trucking Sector Relative to Diesel ICE Vehicles

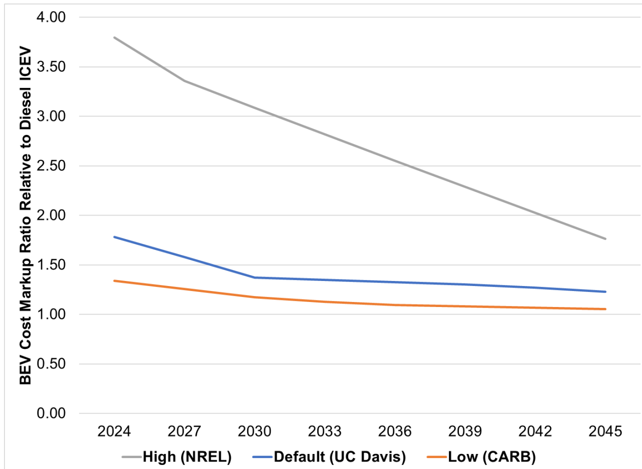
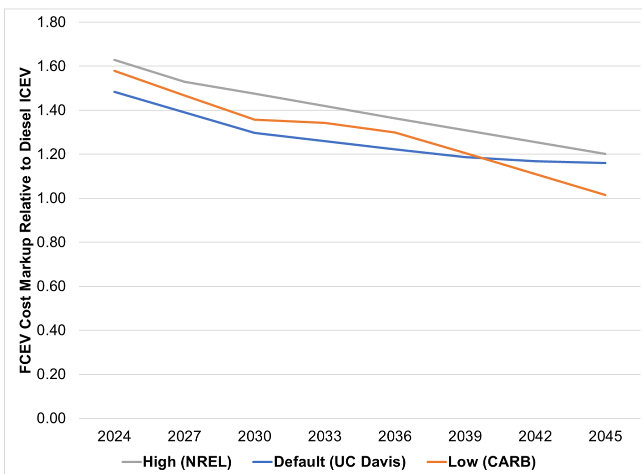


Figure 12: Cost Markups of FCEVs in the Commercial Trucking Sector Relative to Diesel ICE Vehicles



3. Electric Sector

- RPS specification in California requiring 60% of electric retail sales to end-use customers to come from renewable resources by 2030[88]

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[86] Hunter et al., Market Segmentation Analysis of Medium and Heavy Duty Trucks with a Fuel Cell Emphasis, May 31, 2020 (available at https://www.hydrogen.energy.gov/pdfs/review20/sa169_hunter_2020_o.pdf).

[87] The default assumptions are used in the BAU case while the low and the high assumptions are used in the "High Alternative Vehicle Cost" and "Low Alternative Vehicle Cost" sensitivity cases.

[88] Per the specification in Senate Bill No. 100 (available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100). The following resources in California are included under the RPS in the NewERA electricity sector model: Solar Photovoltaic, Concentrated Solar Thermal (Existing only), Onshore Wind, Offshore wind, Solar Photovoltaic with Storage, Onshore Wind with Storage, Geothermal and Small Hydro (Existing facilities smaller than 30 MW).

- SB100 specification in California requiring 100% of electric retail sales to end-use customers to come from renewable and zero-carbon resources by 2045.[89]

4. Energy Efficiency

- The electric energy efficiency targets by sector and the associated avoided costs are drawn from California's Public Utilities Commission's (CPUC) Updated 2021 Energy Efficiency Potential and Goals Study.[90]
- The natural gas efficiency targets by sector are drawn from the California Energy Commission's (CEC) Senate Bill 350 Doubling Energy Savings by 2030 Method Report.[91]

5. Curtailment

The model assumptions that relate to solar and wind curtailment in California were developed using data on solar and wind production and curtailment from CAISO for 2021.[92] The inputs to the model are specified as percentage of generation to be curtailed for different levels of solar and wind penetration percentages by load block.[93,94]

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[89] Per the specification in Senate Bill No. 100 (available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100). In addition to the resources that qualify towards the RPS, , Large Hydro (Existing facilities larger than 30 MW), Nuclear (Existing only) and Natural gas equipped with CCS also qualify towards meeting SB100 requirements in our model. These eligibility criteria are consistent with Attachment B of CARB's 2022 Scoping Plan Scenario Assumptions released as part of the 2022 Scoping Plan Update (available at https://ww2.arb.ca.gov/sites/default/files/2021-12/Revised_2022SP_ScenarioAssumptions_15Dec.pdf).

[90] 2021 Potential and Goals Study, California Public Utilities Commission, July 2021 (available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/energy-efficiency-potential-and-goals-studies/2021-potential-and-goals-study). We specify electric efficiency targets (in units of GWh) and avoided costs (in units of $/MWh) for five sectors: commercial, energy-intensive industrial sectors, other industrial sectors, refineries, and the residential sector. The energy-intensive industrial sectors are comprised of chemicals, paper, primary metals, printing and publishing, stone, glass, and clay manufacturing, and mining. The other industrial sectors are comprised of agriculture, electronics, fabricated metals, food, industrial machinery, lumber and furniture, plastics, textiles, transportation equipment manufacturing and all other industrial sectors.

[91] Senate Bill 350 Doubling Energy Savings by 2030 Method Report, December 2019 (available at https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-IEPR-06). We specify the energy efficiency targets as a percentage improvement in energy intensity versus the BAU case for the building, industrial and residential sectors.

[92] Production and Curtailment Data – 2021, Oversupply and Curtailments, California ISO (available at http://www.caiso.com/informed/Pages/ManagingOversupply.aspx).

[93] Under a typical 8 load block (LB) definition, LB1 and LB2 correspond to the peak and off-peak hours in summer respectively. LB3 and LB4 correspond to the peak and off-peak hours in spring respectively. LB5 and LB6 correspond to the peak and off-peak hours in the fall season. LB7 and LB8 correspond to the peak and off-peak hours in the winter season.

[94] The NewERA model for this study was run in 4 LB mode where each LB is representative of the hours in a season. Under such a load-block definition, the model does not distinguish between on-peak and off-peak hours. Thus, the typical curtailment assumptions described above do not apply in the 4 LB runs that we have carried out for this study.

6. CCS Cost Markups for the Industrial Sector

A. CCS in the Refinery Sector

To model CCS as a technology in the refinery sector, we developed cost markups for capital costs, non-energy (fixed operations and maintenance) costs and fuel (electricity and natural gas) costs that represent the differences in costs between refinery configurations with and without CCS. The data to develop the cost markups were drawn from a SINTEF study on the cost of retrofitting CO_2 capture in an integrated oil refinery[95] and from Chapter 2 of a National Petroleum Council Report presenting a roadmap for the at-scale deployment of carbon capture, use, and storage.[96] The markup for capital costs was estimated to range between 1.34 and 1.56. The markup for non-energy costs was estimated to range between 1.10 and 1.17. The markup for fuel costs was estimated to be 1.23.

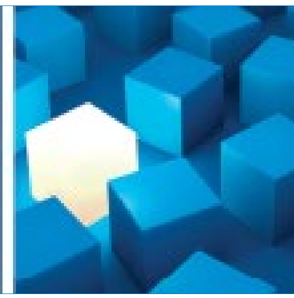
B. CCS in the Energy-Intensive Sectors

To model CCS as a technology in the energy-intensive sectors, we developed cost markups for capital costs, non-energy (labor) costs and fuel (electricity and natural gas) costs that represent the differences in costs between processes in EIS with and without CCS. The data to develop the cost markups were drawn from a paper on the role of CCS in emissions mitigation in hard-to-abate sectors.[97] In this paper, the cost markups were calculated as the difference between the cost input shares that correspond to electricity, natural gas, labor, and capital between a reference plant with no CCS and a plant with natural gas-fired post combustion capture. The cost markup for natural gas use was estimated to be about 16.24 while the markup for electricity use was estimated to be 1.28. The cost markup for labor costs was estimated to be about 1.46 while the markup for capital costs was estimated to be 5.91.

[95] Sigurd Sannan, Kristin Jodal, Simon Roussanaly, Chiara Giraldi, Annalisa Clapis, Understanding the Cost of Retrofitting CO_2 Capture in an Integrated Oil Refinery, Reference Base Case Plants: Economic Evaluation, SINTEF, August 2017 (available at https://www.sintef.no/globalassets/project/recap/deliverable-d3_reference-plants-economic-evaluation_final_code.pdf).

[96] National Petroleum Council Report, Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage, December 2019 (available at https://dualchallenge.npc.org/).

[97] Sergey Paltsev, Jennifer Morris, Haroon Kheshgi, Howard Herzog, Hard-to-Abate Sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation, *Applied Energy* 300 (2021): 117322.



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