DOCKETED	
Docket Number:	19-ERDD-01
Project Title:	Research Idea Exchange
TN #:	243829
Document Title:	SoCalGas Comments - on Communities, Equity, Environmental and Technology Workshops Regarding Long-Term Gas Research Strategy
Description:	N/A
Filer:	System
Organization:	SoCalGas
Submitter Role:	Public
Submission Date:	7/1/2022 1:45:41 PM
Docketed Date:	7/1/2022

Comment Received From: SoCalGas
Submitted On: 7/1/2022
Docket Number: 19-ERDD-01

Comments on Communities, Equity, Environmental and Technology Workshops Regarding Long-Term Gas Research Strategy

Additional submitted attachment is included below.

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July 1, 2022

Jonah Steinbuck, Deputy Director
Research and Development Division
California Energy Commission
Docket Unit, MS-4
Docket No. 19-ERDD-01
715 P Street
Sacramento, CA 95814-5512

Subject: Comments on Communities, Equity, Environmental and Technology Workshops Regarding a Long-Term Gas Research Strategy to Achieve Aggressive Statewide Carbon Neutrality Goals

Dear Deputy Director Steinbuck:

Southern California Gas Company (SoCalGas) appreciates the opportunity to comment on the Communities, Equity, Environmental and Technology Workshops Regarding Establishing a Long-Term Gas Research Strategy to Achieve Aggressive Statewide Carbon Neutrality Goals, held on June 9, 2022, and June 16, 2022, respectively. California needs long-term strategies that utilize both clean molecules and clean electrons to help reach the State's 2045 carbon neutrality goals. Natural gas distribution companies or gas utilities are an important component to enable this transition. We appreciate the thoughtful approach that has led to the long-term research strategy for gas use and offer the following comments grouped into six categories:

(1) SoCalGas' top priority is the safety of the gas system, our employees who operate and maintain it, our customers that rely on it, and the public;
(2) The CEC should continue to explore Renewable Natural Gas (RNG), which has the ability to improve local air quality today and can be carbon-negative;
(3) Converting forest waste to energy can cut harmful climate pollutants compared to controlled burns or wildfires;
(4) A longer-term focus on attracting federal funding opportunities that are consistent with the goals of the Natural Gas R&D Program will achieve greater benefits for ratepayers;
(5) Including a long-term research emphasis on hydrogen hub initiatives will enable California to expand the tools available to achieve ambitious climate goals in a safe, reliable, and resilient manner; and,

(6) Carbon Capture, Utilization, and Storage (CCUS) is an important emissions reduction technology that can be applied across the California energy system, and policymakers must consider how to maximize existing assets suited for carbon storage.

1) SoCalGas' top priority is the safety of the gas system, our employees who operate and maintain it, our customers that rely on it, and the public.

In this section we answer the following: Do you have any other general feedback or areas you would like us to consider?

SoCalGas prioritizes the safety of its natural gas system, our employees who maintain the natural gas infrastructure, our customers who rely on the system to serve their energy needs, and the public. Odorizing gas for the detection of potential leaks is an important component of SoCalGas's safety plan. SoCalGas is engaged in important research to understand the implications of hydrogen blending and pure hydrogen transportation on these safety outcomes and on the pipeline infrastructure's materials and components. SoCalGas is participating with different research consortia and collaborative efforts to perform the research needed to maintain the safety, reliability, and integrity of the system. For example, the NYSEARCH project "Odor Detection Study for Blended Hydrogen (M2021-005)" is a study investigating natural gas odorants for detectability and recognizability when hydrogen, at various concentrations, is present. SoCalGas will use the results to determine any necessary adjustments of odorants in hydrogen to maintain the ability of employees and consumers to detect gas leaks. More information on the research projects that are underway can be found in the SoCalGas 2021 RD&D Annual Report.[1]

During the June 16 Technology Workshop, certain workshop attendees asserted that hydrogen has the potential to leak more than natural gas. SoCalGas respectfully requests to understand if the CEC has conducted a literature review of this topic. SoCalGas is keenly interested in maintaining the highest level of system integrity, for safety and environmental concerns. SoCalGas research efforts have identified very little scholarship in this area, with the most recent research suggesting that Hydrogen and Natural Gas leak at similar rates in low pressure distribution systems, but that more research is warranted in this area.[2] Research on this topic could prove to be valuable, in terms of the long-term decarbonization of the gas system.

2) The CEC should continue to explore Renewable Natural Gas (RNG), which has the ability to improve local air quality today and can be carbon negative.

In this section we answer the following: Is there anything else you want us to consider?

During the June 9 CEC Communities, Equity, and Environmental Workshop Regarding Establishing a Long-Term Gas Research Strategy to Achieve Aggressive Statewide Carbon Neutrality Goals, a representative from Central California Environmental Justice Network (CCEJN) highlighted concerns regarding the release of criteria pollutants from trucks that are

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[1] *See* SoCalGas 2021 Annual Report, available at: https://www.socalgas.com/sites/default/files/2021%20SoCalGas%20RD%26D%20Annual%20Report.pdf

[2] *See* Hydrogen leaks at the same rate as natural gas in typical low-pressure gas infrastructure, Mejia et. al., Mar 2020, available at: https://www.sciencedirect.com/science/article/abs/pii/S0360319919347275?via%3Dihub

transporting biomass to gasification facilities in the process of creating renewable natural gas (RNG).[3] The implication of this assertion is that these emissions could impact communities of concern.

SoCalGas is supportive of reducing greenhouse gas (GHG) emissions and improving local air quality. Heavy-duty trucks fueled with RNG provide the most effective benefit-cost for achieving decarbonization and addressing public health and air quality benefits by reducing short-lived climate pollutants (SLCPs), greenhouse gas (GHG), diesel, and nitrogen oxide (NOx) emissions.[4] Recognizing this, Senator Bob Wieckowski, at the Senate Budget and Fiscal Review Subcommittee on the Zero-Emission Vehicle Package, asked California Air Resources Board (CARB) and CEC representatives, "shouldn't [the State] consider short-term solutions for immediate emission reductions today?"[5] SoCalGas submits that in the public interest the answer should be in the affirmative. One short-term solution the CEC should consider is replacing traditional diesel or gasoline with RNG to fuel heavy-duty trucks, because RNG trucks are commercially available today and capable of replacing diesel-fueled heavy-duty trucks on a one-for-one basis at scale. Further, switching to cleaner fuels for use in heavy-duty trucks can significantly reduce NOx, particulate matter, and GHG emissions, providing immediate air quality and climate benefits to all communities, including communities of concern.

In 2020, RNG used as a transportation fuel lowered GHG emissions equivalent to taking approximately 760,000 passenger vehicles off the road or reducing CO_2 emissions from approximately 394 million gallons of gasoline consumed.[6] A benefit of RNG fuel often overlooked is that it can be derived from waste produced by industrial and agricultural activities including landfills, animal manure, and solid waste. Landfills are a leading source of methane emissions, and the decomposition of organic waste in landfills recently accounted for 21 percent of statewide methane emissions.[7] RNG fuel production can capture and allow the productive use of methane that would otherwise escape into the atmosphere.[8] A recent assessment conducted by Gladstein Neandross & Associates (GNA) studied the existing and developing RNG production capacity in California for use in motor vehicles to provide policy makers with a more accurate and data-driven estimate for the total volume of RNG that will be produced in-state and made available for

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[3] *See* CEC Communities, Equity, and Environmental Workshop Regarding Establishing a Long-Term Gas Research Strategy to Achieve Aggressive Statewide Carbon Neutrality Goals **held on** June 9, 2022, available at: https://energy.zoom.us/rec/share/rrulgEy1UjljDT94nSG23gK4APW17lyVzJCRaOMjl4NnwrIU-0_ujQ9_SnEB6zC_.G7FHuj495tKl_kmu

[4] *See* SoCalGas Comments – on the 2021-2023 Investment Plan update for the Clean Transportation Program, California Energy Commission (CEC) Docket 21-ALT-01, September 30, 2021, available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=239890&DocumentContentId=73331.

[5] *See* Legislative Analyst Office comments on Zero-Emission Vehicle Package for the Senate Budget and Fiscal Review Subcommittee Number 2 Hearing held March 2, 2022, at page 10, available at https://sbud.senate.ca.gov/sites/sbud.senate.ca.gov/files/Sub%202%20Agenda%203.2%20Final.pdf.

[6] *See* "Decarbonize Transportation with Renewable Natural Gas," RNG Coalition and NGV America, April 2021, available at: https://ngvamerica.org/wp-content/uploads/2021/04/Decarbonize-Transportation-with-RNG-Updated-April-16-2021.pdf.

[7] *See* CARB 2022 Scoping Plan Update – Short-Lived Climate Pollutants Workshop Presentation on September 8, available at: https://ww2.arb.ca.gov/sites/default/files/2021-09/carb_presentation_sp_slcp_september2021_0.pdf.

[8] *See* "What Is Renewable Natural Gas," American Geoscience Institute, 2022, available at: https://www.americangeosciences.org/critical-issues/faq/what-renewable-natural-gas

transportation use by California fleet operators in the near term.[9] The study asserts that "[i]f California were to adopt policies to encourage the purchase and deployment of new near zero emission (NZE) natural gas trucks to consume this new California-derived, carbon negative, diesel displacing clean fuel, the environmental benefits would be significant."[10]

3) Converting forest waste to energy can cut harmful climate pollutants compared to controlled burns or wildfires.

In this section we answer the following: Have we missed any key considerations from our conversation thus far?

Currently, the State employs various wildfire management techniques and is considering prescribed burning (i.e., burning small pockets of biomass in a controlled setting to create fuel breaks) as a key strategy for climate resilience and reduced wildfire risk in the draft scenarios for the 2022 Scoping Plan Update.[11]

One avenue the State could consider as an alternate wildfire mitigation tool is to convert biomass fuel into renewable fuels for use in the transportation sector. CARB estimated in 2020 that wildfires consumed about 81.1 million short tons of fuel which emitted over 100 million metric tons of CO_2 and approximately 1.4 million tons of particulate matter (PM).[12] The attached Ramboll analysis found that converting 1,000 acres of forest biomass into renewable fuels for the transportation sector can reduce non-biogenic GHG emissions by 90 percent compared to prescribed burning. As such, this avenue could avoid direct GHG and SLCP emissions and offset GHG emissions from the use of fossil fuels for transportation.

4) A longer-term focus on attracting federal funding opportunities that are consistent with the goals of the Natural Gas R&D Program will achieve greater benefits for ratepayers.

In this section we answer the following: Do you have any other areas you would like us to consider?

The larger the amount of research & development (R&D) resources we have available upfront for California to utilize, the better positioned California will be to achieve our net-zero climate commitments. According to the CEC's 2020 Natural Gas R&D Final Report, the program has provided on average an estimated $65 million per year in energy cost savings,[13] more than 30

[9] *See* An Assessment: California's In-State RNG Supply for Transportation 2020-2024, GNA, available at: https://cdn.gladstein.org/pdfs/whitepapers/report-assesment-california-in-state-rng.pdf
[10] *See* An Assessment: California's in-state RNG supply for transportation 2020 -2024, at p.5.
[11] "Natural and Working Lands Scoping Plan Draft Alternative Scenarios," California Air Resources Board, December 2021. Available at https://ww2.arb.ca.gov/sites/default/files/2021-12/NWLScenariosForPublicDistribution.pdf.
[12] *See* "Wildfire Emission Estimates for 2020," California Air Resources Board, July 2021, at pg. 1.
[13] For example, CEC-funded projects on high-efficiency hot water systems in commercial food service, and if the recommendations are implemented by 12% of the food service facilities, that could result in an annual energy reduction of about 23 million therms, with an associated reduction of 133,000 tons of CO2. The annual energy cost reduction translates to about $23 million

commercialized technologies, and approximately 9,000 publications referencing research results from CEC-funded natural gas projects over the years.[14]

Companies developing clean energy technologies often rely on several sources of funding, including private and public sources to support technology development and deployment. Providing match funding or cost share opportunities, such as through the CEC's Cost Share for Federal Clean Energy Funding Opportunities, would enable stakeholders to leverage available funding and maximize opportunities for clean energy research through the Natural Gas R&D Program. Similar to how cost-sharing is positioned to complement the Electric Program Investment Charge (EPIC) 2021–2025 Investment Plan, match funding should be set aside for federal dollars that are aligned with the initiatives set forth in the Natural Gas R&D Program.[15] The Natural Gas R&D Program[16] established a baseline of funding and has remained at $24 million in the last several years, which has not kept up with inflation. For a long-term gas research program, the CEC should consider whether this amount of funding is sufficient and explore opportunities to increase funding for public interest energy research. It is also in the public interest to utilize the limited Natural Gas R&D funding to attract more capital from the federal government via cost share grants.

5) Including a long-term research emphasis on hydrogen hub initiatives will enable California to better position itself to achieve ambitious climate goals.

In this section we answer the following: Are there any technologies or decarbonization strategies that we have not identified?

By aligning with the national strategy that focuses on various hydrogen pathways including the development of hydrogen hubs and sector focused research and development directives, California better positions itself to achieve its ambitious climate goals and to be a leader in solutions that may be replicated across the nation.[17] In other words, an integrated energy solution, which includes various forms of clean energy and technologies, will provide more options, configurations, and potential synergies for all stakeholders (regulated utilities, private and public companies, local, state, and federal organizations, and policymakers) to learn from, refine assumptions, and make more informed decisions.

To provide some informative international examples, the Humber industrial cluster in Yorkshire is the United Kingdom's (U.K.'s) largest cluster by industrial emissions, emitting 10 million tons

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[14] *See* 2020 Natural Gas Research & Development Program, Annual Report, July 1, 2019 – June 30, 2020, CEC, available at: https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-073.pdf

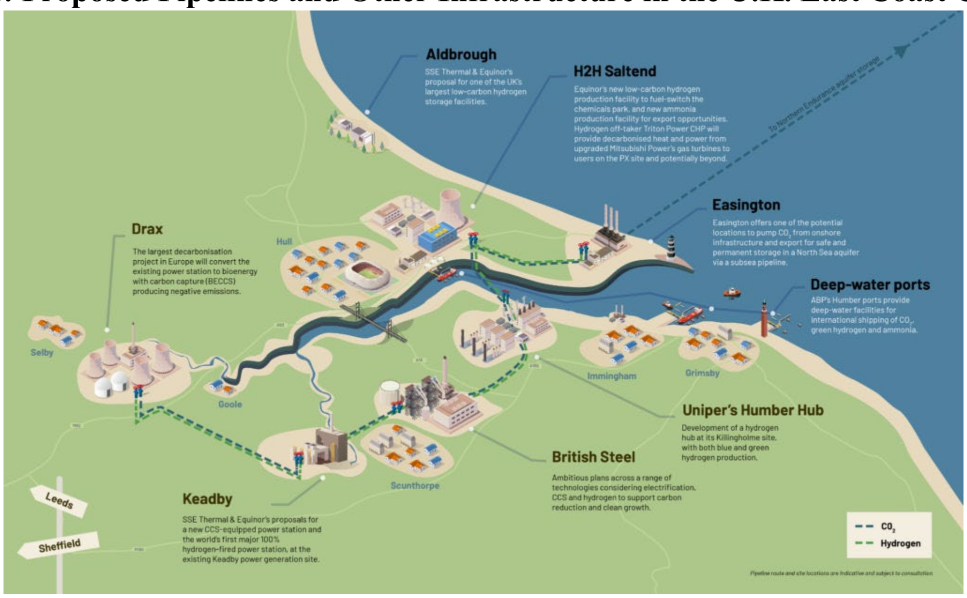
[15] *See* EPIC 2021-2025 Investment Plan, Commission Final Report, available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=240609

[16] The Natural Gas Research and Development program funds the development and deployment of improved natural gas technologies and practices. Established by the CPUC in 2004, pursuant to Assembly Bill 1002, the program is administered by the California Energy Commission (CEC's) R&D Division.

[17] *See* Department of Energy Hydrogen Program Plan, U.S. DOE, available at: https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf

of CO_2 per year, more than two percent of the U.K.'s total greenhouse gas (GHG) emissions.[18] Primary industries include steel, chemicals, cement, and oil refineries. Zero Carbon Humber[19] aims to establish the world's first net-zero industrial cluster by 2040 via the creation of Carbon Capture and Storage (CCS) infrastructure and the production of blue and green hydrogen. There will be three major areas of project work: (1) develop a carbon-capture usage and storage network; (2) produce low-carbon hydrogen and create shared hydrogen infrastructure; and (3) in the longer term, produce green hydrogen using offshore wind electrolysis. Hydrogen to Humber (H2H) Saltend will be the first mover in utilizing the shared CO_2 and hydrogen transport and storage infrastructure. This will eventually enable multiple carbon abatement projects in the region to scale quickly to achieve net-zero targets for the cluster, and U.K. industrial users will be able to reduce emissions by capturing carbon and transporting it via shared pipelines for offshore storage, as depicted in Figure 2 (below). Access to shared hydrogen infrastructure will spur demand for use as feedstock in industrial processes and enable the potential for further use outside the cluster.

Figure 2: Proposed Pipelines and Other Infrastructure in the U.K. East Coast Cluster[20]

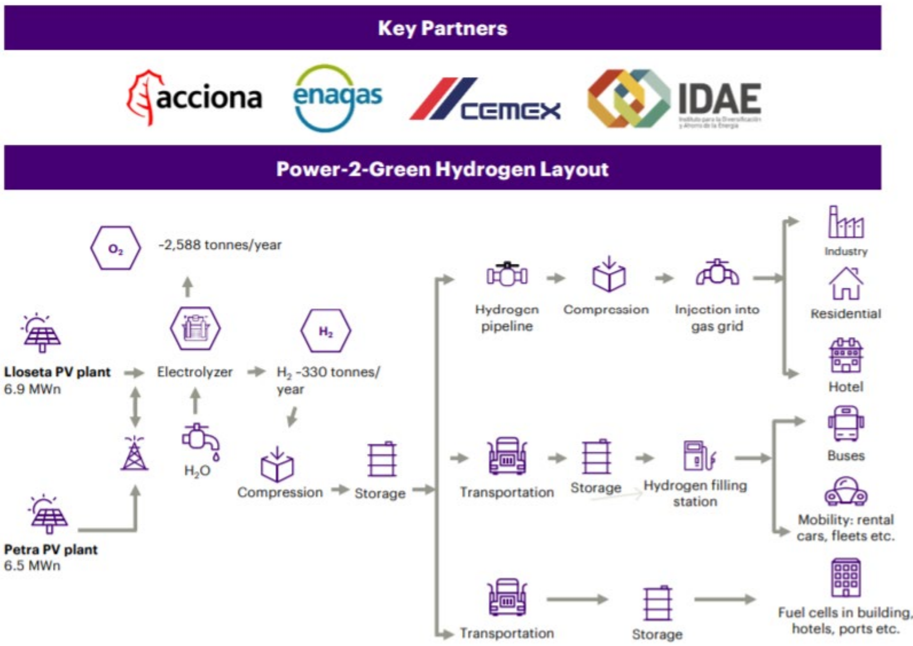


As another example, Majorca Green Hydrogen, Power-2-Green Hydrogen,[21] project aims to pioneer a solution for island GHG emissions reduction and industrial reconversion on the island of Majorca, Spain. The Power-2-Green Hydrogen is planned as a revitalization project for the town of Lloseta in Central Majorca, which has been significantly impacted by the end of cement production, a major employer in the area. The project consists of two solar PV plants making up more than 13 MW of combined generation capacity and a 2.5 MW polymer electrolyte membrane (PEM) electrolyzer. The output from the electrolyzer will support multiple end-use applications:

[18] *See* Industrial Clusters, Working together to achieve net zero, Accenture, p. 27, available at: https://www.accenture.com/_acnmedia/PDF-147/Accenture-WEF-Industrial-Clusters-Report.pdf.
[19] *See* Zero Carbon Humber: Delivering Our Net Zero Future, ZCH, available at: https://www.zerocarbonhumber.co.uk/the-vision/.
[20] *See* "What a Zero Carbon Humber would look like," available at: https://www.zerocarbonhumber.co.uk/.
[21] *See* Power to Green Hydrogen Mallorca, available at: https://www.acciona.com/projects/power-to-green-hydrogen-mallorca/.

Powering part of the island's public transportation fleet; green hydrogen injected into the gas grid to supply industrial parks; and as backup energy for buildings (public buildings, ports, hotels, etc.). Figure 3 (below) shows the key partners for the project as well as an initial layout.

Figure 3: Green Hydrogen Schematic for the Majorca Cluster[22]



Again, hydrogen hub research and development have important intersections with jobs, equity and technological diversity within the State of California and has the potential to positively impact low-income and disadvantaged communities in which those hard-to-abate sector activities are located. According to a recent report by California 100 on policies and future scenarios, zero-carbon technologies are emerging but have been slow to commercialize or reach hard-to-decarbonize sectors such as steel, cement, agriculture, and aviation; [23] addressing research and development efforts to coordinate with federal funding to support a hydrogen hub in California will likely produce real societal climate benefits, and particularly for communities of concern.

6) **Carbon Capture, Utilization, and Storage (CCUS) is an important emissions reduction technology that can be applied across the California energy system, and policymakers must consider how to maximize existing assets and reduce stranded assets.**

In this section we answer the following: Are there any technologies that we have not identified?

[22] *Ibid.*

[23] *See* California 100, The Future of Energy, Environment, and Natural Resources, A California 100 Report on Policies and Future Scenarios, Mar 2022, available at: https://california100.org/app/uploads/2022/03/The-Future-of-Energy-Environment-and-Natural-Resources-ISSUE-REPORT-Single-pages-Round-3.pdf

a) **Carbon Capture, Utilization, and Storage (CCUS) is an important emissions reduction technology that can be applied across the California energy system.**

California can continue its climate leadership by becoming a more attractive location for federal funding opportunities.[24,25] To strengthen California's "toolbox" to decarbonize the energy ecosystem, an incremental and separate provision of the Infrastructure Investment and Jobs Act (IIJA) specifically allocates over $12 billion[26] to CCUS opportunities. This funding may result in accelerated advancement of other promising technologies that, once scaled, could favorably impact decarbonization efforts.

On June 9, workshop participants raised potential issues regarding groundwater and drinking water. Groundwater management concerns are critical in California and all potential CCUS projects would adhere to state regulations governing groundwater. It is critical to adhere to all California state regulations governing oil and gas operations and groundwater to provide the greatest level of safety.[27]

b) **Policymakers must consider how to maximize existing assets suited for carbon storage.**

From an asset perspective, policymakers should consider how to maximize existing assets by repurposing them in the context of carbon capture technologies. Once the leading U.S. oil producer, California encompasses many depleted oil and gas fields well suited for carbon storage. The State is also rich in geologic assets suited for carbon storage. Serpentinite, the state rock, can store carbon via enhanced weathering, a natural process that traps CO_2 over geologic time. California is home to numerous industries—chemicals, transportation fuels, steel, cement, plastics, and rubber products—that rely on energy-intensive production processes and emit correspondingly large quantities of CO_2. Many of these industries are vital to the modern economy. However, they

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[24]During the CEC Business Meeting held on January 13, 2022, Commissioner Monahan stated she would lead an effort to try to direct federal funding from the U.S. Department of Energy (DoE) infrastructure bill towards California's Clean Transportation Program. Considering a more inclusive definition of "clean hydrogen", based on carbon intensity instead of color, could make it easier for California to align with federal requirements.

[25] *See* "Meeting of the California Energy Commission," CEC, January 13, 2022, available at: https://www.energy.ca.gov/event/meeting/2022-01/meeting-california-energy-commission.

[26] *See* "Carbon Utilization Research Council (CURC) Welcomes House Passage of Infrastructure Investment and Jobs Act," CURC, available at: http:/www.curc.net/curc-welcomes-house-passage-of-infrastructure-investment-and-jobs-act.

[27] All wellbores in the state are required to have an identified depth for the base of fresh water (BFW)—equivalent to water with less than 3,000 ppm total dissolved solids—and underground source of drinking water (USDW)—less than 10,000 ppm total dissolved solids. Depths of these levels vary by formation, but layers targeted for injection would typically target below both zones to avoid permitting requirements and interference with drinking water supplies. CO2 sequestration projects that target storage below these zones will incorporate good cement barriers in the wells to prevent contamination of these shallower zones. Repurposed wells will be evaluated for cement quality at depths where leakage to groundwater could occur. Moreover, geologic logs from new wells can be correlated to neighboring wells to determine BFW and USDW, helping ensure wells are properly encased and cemented at these respective zones. During operation, CO2 injection wells, the formations they target, and overlying formations would need to be carefully monitored and evaluated. Borehole fiberoptics, temperature and pressure sensors, monitoring wells, or other monitoring and data collection facilities and equipment would be deployed to rapidly identify any potential leaks into adjacent formations. Regular monitoring would detect any need for repairs or replacement.

contribute approximately 21 percent of California's total GHG emissions[28] and are hard to electrify. For California to meet its decarbonization goals and lead the clean energy transition, all available solutions to tackling these industrial emissions must be pursued. Using CCUS, facilities can capture CO2 emissions and permanently store them. According to researchers at Stanford University, CCUS could enable these industries to rapidly decarbonize while continuing to make major contributions to the State's economy and helping it meet its near-term and mid-century climate targets.[29]

California's abundance of favorable geology, depleted oil and gas fields, and heavy industry presence only paint part of the picture. Thousands of people work in the State's oil and gas industries[30] and have the skills and capabilities required to manage and operate large CCUS facilities and pipelines. The state is also home to some of the world's leading national laboratories and universities—including Lawrence Livermore National Laboratory (LLNL), Stanford University, and the University of California system—many of which dedicate considerable intellectual power and resources to solving the climate crisis. Their efforts would stall, however, without investment capital.

Conclusion

In closing, we appreciate the opportunity to comment on the long-term strategy for gas use in California and support the CEC's continued efforts to advance research and development on the transition to clean energy solutions statewide. Advancing decarbonization goals by deploying available technologies today is critical to achieving California's climate and air quality goals. In addition, we reiterate that SoCalGas is committed to the safety of the natural gas system, the employees who operate and maintain the natural gas system, customers who use the natural gas pipeline, and the public. We are engaged in research regarding the implications of hydrogen blending and pure hydrogen transportation. We look forward to working with CEC Staff in establishing a long-term gas research strategy that will positively affect the public interest.

Respectfully,

/s/ Kevin Barker

Kevin Barker
Senior Manager
Energy and Environmental Policy

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[28] *See* California Greenhouse Gas Emissions for 2000 to 2019, Trends of Emissions and Other Indicators, available at: https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf
[29] *See* An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions at S1.
[30] *See* Shannon M. Sedgwick, Tyler Laferriere, Eric Hayes, Somjita Mitra, Ph.D., "Oil And Gas In California: The Industry, Its Economic Contribution and User Industries at Risk In 2017," Los Angeles County Economic Development Corporation, July 2019, available at: https://laedc.org/2019/08/27/oil-and-gas-industry-in-california-2019-report/

RAMBOLL

ENVIRONMENT
& HEALTH

MEMORANDUM

To: Kevin Barker
Southern California Gas Company

From: Sheetal Madnani, Akshay Ashok, Varalakshmi Jayaram, and Julia Lester
Ramboll US Consulting, Inc.

Subject: **COMPARING EMISSIONS FROM PRECRIBED BURN OF WOODY BIOMASS TO EMISSIONS FROM CONVERSION OF WOODY BIOMASS TO RENEWABLE FUEL**

January 27, 2022

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INTRODUCTION

A key strategy towards achieving the goal of carbon neutrality set out in California Air Resources Board's (CARB's) 2022 Scoping Plan is the management of California's Natural and Working Lands to minimize emissions and maximize sequestration through natural carbon sinks such as forests. The State currently uses several forest management strategies such as prescribed burning, creating fuel breaks, and forest thinning that reduce wildfire risk, but can result in greenhouse gas (GHG) and short-lived climate pollutant (SLCP) emissions.[1]

Ramboll has performed an assessment of an alternative forest management strategy in which biomass fuel removed from the forest is converted into renewable fuels for use in the transportation sector instead of being burned in-situ. The proposed approach would not only avoid direct GHG and SLCP emissions from the burning activities, but also offset GHG emissions from use of fossil fuels for transportation. The following sections present our approach and methodology, discuss results of the study, and state important conclusions and considerations of our work.

APPROACH AND METHODOLOGY

To evaluate the emissions reductions that this alternative approach can generate, Ramboll conducted a comparative analysis of two scenarios. Both scenarios include the treatment of 1,000 acres of woody biomass from California forestland. In Scenario 1, this treatment is in the form of prescribed burn: 1,000 acres of forest are burned in a controlled setting, and the emissions associated with this burn are quantified. In Scenario 2, the woody biomass from 1,000 acres of forest is converted into renewable diesel through a CARB-certified pathway. To capture the climate benefit of generating renewable diesel, the analysis assumes that the renewable diesel produced displaces an equivalent amount of fossil diesel. Scenario 1 includes

[1] Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/ca_ghg_wildfire_forestmanagement.pdf. Accessed: December 2021.

emissions associated with the use of this displaced fossil diesel, while Scenario 2 includes emissions associated with the use of renewable diesel. This memorandum describes the results of Ramboll's comparative evaluation of lifecycle emissions from both scenarios outlined. The analysis quantifies prescribed burn and transportation emissions of SLCPs – methane (CH_4) and black carbon (BC) – as well as other GHGs – carbon dioxide (CO_2) and nitrous oxide (N_2O).

The methodology and assumptions used in this study are described below.

- **Pollutants Assessed**: This study evaluates emissions from prescribed burning of woody biomass, as well as total exhaust emissions from the use of fossil and renewable diesel. The pollutants assessed are CH_4, CO_2, N_2O, and BC. Additionally, the study evaluates GHG emissions from upstream processing of fossil and renewable diesel. GHG emissions are presented in metric tons of CO_2-equivalents (CO_2e) using 100-year GWP values of 25, 1, and 298 for CH_4, CO_2, and N_2O respectively.[2] The 100-year GWP for BC was assumed to be 900, following CARB's 2015 Black Carbon Emissions Inventory.[3]
- **Prescribed Burn Emissions**: The methodology of estimating prescribed burn emissions from a 1,000-acre unit of California forest vegetation varied depending on the pollutant of interest.
  - CO_2 emissions were estimated as a three-year average over 2017-2019, using CARB's published estimates of prescribed fire acreage and emissions.[4] See **Table 1** for CO_2 emissions estimates. Note that while these have been calculated for consistency, they are excluded from the initial analysis since they are biogenic in nature.[5] Specifically, the CO_2 released through the combustion of forest biomass is offset by the CO_2 that the biomass has sequestered in its lifetime, and thus biogenic CO_2 emissions from fire result in relatively minimal change in the total concentration of atmospheric CO_2 that drives climate change.[6]
  - Since CARB does not publish $PM_{2.5}$ emissions for prescribed burns, the $PM_{2.5}$ emission factors were estimated based on CARB's annual wildfire emissions inventory[7,8] over the last four years (2017-2020). BC emissions were then estimated as a fraction of $PM_{2.5}$ emissions based on a particulate matter speciation factor of 0.202594 for the "Forest Management Burning" profile provided in CARB's 2015 Black Carbon Emissions Inventory.[9] Refer to **Table 2** for details.

2 Available at: https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html. Accessed: December 2021.

3 Available at: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf. Accessed: December 2021.

4 Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/ghg_emissions_forest_management_webinar_slides.pdf. Accessed: December 2021.

5 This aligns with guidance from the US EPA, which states that "Emissions of CO_2 from [wildfires and prescribed burns] as well as other biogenic sources are part of the carbon cycle, and as such are typically not included in greenhouse gas emission inventories." Available at: https://www.epa.gov/sites/default/files/2020-10/documents/13.1_wildfires_and_prescribed_burning.pdf. Accessed: December 2021.

6 Available at: https://www.ieabioenergy.com/iea-publications/faq/woodybiomass/biogenic-co2/. Accessed: December 2021.

7 2017, 2018, and 2020 wildfire estimates available at: https://ww2.arb.ca.gov/sites/default/files/2021-07/Wildfire%20Emission%20Estimates%20for%202020%20_Final.pdf. Accessed: December 2021.

8 2019 wildfire estimates available at: https://ww3.arb.ca.gov/cc/inventory/pubs/estimationmethods.pdf. Accessed: December 2021.

9 Available at: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf. Accessed: December 2021.

- CH_4 and N_2O emission were estimated using the US EPA AP-42 Compilation of Air Emissions Factors "Wildfires and Prescribed Burning" documentation.[10] These emissions factors, provided in pounds of pollutant per bone dry ton (BDT) of biomass consumed during prescribed burn, were converted to a metric ton of pollutant per acre burned using the US EPA AP-42 fuel loading factor for California of 18.9 BDT of biomass per acre. See **Table 3** for CH_4 and N_2O emissions estimates.

- **Conversion of Biomass to Renewable Diesel**: Ramboll estimated the renewable diesel yield from pyrolysis of biomass based on data published a 2021 study funded by United States Department of Energy (2021 DOE Study).[11] We also found renewable diesel yield estimates in two other literature sources[12,13]; but chose to use the value from the 2021 DOE Study as it represents the most efficient conversion and is conservative in that it results in the smallest percentage reduction in GHG emissions in Scenario 2 as compared to Scenario 1. As shown in **Table 4**, Ramboll used the US EPA AP-42 fuel loading factor for California[14] of 18.9 BDT of biomass per acre and the renewable diesel yield from the 2021 DOE Study to estimate the gallons of renewable diesel that can be generated from 1,000 acres of California forestland. For the purposes of this analysis, this quantity (presented in **Table 4**), is assumed to be the fuel usage for both conventional and renewable diesel vehicles.

- **Emissions from Fossil Diesel Use**: Ramboll used the most current version of CARB's on-road mobile source emission inventory EMFAC2021[15] to estimate the tailpipe emission rates of pollutants from diesel vehicles. To model the average emissions across all types of diesel-fuel vehicles, all vehicle categories and an aggregate model year parameter were applied. Tailpipe emission rates (g/gal) are calculated for each calendar year by taking total emissions and dividing by the total fuel consumption across all diesel vehicles. These emission factors are presented in **Table 5**. Input parameters for the EMFAC2021 model run are shown below:
  - Run Mode: Emissions
  - Region: Statewide
  - Calendar Years: 2021
  - Season: Annual
  - Vehicle Category: EMFAC202x – All Categories
  - Model Year: Aggregated
  - Fuel: Diesel

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[10] Available at: https://www.epa.gov/sites/default/files/2020-10/documents/13.1_wildfires_and_prescribed_burning.pdf. Accessed: December 2021.

[11] Hunter Mack, et al., Renewable Fuel Additives from Woody Biomass, US Department of Energy Bioenergy Technologies Office, 2021. Available at: https://www.energy.gov/sites/default/files/2021-04/beto-07-peer-review-2021-cooptima-mack.pdf. Accessed: December 2021.

[12] Rajeeva Thilakaratne, et al., Mild Catalytic Pyrolysis of Biomass for Production of Transportation Fuels: A Techno-Economic Analysis, Iowa State University, 2014. Available at: https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1061&context=imse_pubs. Accessed: December 2021.

[13] Madhumita Patel, et al., A Techno-Economic Assessment of Renewable Diesel and Gasoline Production from Aspen Hardwood, 2018. Available at: https://link.springer.com/article/10.1007/s12649-018-0359-x. Accessed: December 2021.

[14] Available at: https://www.epa.gov/sites/default/files/2020-10/documents/13.1_wildfires_and_prescribed_burning.pdf. Accessed: December 2021.

[15] Available at: https://arb.ca.gov/emfac/emissions-inventory/. Accessed: December 2021.

- Speed: Aggregated
- Pollutants: CH_4, CO_2, N_2O, $PM_{2.5}$

The upstream emission factor for conventional diesel use was estimated from the CA-GREET 3.0 Lookup Table Pathways,[16] and the final factor is presented in **Table 6**.

- **Emissions from Renewable Diesel Use:** Tailpipe emissions from renewable diesel use were assumed to be equivalent to those calculated for conventional diesel use, presented in **Table 5**. Since the CO_2 emissions generated by the combustion of renewable diesel are considered biogenic, they are excluded from the initial analysis.[17] Specifically, the biomass used to produce the renewable diesel is part of the terrestrial carbon cycle, and thus the combustion of this biomass simply returns to the atmosphere carbon that was previously absorbed by the plants as they were growing.[18] Upstream emissions for renewable diesel were estimated using a certified pathway carbon intensity (CI) for renewable diesel production from forest residues under the California LCFS program (Pathway # T2P-1071).[19] The final estimated emission factor is presented in **Table 6.**
- **Tailpipe Black Carbon Emissions**: Since EMFAC calculates exhaust $PM_{2.5}$ emissions but does not calculate BC emissions, Ramboll calculated BC emissions based on $PM_{2.5}$ emissions and particulate matter speciation factor of 0.264363 for "Diesel Vehicle Exhaust" profile provided in CARB's 2015 Black Carbon Emissions Inventory.[20] These BC emissions are presented alongside tailpipe emissions of other pollutants in **Table 5**.
- **Total Carbon Dioxide Emissions:** Although CO_2 emissions generated by the combustion of renewable diesel are considered biogenic, total GHG emissions (including CO_2 emissions from renewable diesel combustion and burning) were also assessed so that information can be explicitly presented. In this analysis approach, presented in **Table 7**, tailpipe CO_2 emissions from renewable diesel use in Scenario 2 and the prescribed burn CO_2 emissions in Scenario 1 are included in the total GHG emissions regardless of the biogenically-based nature of both fuels.[21]

RESULTS

Ramboll's analysis shows that converting 1,000 acres of forest into renewable diesel instead of subjecting the same area to a prescribed burn can reduce non-biogenic GHG emissions significantly. As indicated in **Table 6**, Scenario 2 (in which prescribed burn and fossil diesel use in the transportation sector is replaced with converting forest biomass to renewable diesel for use in transportation) can reduce GHG emissions by up to 90% compared to Scenario 1 (the prescribed burn approach). With

[16] Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf. Accessed: December 2021.

[17] This aligns with guidance from the US EPA, which states that "EPA's policy in forthcoming regulatory actions will be to treat biogenic CO_2 emissions resulting from the combustion of biomass from managed forests at stationary sources for energy production as carbon neutral." Available at: https://www.epa.gov/sites/default/files/2018-04/documents/biomass_policy_statement_2018_04_23.pdf. Accessed: December 2021.

[18] Available at: https://www.ieabioenergy.com/iea-publications/faq/woodybiomass/biogenic-co2/. Accessed: December 2021.

[19] Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/current-pathways_all.xlsx. Accessed: December 2021.

[20] Available at: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf. Accessed: December 2021.

[21] This is in line with guidance from the US EPA, which states that "tailpipe emissions of CO_2 from RNG fuels are considered carbon neutral because the carbon is biogenic, while tailpipe emissions of CO_2 from fossil natural gas fuels are not." Available at: https://www.epa.gov/sites/default/files/2020-07/documents/lmop_rng_document.pdf. Accessed: December 2021.

reference to direct emissions of SLCPs, Scenario 2 provides a reduction of up to 99% compared to Scenario 1 for methane and black carbon.

A second approach in quantifying GHG emissions is presented in **Table 7**, in which tailpipe CO_2 emissions from renewable diesel use in Scenario 2 and the prescribed burn CO_2 emissions in Scenario 1 are included despite the biogenically-based nature of both fuels.[22] Even with the inclusion of biogenic carbon emissions, Scenario 2 can reduce total GHG emissions by up to 73% and direct emissions of SLCP by up to 99% compared to Scenario 1. These results clearly indicate that the conversion forest biomass to renewable diesel for use in transportation provides a significant reduction in GHG emissions as compared to prescribed burns, whether total or non-biogenic GHG emission reductions are considered.

CONCLUSION

While CARB poses prescribed burn as a potential strategy towards meeting its 2022 Scoping Plan Natural and Working Lands Objectives of climate resiliency and wildfire risk reduction, Ramboll's analysis has shown that an alternative approach to forest management – one that converts forest biomass to renewable fuel – is more aligned with CARB's overall goal of achieving carbon neutrality. As such, CARB should strongly consider prioritizing this approach in its development of Natural and Working Lands scenarios for modeling. This analysis indicates that converting biomass to renewable fuels would be a strategy applicable for inclusion in Draft Scenarios 2, 4, and 5, which aim to prioritize climate resilience, wildfire reduction, and resource utilization respectively. Replacing an increase in prescribed burn with increased availability of biomass for use in renewable fuels production will generate significant emissions reductions in both GHGs and SLCPs, bringing CARB closer to its goal of achieving carbon neutrality while also generating reductions in SLCPs.

It should be noted that the estimates provided here with reference to emissions reductions are conservative. A less efficient conversion of forest biomass to renewable diesel would lead to a lower yield value, lower tailpipe emissions for fossil and renewable diesel, and thus a higher emissions reduction for Scenario 2 as compared to Scenario 1.

[22] This is in line with guidance from the US EPA, which states that "tailpipe emissions of CO_2 from RNG fuels are considered carbon neutral because the carbon is biogenic, while tailpipe emissions of CO_2 from fossil natural gas fuels are not." Available at: https://www.epa.gov/sites/default/files/2020-07/documents/lmop_rng_document.pdf. Accessed: December 2021.

TABLES

Table 1. Carbon Dioxide Emissions from 1,000 Acres of Prescribed Burn
Southern California Gas Company
Los Angeles, California

Year	Total Area Used for Prescribed Burn[1] (acres)	CO_2 Emissions from Prescribed Burn[1] (MMT)	Annual CO_2 Emission Factor (MT/acre)	Average CO_2 Emission Factor (MT/acre)	CO_2 Emissions from 1,000 Acres of Prescribed Burn (MT)
2017	35,000	0.4	11.43	13.33	13,330
2018	39,000	0.6	15.38		
2019	107,000	1.4	13.18		

Notes:

[1] Prescribed burn acreage and emissions estimated from figures provided by CARB in its December 2020 Technical Estimation of GHG Emissions of Wildfire and Forest Management Activities Workshop. Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/ghg_emissions_forest_management_webinar_slides.pdf. Figures also available at: https://ww3.arb.ca.gov/cc/inventory/pubs/ca_ghg_wildfire_forestmanagement.pdf

Conversions Factors:
1,000,000 MT/MMT

Abbreviations:
CO_2 - Carbon dioxide
MT - Metric ton
MMT - Million metric ton

Table 2. Black Carbon Emissions from 1,000 Acres of Prescribed Burn
Southern California Gas Company
Los Angeles, California

Year	Total Area Burned[1,2] (acres)	$PM_{2.5}$ Emissions[1,2] (thousand short tons)	BC Emissions[3] (thousand short tons)	Annual BC Emission Factor (MT/acre)	BC Emission Factor (MT/acre)	BC Emissions from 1,000 Acres of Prescribed Burn (MT)
2017	1,340,000	337	68.3	0.0462	0.0449	44.86
2018	1,590,000	421	85.3	0.0487		
2019	278,556	47.5	9.62	0.0313		
2020	4,080,000	1,181	239	0.0532		

Constants:
Black Carbon Speciation Factor[3] 0.202594

Notes:
[1] Acreage of forest burned and emission estimates for 2017, 2018, and 2020 are from CARB's "Wildfire Emission Estimates for 2020" document. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-07/Wildfire%20Emission%20Estimates%20for%202020%20_Final.pdf

[2] Acreage of forest burned and emission estimate for 2019 is from CARB's "Wildfire Emission Estimates for 2019" document. Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/estimationmethods.pdf

[3] Black carbon emissions estimated as a fraction of $PM_{2.5}$ emissions, using CARB's speciation factor for Forest Management Burning. Available at: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf.

Conversion Factors:
907,185 g/ton
1.10231 tons/MT
1,000 tons/thousand short ton

Abbreviations:
BC - Black carbon
g - Gram
MT - Metric ton
$PM_{2.5}$ - Particulate matter less than 2.5 microns in diameter

Table 3. Methane and Nitrous Oxide Emissions from 1,000 Acres of Prescribed Burn
Southern California Gas Company
Los Angeles, California

Pollutant	Emission Factors[1] (lbs of pollutant/BDT of biomass)	Emission Factors[1] (MT of pollutant/acre burned)[2]	Emissions from 1,000 Acres of Prescribed Burn (MT)
CH_4	11.1	0.095	95
N_2O	0.46	0.00394	3.94

Constants:

Fuel Loading[3] 18.90 BDT of biomass/acre

Notes:

[1] CH_4 and N_2O emission factors estimated using Table 13.1-5 of the EPA AP-42 Compilation of Air Emissions Factors. Available at: https://www.epa.gov/sites/default/files/2020-10/documents/13.1_wildfires_and_prescribed_burning.pdf. It is assumed that the AP-42 regional fuel type applicable for California is "Boreal and Coniferous Forests", per the US Department of Agriculture's Forest Inventory and Analysis report. Report is available at: https://www.fs.fed.us/pnw/pubs/pnw_gtr913.pdf

[2] Calculated by multiplying AP-42 emission factors by fuel loading values from CARB wildfire estimates. EPA AP-42 factors are assumed to be in units of lbs/bone dry tons of biomass, per Tables 4-6 in the relevant supporting documentation titled "Development of Emission Factors for Estimating Atmospheric Emissions from Forest Fires". Available at: https://www3.epa.gov/ttnchie1/ap42/ch13/final/c13s01.pdf

[3] Fuel loading estimated using CARB wildfire emissions estimates. See Table 4 for further details.

Conversion Factors:

2,000 lbs/ton
1.10231 tons/MT

Abbreviations:

BDT - Bone Dry Ton
CH_4 - Methane
lbs - Pounds
MT - Metric ton
N_2O - Nitrous oxide

Table 4. Production of Renewable Diesel from 1,000 Acres of Woody Biomass
Southern California Gas Company
Los Angeles, California

Fuel Loading		
Total Area Burned in Wildfires[1,2]	2019	278,556 acres
	2020	4,200,000 acres
Total Biomass Fuel Consumed by Burning[1,2]	2019	3,545,005 BDT
	2020	81,097,083 BDT
Average Fuel Loading[3]		18.90 BDT/acre
Yield		
Yield Estimate for Conversion of Biomass to Renewable Diesel [4,5]		76 DGE/BDT biomass
Fuel Production		
Renewable Diesel Generation Rate[6]		1,440 gal/acre
Volume of Renewable Diesel Generated for 1,000 Acres		1,440,204 gal

Notes:

[1] Wildfire acreage and fuel consumption for 2019 was calculated in CARB's "Wildfire Emission Estimates for 2019" document. Available at: https://ww3.arb.ca.gov/cc/inventory/pubs/estimationmethods.pdf

[2] Wildfire acreage and fuel consumption for 2020 was calculated in CARB's "Wildfire Emission Estimates for 2020" document. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-07/Wildfire%20Emission%20Estimates%20for%202020%20_Final.pdf

[3] Average fuel loading estimated as ratio of total fuel consumed in 2019 to 2020 to total area burned in 2019 to 2020.

[4] Biodiesel yield from woody biomass was derived from a 2021 study funded by the Department of Energy's Bio-Technologies Office, titled "Renewable Fuel Additives from Woody Biomass". It is assumed that the study models biomass consumption in dry tons. Available at: https://www.energy.gov/sites/default/files/2021-04/beto-07-peer-review-2021-cooptima-mack.pdf

[5] Two other sources for yield estimates were consulted: a 2014 study funded by the Iowa State University estimated a yield of 53.16 DGE/BDT biomass, and a 2018 study funded by the University of Alberta estimated a yield of 53.85 DGE/BDT biomass. We have chosen to model the most efficient conversion (the Department of Energy estimate of 76 DGE/BDT biomass) since it results in the most conservative approach (i.e. the smallest percentage reduction in emissions from Scenario 2 relative to Scenario 1).

[6] Volume of renewable diesel generated was estimated as a product of the average fuel loading and the yield estimate from the Department of Energy.

Conversion Factors:

453.592	g/lb
907,185	g/ton
1,000,000	g/Mg
1.10231	tons/MT

Abbreviations:

BDT - Bone Dry Ton
DGE - Diesel Gallon Equivalent
g - Gram
gal - Gallon
Mg - 10^6 grams
MT - Metric ton

 Ramboll

Table 5. Diesel Vehicle Tailpipe Emissions
Southern California Gas Company
Los Angeles, California

Pollutant	EMFAC Emissions Output[1] (tons/year)	Tailpipe Emission Factor (g/gal)	Total Tailpipe Emissions for Scenario Analysis[2] (MT)
CO_2	35,213,832	10,155	14,626
CH_4	140	0.040	0.0581
N_2O	5,548	1.600	2.30
$PM_{2.5}$	1,028	0.296	0.427
BC[2]	--	0.078	0.1128

Constants:

EMFAC Annual Diesel Fuel Consumption in 2021[1]	3,145,637,623 gals/year
Black Carbon Speciation Factor[3]	0.264
Renewable Diesel Produced from 1,000 Acres of Biomass[4]	1,440,204 gals

Notes:

[1] Data obtained from EMFAC 2021 Database. Available at: https://arb.ca.gov/emfac/emissions-inventory/. Modeled with a California Statewide region type, calendar year range 2021, annual season, all EMFAC202x vehicle categories, aggregate model year, aggregate speed, and diesel vehicles only.

[2] Tailpipe emissions are conservatively estimated to be equivalent for vehicles that use either fossil or renewable diesel fuel.

[3] CARB's speciation profile for a diesel vehicle exhaust is used for this calculation. Available at: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf

[4] Diesel fuel consumption used to calculate total tailpipe emissions is estimated through average yield of renewable diesel from 1000 acres of woody biomass. See Table 4 for further details.

Conversion Factors:

907,185 g/ton
1.10231 tons/MT

Abbreviations:

BC - Black carbon
CH_4 - Methane
CO_2 - Carbon dioxide
g - Gram
gal - Gallon
MT - Metric ton
N_2O - Nitrous oxide
$PM_{2.5}$ - Particulate matter less than 2.5 microns in diameter

Table 6. Emissions Comparison for Prescribed Burn and Renewable Diesel Production Scenarios
Southern California Gas Company
Los Angeles, California

Greenhouse Gas	Units	Scenario 1 Prescribed Burning and Fossil Diesel Transportation Fuel	Scenario 2 Conversion of Biomass to Renewable Diesel Transportation Fuel	Reduction of Emissions in Scenario 2 Compared to Scenario 1	Percent Reduction of Emissions in Scenario 2 Compared to Scenario 1
Direct Emissions[1]					
CO_2 Emissions[2]	MT	14,626	0	14,626	100.0%
CH_4 Emissions	MT	95	0.058	95	99.9%
N_2O Emissions	MT	6	2	4	63.1%
BC Emissions	MT	45	0.113	45	99.7%
Total Direct SLCP Emissions[3,4,5]	MT CO_2e	42,853	103	42,750	99.8%
Total Direct GHG Emissions[4,5]	MT CO_2e	59,341	790	58,551	98.7%
Indirect Emissions[6]					
Upstream GHG Emission Factor[7,8]	gCO_2e/MJ	25.59	27.33	--	--
Total Indirect GHG Emissions	MT CO_2e	4,956	5,293	-337	-6.8%
Total Emissions					
Total GHG Emissions	**MT CO_2e**	**64,297**	**6,083**	**58,214**	**90.5%**

Constants:

Diesel Fuel Consumption[9]	1,440,204	gal
Diesel Fuel Density[10]	134.47	MJ/gal

Notes:

[1] Direct emissions include tailpipe emissions from fossil and renewable diesel, as well as prescribed burn emissions for Scenario 1. It is assumed that fossil and renewable diesel have equivalent tailpipe emissions. See Table 1, Table 2, Table 3, and Table 5 for details.

[2] Since CO_2 emissions from prescribed burn are biogenic, these are excluded for Scenario 1. Similarly, tailpipe CO_2 emissions created from the use of renewable diesel are biogenic, and thus excluded from Scenario 2.

[3] Short lived climate pollutants are climate forcers with short atmospheric lifetimes. Here, this includes methane and black carbon. CARB definition for SLCPs is available at: https://ww2.arb.ca.gov/our-work/programs/slcp

[4] CO_2, CH_4, and N_2O GWP values from IPCC AR4. Available at: https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

[5] BC GWP value from CARB Black Carbon Emission Inventory. Available at: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf

[6] Indirect emissions include upstream emissions associated with the production of fossil and renewable diesel for use in the transportation sector.

[7] Upstream emission factor for Scenario 1 estimated from CA-GREET3.0 Lookup Table Pathways. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf

[8] Upstream emission factor for Scenario 2 estimated from LCFS Certified Pathways, Pathway # T2P-1071 Ensyn Technologies Pyrolysis Oil from Forest Residue to Renewable Diesel. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/current-pathways_all.xlsx

[9] Diesel fuel consumption used to calculate total tailpipe emissions is estimated through yield of renewable diesel from 1000 acres of woody biomass. See Table 4 for further details.

[10] Fuel Specific Energy Density from CARB GHG Quantification Methodology for Low Carbon Transportation Program. Available at: https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/carb_oratd_finalqm_16-17.pdf

Conversion Factors:

907,185	g/ton
1.10231	tons/MT

Greenhouse Gas Factors:

Pollutant	100-yr GWP
CO_2	1
CH_4	25
N_2O	298
BC	900

Abbreviations:

BC - Black carbon
CH_4 - Methane
CO_2 - Carbon dioxide
CO_2e - Carbon dioxide equivalent
g - gram
gal - gallon
GHG - Greenhouse Gas
GWP - Global warming potential
MJ - 10^6 joules
MT - Metric ton
N_2O - Nitrous oxide
SLCP - Short Lived Climate Pollutant

Table 7. Emissions Comparison for Prescribed Burn and Renewable Diesel Production Scenarios, Including Biogenic Carbon Dioxide
Southern California Gas Company
Los Angeles, California

Greenhouse Gas	Units	Scenario 1 Prescribed Burning and Fossil Diesel Transportation Fuel	Scenario 2 Conversion of Biomass to Renewable Diesel Transportation Fuel	Reduction of Emissions in Scenario 2 Compared to Scenario 1	Percent Reduction of Emissions in Scenario 2 Compared to Scenario 1
Direct Emissions[1]					
CO_2 Emissions	MT	27,956	14,626	13,330	47.7%
CH_4 Emissions	MT	95	0.058	95	99.9%
N_2O Emissions	MT	6	2	4	63.1%
BC Emissions	MT	45	0.113	45	99.7%
Total Direct SLCP Emissions[2,3,4]	MT CO_2e	42,853	103	42,750	99.8%
Total Direct GHG Emissions[3,4]	MT CO_2e	72,671	15,416	57,255	78.8%
Indirect Emissions[5]					
Upstream GHG Emission Factor[6,7]	gCO_2e/MJ	25.59	27.33	--	--
Total Indirect GHG Emissions[6,7]	MT CO_2e	4,956	5,293	-337	-6.8%
Total Emissions					
Total GHG Emissions	**MT CO_2e**	**77,627**	**20,709**	**56,918**	**73.3%**

Constants:

Diesel Fuel Consumption[8]	1,440,204	gal
Diesel Fuel Density[9]	134.47	MJ/gal

Notes:

[1] Direct emissions include tailpipe emissions from fossil and renewable diesel, as well as prescribed burn emissions for Scenario 1. It is assumed that fossil and renewable diesel have equivalent tailpipe emissions. See Table 1, Table 2, Table 3, and Table 5 for details.

[2] Short lived climate pollutants are climate forcers with short atmospheric lifetimes. Here, this includes methane and black carbon. CARB definition for SLCPs is available at: https://ww2.arb.ca.gov/our-work/programs/slcp

[3] CO_2, CH_4, and N_2O GWP values from IPCC AR4. Available at: https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

[4] BC GWP value from CARB Black Carbon Emission Inventory. Available at: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf

[5] Indirect emissions include upstream emissions associated with the production of fossil and renewable diesel for use in the transportation sector.

[6] Upstream emission factor for Scenario 1 estimated from CA-GREET3.0 Lookup Table Pathways. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut-doc.pdf

[7] Upstream emission factor for Scenario 2 estimated from LCFS Certified Pathways, Pathway # T2P-1071 Ensyn Technologies Pyrolysis Oil from Forest Residue to Renewable Diesel. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/current-pathways_all.xlsx

[8] Diesel fuel consumption used to calculate total tailpipe emissions is estimated through average yield of renewable diesel from 1000 acres of woody biomass. See Table 4 for further details.

[9] Fuel Specific Energy Density from CARB GHG Quantification Methodology for Low Carbon Transportation Program. Available at: https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/carb_oratd_finalqm_16-17.pdf

Conversion Factors:

907,185	g/ton
1.10231	tons/MT

Greenhouse Gas Factors:

Pollutant	100-yr GWP
CO_2	1
CH_4	25
N_2O	298
BC	900

Abbreviations:

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CH_4 - Methane
CO_2 - Carbon dioxide
CO_2e - Carbon dioxide equivalent
g - gram
gal - gallon
GHG - Greenhouse Gas
GWP - Global warming potential
MJ - 10^6 joules
MT - Metric ton
N_2O - Nitrous oxide
SLCP - Short Lived Climate Pollutant