AN ASSESSMENT: CALIFORNIA'S IN-STATE RNG SUPPLY FOR TRANSPORTATION

2020 -2024

A survey of the existing and developing RNG production capacity in California for use in motor vehicles

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Acknowledgements

This report would not have been possible without the generous support of the following sponsors:

- California Natural Gas Vehicle Partnership
- Clean Energy Renewable Fuels
- Pacific Gas & Electric
- Shell
- South Coast Air Quality Management District
- Southern California Gas Company
- Trillium, A Loves Company
- TruStar Energy

Many people provided guidance and feedback that directly contributed to the quality of this research. They include Todd Campbell (Clean Energy), Tyler Henn (Clean Energy Renewable Fuels), Jim Bier (Ameresco), Jim Lucas (Southern California Gas Company), Chris DiGiovanni (PG&E), Ryan Erickson (Trillium), Matt Miyasato (South Coast Air Quality Management District), Patrick Young (Shell), Yaniv Scherson (Anaergia), Mike Silva (CR&R), Harrison Clay (BP), Tim Olson (California Energy Commission), Julia Levin (Bioenergy Association of California), Lyle Schlyer (Calgren), Sam Wade (Coalition for Renewable Natural Gas), Greg Kester (California Association of Sanitation Agencies), Scott O'Neill (Waste Management), Jerod Smeenk (Frontline Energy), Mark McDannel (Sanitation Districts of Los Angeles County), Leah Walker (City of Petaluma), Steven Nebozuk (City of Sacramento), Matthew Zucca (City of San Mateo), Evan Edgar (Edgar & Associates), William Graham (DVO), Robbie Macias (Aemetis), Brian Habersack (California Energy Exchange Corporation), Kevin Best (RealEnergy), Fred Tornatore (TSS Consultants), Charles Helget and Brian Martz (Republic Services), Scott Edelbach (TruStar Energy); David Fink (City of San Mateo), Mike Prinz (Las Gallinas Valley Sanitation District), Ray Arthur (City of Fresno), Marisa Tricas (City of Roseville), and Carolyn Ginno (City of San Diego). Thanks goes to everyone listed above for their time, perspective and assistance.

Executive Summary

In the summer of 2019, staff at the California Air Resources Board (ARB) drafted a proposal to disqualify natural gas vehicles (NGVs) from one of the state's most popular programs promoting the purchase of advance, clean transportation technology, the Heavy-Duty Vehicle Incentive Program (HVIP). Proponents of increasing the use of near-zero emission NGVs fueled by renewable natural gas (RNG) opposed the modification suggested by the air agency's staff. After several months of back-and-forth, the parties eventually reached an arrangement. The accommodation limited future HVIP funding to natural gas fueled heavy-duty vehicles equipped with an 11.9L low NOx engine. The compromise added an additional requirement: in order to qualify for the HVIP funding, the new vehicle must be fueled with RNG produced within the state of California.

At the time that this understanding was reached, neither the ARB nor the NGV/RNG industries had any sense of the supply of California-produced RNG. When this new constraint was placed on future NGVs applying to the HVIP, no one knew how much in-state RNG was being produced in California. Nor was it known when new supplies would be coming online, and how much California RNG would be available in the future. The only prior projections performed on future RNG supply were theoretical. Without better data on the in-state supply of RNG, it is not possible for ARB or the industry to know if HVIP applicants can comply with this new requirement. Moreover, if other authorities try to apply this same constraint to their state and local vehicle incentive programs, the effort would be hampered by the same absence of data. The estimated RNG inventory described in this report attempts to fill this void.

Most existing studies of future RNG supply have focused on hypothetical potential future supply. Researchers have looked at the availability of organic feedstocks that could be used for RNG production. Using volume projections for such raw materials, they estimated the amount of gas that theoretically could be produced. Such studies have also primarily focused on supplies of materials that can easily be anaerobically digested (i.e. high moisture, low-solids content). They have tended to ignore other technologies that could be used to produce high-BTU renewable methane, such as pyrolysis, gasification, and electrolysis.

The goal of this study is to provide stakeholders and policy makers with a much more accurate, data-driven estimate for the total volume of RNG that will be produced in-state and made available for transportation use by California fleet operators in the near term. By using information provided by state and local agencies, project developers, 3rd party marketers and other reliable sources, this inventory assesses the actual RNG production of existing and developing projects. It provides a reasonably reliable estimate of the actual supply of in-state RNG that was being produced on January 1, 2020, the growth in production that will take place by quarter over the next four years, and the total supply of California-produced RNG that will be flowing to transportation end users in California on January 1, 2024. This research determined that 160 California-based RNG production facilities will be supplying more than 15.8 million MMBTU, or nearly 119 million diesel gallon equivalents (DGE), to transportation end users by the beginning of 2024. As a significant proportion of the growth in "domestic" production will come from California dairies, the energy weighted Carbon Intensity (CI) value of the projected instate supply of RNG will be approximately -101.74 gCO2e/MJ.

If 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. Adjusted for Energy Economy Rating (EER), 119 million DGE would be sufficient to fuel 13,731 natural gas trucks annually. If the HVIP was to provide a $45,000 voucher toward the purchase of each of these new NZE heavy-duty natural gas trucks, it would cost the state $618 million. Assuming a fifteen-year life for these vehicles, they would generate 51.4 million metric tonnes of CO_2e and 20.8 thousand tons of NO_x reductions, at a cost of $12.03/MT of CO_2e and $29,702 per ton of NO_x.

This RNG supply estimate only represents those projects that exist or are in development and meet this study's criteria for inclusion at the time of publication. It provides a snapshot in time. Given the accelerating pace of development of new RNG production in the state, unannounced grant awards, as well as the impacts of new regulations such as CalRecycle's SB 1383 organics recycling and procurement requirements, these results are likely to be conservative, and actual in-state RNG production on 1/1/24 will be significantly greater.

Introduction

In July of 2019 staff at the California Air Resources Board (ARB) proposed to "graduate" natural gas vehicles (NGVs) from the Heavy-Duty Vehicle Incentive Program (HVIP). The HVIP is one of three advanced clean vehicle incentive programs that are administered by the ARB and funded by the Greenhouse Gas Reduction Fund (GGRF), which itself is bankrolled by the proceeds from state's Cap & Trade program. The HVIP provides buyers of qualified clean heavy-duty vehicle technology with a voucher at the point of sale, a method of incentivizing the purchase of advanced, innovative and cleaner motor vehicle technology.[1]

Given the resources of the HVIP program (it is one of the best-funded advanced clean vehicle incentive programs in the country), stakeholders in the NGV industry resisted ARB's proposed change. Ensuing discussions resulted in ARB staff putting forward an alternative proposal that was approved by the ARB Board in October 2019. The revised requirement allowed for the continued participation in the HVIP of only the largest, commercially available low-NO_x natural gas engines (11.9 Liter), and only when it could be proven that NGVs equipped with such engines were being fueled by renewable natural gas (RNG) produced by a California-based facility.[2]

The apparent intent of ARB staff in promulgating this new in-state fuel source requirement was to spur investment in and development of RNG production infrastructure in California to help reduce fugitive methane emissions, which would support of the goals of SB 1383.[3] However, the condition was established without any understanding of the current or future supply of in-state RNG. Setting aside the wisdom of creating a prerequisite for the receipt of state support without a sense of the industry's ability to comply, these were the circumstances that both regulators and stakeholders found themselves in at the end of 2019.

To address this vacuum in the understanding of this important low carbon energy supply, GNA set out to inventory the total volume of RNG that was being produced at California facilities and being delivered for motor vehicle use at the end of 2019. In addition, to provide regulators and stakeholders with the most accurate assessment of new volumes of in-state RNG that will come on line in the near future, GNA has surveyed the industry and developed a database of new RNG production facilities that will be bringing fuel to the state's transportation end users between January 1, 2020 and December 31, 2023. To best understand the benefits of this emerging, "domestically-produced" fuel supply, GNA has also:

- estimated the cumulative, energy weighted carbon intensity (CI) value of the in-state RNG supply;
- projected the criteria and toxic air contaminant reductions that could result if this new fuel were used per ARB's revised requirement for new NGVs funded by HVIP vouchers; and,
- collected available data on the public and private investment that will be made in these new cleaner, low-carbon, California-based transportation fuel production facilities.

[1]Vouchers are regarded by most end users as preferable to other forms of clean vehicle incentives, such as grants, which have longer lead times, involve much more paperwork, and are rife with uncertainty.
[2]NO_x stands for oxides of nitrogen, one of the primary precursors in the atmosphere, of tropospheric ozone, also known as "smog".
[3]SB 1383 (Lara, Chapter 395, Statutes of 2016) targets the reduction of short-lived climate pollutants (SLCP), including mandating a 40 percent reduction in fugitive methane emissions by 2030. See https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383

The Environmental Protection Benefits of Renewable Natural Gas

RNG is methane that is produced from the decomposition of organic matter, cleaned up to gas pipeline quality, and made available for use in motor vehicles. It comes primarily from landfills, wastewater treatment plants, the operations of large animal husbandry facilities (dairies, swine, livestock, and poultry), dead and dying trees, food processing, and agriculture. Unlike fossil gas, which was primarily created over hundreds of millions of years from the decay of animals and plants in the crust of the earth, biomethane is created contemporaneously. Whereas fossil gas releases carbon that has been sequestered for millennia, biomethane recycles carbon that is already present in the biosphere. As a result, biomethane does not add to the atmosphere's carbon budget.

Methane is a powerful global warming gas that is a common by-product of modern society. If left uncontrolled, given its higher Global Warming Potential (GWP), it can contribute to climate change.[4] However, when methane is captured, cleaned, and used as RNG as an alternative for gasoline, diesel or even fossil natural gas in transportation applications, it reduces the carbon intensity of the operation of the vehicle in which it is used. The climate benefit will depend on the source (i.e. feedstock) from which the RNG is derived.[5] See Table 1 for a list of a variety of different carbon intensity pathways, included several RNG sources, certified by ARB.

Table 1: Carbon Intensity Values of Various Fuels[6]

Feedstock	Facility Location	Fuel Producer	Certified CI
California Diesel	n/a	n/a	100.82
California Gasoline	California	n/a	100.45
California Grid Electricity	California	n/a	82.92
Fossil Natural Gas	California	Pacific Gas & Electric	80.59
Landfill Gas	Kansas	Clean Energy	45.31
Landfill Gas	Louisiana	Athens Services	39.46
Landfill Gas	Washington	Clean Energy	30.90
Wastewater Sludge	California	n/a	7.75
HSAD Food & Green Waste	California	Blue Line Transfer	-22.93
Dairy Manure	Indiana	AMP Americas LLC	-254.94
Swine Manure	Missouri	Element Markets	-372.35

(CI is measured in grams of CO2e per megajoule of energy)

[4]Global Warming Potential is a measure of the ability of a greenhouse gas to trap heat. The yardstick for GWP is carbon dioxide, which has a GWP of 1 over the first hundred years of its presence in the atmosphere. Methane has a GWP of 25, but has a short-term (first 20 years) GWP of 84.
[5]The carbon intensity of RNG is also impacted by the energy used to process the raw gas in to a fuel suitable for use in a NGV or injection in to a pipeline, the distance of the production facility from California-based end users, current disposal practices for the organic waste and other factors. The climate benefit will also be impacted by the Energy Economy Ratio (EER) of the vehicle, as diesel (combustion ignition) engines are about 10% more fuel efficient than natural gas engines (spark ignition).
[6]https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/current-pathways_all.xlsx

It is worth noting that, within the LCFS program, ARB has tracked the average energy weighted carbon intensity of the both the renewable CNG and LNG consumed in California as a transportation fuel. The average for renewable CNG over the last seven years (2013 – 2019) has been 30.3 gC02e/MJ, while renewable LNG has averaged 39.8 gC02e/MJ.[7]

The Use of Renewable Natural Gas as a Transportation Fuel

As the CI values in Table 1 indicate, medium and heavy-duty NGVs fueled with methane from renewable feedstocks exhibit substantially better GHG profiles than vehicles fueled by diesel, gasoline or conventional natural gas. In some cases -- particularly when considering supplies of RNG from dairies and high solid anaerobic digesters (HSAD) -- emissions of climate-altering gases can be negative, i.e. their use as a transportation fuel actually reduces the global warming potential in the atmosphere. Use of these low- and negative-carbon fuels directly in today's medium and heavy-duty NGVs provides real and immediate reductions in emissions of GHGs, criteria pollutants and toxic air contaminants.[8]

Use of RNG as a transportation fuel is a relatively new phenomenon that is much more prevalent in California than in the rest of the U.S. In 2019, 717 million gasoline gallon equivalents (GGE) of natural gas were consumed in U.S. motor vehicles. Of that total, conventional (fossil) natural gas accounted for 440 million GGE, while 277 million GGE, or 39% of the total, was supplied by sources of renewable natural gas. As almost all of that natural gas was consumed in medium and heavy-duty NGVs that use diesel as the baseline fuel, the diesel gallon equivalent (DGE) of those same figures is 618 million, 379 million and 239 million respectively.[9] See Table 2 below:

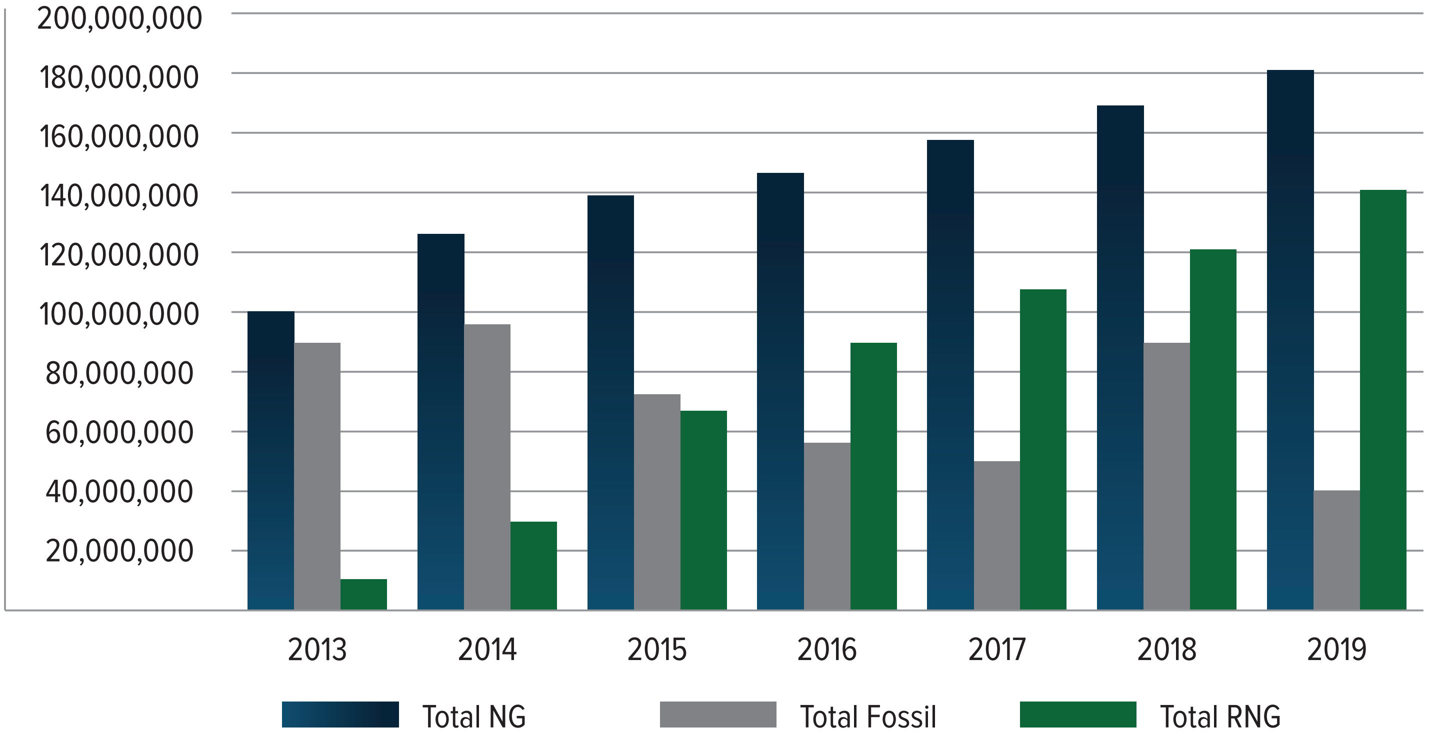
Table 2: Total Natural Gas Use as Transportation Fuel, U.S., 2019

	GGE	DGE	% of total use
Fossil Gas Use in NGVs	440,000,000	379,000,000	61.3%
RNG Use in NGVs	277,000,000	239,000,000	38.7%
Total Natural Gas Use in NGVs	717,000,000	618,000,000	100.0%

Although approximately 11% of the total motor vehicles in the U.S. are registered in California, use of natural gas as a transportation fuel is more prevalent there than nationally.[10] In California, the total volume of natural gas used as a transportation fuel is roughly a third of the country's total consumption of natural gas as a vehicle fuel (29.1%). In addition, the proportion of natural gas used by vehicles in California that comes from renewable resources is much greater. In 2019, 179.9 million DGE of natural gas was used by NGVs and registered in California's Low Carbon Fuel Standard database.[11] The percentage of the total natural gas burned as a vehicle fuel in California that was renewable, however, was 77.4%, or 139.3 million DGE.[12] The higher percentage of RNG use in California's NGVs is directly attributable to the state's Low Carbon Fuel Standard, and the incentives that it provides for low carbon transportation fuels.

[7]See "LCFS Quarterly Data Spreadsheet", April 30, 2020 Update, Bio-CNG CI Avg and Bio-LNG CI Avg, https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm.
[8]Today's medium and heavy-duty natural gas engines emit 90 percent less NOx and particulate matter (PM) than the current emission standards for medium and heavy-duty engines.
[9]See "Decarbonize Transportation with Renewable Natural Gas", a report issued by Natural Gas Vehicles America and the Coalition for Renewable Natural Gas, April 20, 2020.
[10]There were 273.6 million motor vehicles registered nationally in 2018, while the total number of motor vehicles registered in California was 29,830,797 in 2015. See https://www.energy.ca.gov/data-reports/energy-almanac/transportation-energy/summary-california-vehicle-and-transportation and https://www.statista.com/statistics/183505/number-of-vehicles-in-the-united-states-since-1990/#:~:text=How%20many%20registered%20motor%20vehicles,at%206.3%20million%20in%202016.
[11]Although it is possible that some natural gas is used as a transportation fuel in California and is not registered in the LCFS, given the financial incentive, it is likely that the volume of unregistered fuel is low, and that the figures reported in the LCFS provide the most accurate inventory of natural gas use as a transportation fuel in California.
[12]See "LCFS Quarterly Data Spreadsheet", April 30, 2020 Update, https://ww3.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm.

Figure 1: Trends in Increasing RNG Consumption in California



It is important to note that natural gas use as a transportation fuel in California enjoyed robust growth between 2013 and 2019. During this period, total fuel use grew at roughly 7.5% per year. During this same period, the proportion of RNG to total natural gas use as a motor vehicle fuel grew from 10.3% in 2013 to 77.4% in 2019.[13]

Prior Estimates of RNG Supply Potential

It is very important for both policy makers and proponents of increased use of natural gas as a transportation fuel to better understand the current and future production capacity of California RNG facilities. This knowledge is critical given the upward trend in the use of natural gas as a medium and heavy-duty vehicle fuel, the increasing proportion of fuel use that is made up of RNG, and the new ARB requirement that, to receive a HVIP voucher, a heavy-duty NGV must be fueled with RNG from a California-based facility

Over roughly the past decade there have been several studies that have attempted to project future California-sourced RNG supply. Virtually all of the prior studies of RNG supply in the state of California have been estimates based on theoretical assessments of the available biomass resources. These studies have used a variety of methodologies to make projections of the future renewable gas potential. These methodologies have primarily revolved around the application of three criteria: the RNG that could be produced from the total available biomass (gross resource), the RNG that could be reasonably expected to be produced from current technology (technically recoverable RNG), and the RNG that could be reasonably expected to be produced under current economic conditions and be commercially competitive (economically recoverable RNG).
There are multiple examples of such studies. Although this section is not meant to be a comprehensive review of the

[13]Ibid.

literature, it is worthwhile to highlight some of the more notable prior studies that project the future impact of renewable gases on energy supplies. This report is not meant to discount the validity or value of these past studies – each made a significant and important contribution to the growing body of literature that seeks to improve understanding of this essential renewable energy resource. This section is only intended to identify the methodologies used in these past evaluations of future RNG supply and differentiate them from the approach used in this assessment.

Note that, since this report focuses on the development of the capability to produce RNG for transportation end uses, it does not address the plethora of research that has been conducted about opportunities to use biomass for power generation, either by using produced RNG to generate electricity or through technologies that combust biomass directly.

An important early work in the effort to understand the biomethane potential of in state resources was "Biomethane from Dairy Waste", prepared for Western United Dairymen, a trade association that represents 60% of the milk produced in California. This study made essential distinctions between the kinds of manure management systems operated by the state's dairies, and the impact these various methods have on potential biogas production. By separating the biogas potential by manure management system, the assessment estimated the total potential methane production potential from "existing technology and practices" at 39.2 million ft^3/day, or 14.3 BCF annually.[14] This estimate was based on the assumption that the entire resource base at the time of the study (1.7 million cows spread among 2,125 dairies [CDFA estimate from 2003]) would be harnessed to produce dairy biogas.

The work of Stephen Kaffka and Rob Williams of UC Davis' California Biomass Collaborative serves as a primary basis for estimating California's RNG supply potential. One of their most important evaluations was "An Assessment of Biomass Resources in California, 2013 – DRAFT". In this study the authors were the first to draw important distinctions, described above, between the various kinds of energy potential assessments. In their study, submitted to the CEC in 2015, Kaffka and Williams differentiated between the gross resource base and the technically recoverable resource base, estimating that the latter is equal to 45% of the total (gross) organic material available annually in the state. They projected that 93 BCF of biomethane (679 million DGE) could be produced annually.[15] The table from the report summarizing the resource base is reproduced below.

Figure 2: Biogas Technical Potential from 2015 California Biomass Collaborative

Feedstock	Ammount Technically Available	Biomethane Potential (billion cubic feet)
Animal Manure	3.4 MM BDT	19.7
Landfill Gas	106 BCF	53
Municipal Solid Waste (food, leaves, grass fraction)	1.2 MM BDT	12.6
Wastewater Treatment Plants	11.8 BCF (gas)	7.7
Total		93

(Table 3.2.4.1 Biogas Technical Potential from California Resources, p. 46)

[14]Krich, et. al., "Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California", prepared for Western United Dairymen, July 2005, p. 23.
[15]Williams, et. al., "An Assessment of Biomass Resources in California, 2013 – DRAFT", Prepared for the California Energy Commission, Prepared by the California Biomass Collaborative, March 2015, CEC-500-11-020, p. 46.

Another early assessment of the possible RNG supply from all organic resources in California came from the Bioenergy Association of California (BAC). In "Decarbonizing the Gas Sector: Why California Needs a Renewable Gas Standard" (November 2014), the authors conclude that:

> *California could produce almost 300 billion cubic feet of renewable gas per year just from organic waste --the waste from food and food processing, livestock, agriculture, yard waste, construction debris and other wood waste, soiled paper and forest biomass. Instead of landfilling or burning that waste, California could use it to generate enough renewable electricity to power 2 to 3 million homes or to generate 2.4 billion gallons of clean, ultra-low carbon transportation fuels.*[16]

The 2014 BAC report reached its estimates by taking the total amount of technically available biomass resources (either in bone dry tons or, in the case of landfills and wastewater treatment plants, biogas production in billions of cubic feet per year) and, using energy conversion factors, projected the total possible fuel production from that resource base in gasoline gallon equivalents.

Amy Myers Jaffe of UC Davis led a study performed for the ARB by UC Davis Institute of Transportation Studies that was published in June 2016 entitled "The Feasibility of Renewable Natural Gas as a Large Scale, Low Carbon Substitute." This study was notable for its effort to deploy economic modeling to estimate the RNG supply that would be stimulated by various economic factors, not the least of which was the price of Low Carbon Fuel Standard credits (LCFS, a California program) and Renewable Identification Numbers (RINs – the metric utilized by the Federal Renewable Fuel Standard). Jaffe's study also compared costs of RNG to conventional transportation fuels, including fossil natural gas. This novel and groundbreaking study projected the levels of price support (i.e. combinations of energy, carbon and renewable credit value) that would be required to incentivize production of biomethane. Using this econometric modeling, the report found that as much as 82.8 BCF (604 million DGE) of RNG could be produced annually in California.[17]

Finally, the most recent study, released in December 2019, was conducted by ICF on behalf of the American Gas Foundation (AGF). This report, "Renewable Sources of Natural Gas: Supply & Emission Reduction Assessment", was conducted as a follow up to a 2011 AGF RNG study, and evaluated the potential for RNG to "contribute meaningfully and cost effectively" to GHG reductions across the U.S. out to 2040.[18] The ICF analysis cast a considerably wider net, looking at the RNG resource potential of feedstocks not contemplated in the studies mentioned above. The nine sources of RNG included in the ICF projection includes landfill gas, animal manure, water resource recovery facilities (WRRFs), food waste, agricultural residues, forestry and forest product residues, energy crops, the use of renewable electricity, and the non-biogenic fraction of municipal solid waste (MSW).

To project the supply potential, ICF developed three scenarios for each of the nine resources listed above, each focused on different assumptions regarding the total resource utilization of each feedstock. This methodology resulted in a nationwide Low Resource projection of 1,910 trillion BTU (tBtu) of RNG by 2040, and a High Resource potential of 4,510 tBtu. Although the ICF study did not break out the RNG potential for California, it did break out the "Pacific Region", which includes California, Oregon and Washington. For these three states, the RNG supply

[16] Levin, et al, "Decarbonizing the Gas Sector: Why California Needs a Renewable Gas Standard", Bioenergy Association of California, (November 2014), p. 4
[17] This estimate assumed the LCFS credit price at $120/MT and the RIN value at $1.78. By way of reference, the LCFS credit price average $203/MT and the D-Code 3 RIN credit price averaged $1.17/RIN in May 2020. See Jaffe, "The Feasibility of Renewable Natural Gas as a Large Scale, Low Carbon Substitute," Prepared for the California Air Resources Board and the California Environmental Protection Agency, Contract No. 13-307, Sustainable Transportation Energy Pathways (STEPS) Program, June 2016, Institute of Transportation Studies, University of California, Davis, p. xiii
[18] Phillip Sheehy, "Renewable Sources of Natural Gas: Supply & Emission Reduction Assessment," Presentation to Renewable Gas 360 Symposium, Slide 2, Sacramento, CA, January 23, 2020.

potential ranged from a low of 192.9 to 359.4 tBtu, or 187 BCF to 349 BCF.[19] In addition to these assessments of the RNG supply potential, the ICF study also estimated that, in the absence of technical and economic constraints, the technical resource potential for RNG supply in the U.S. is nearly 13,960 tBtu.[20]

Each of these studies yield important and valuable information on the possibilities for future RNG production and provide law makers and regulators with useful guidance regarding how to promote the increased use and production of renewable gases with supportive public policy and incentives.

Methodology Used for this California RNG Supply Inventory

The prior section summarized several examples of the methodologies that have been utilized to estimate the potential future RNG supply from California-based biomethane production. This assessment differs in that it focuses on actual in-state RNG projects that exist or are currently under development. This study is not modeling the future; it is a tally of real RNG production facilities that developers have either built or are in the process of building. This inventory counts tangible projects and totals the cumulative volume of RNG that these developers claim they will bring to California's transportation fuel market by established dates.

To obtain the most accurate information available on current and future in-state RNG production, the authors of this report have communicated directly with RNG project developers/operators, government agencies, relevant trade associations, natural gas utilities, fuel marketers and other pertinent stakeholders to collect data on existing and planned RNG production facilities in California. Much of the data for this catalogue of California RNG production has been obtained from state and local agencies that have provided public funding, usually in the form of grants, to the developers of RNG production facilities. In addition, the authors have done extensive outreach to project operators and developers to secure information necessary to increase the fidelity of this assessment.

This inventory differentiates between projects that are or will be producing biogas for the purpose of generating electricity and those that will be cleaning the gas to vehicle and/or pipeline quality specifications. Thus, unlike the studies cited in the prior section, this is not an inventory of total RNG production. There are dozens of facilities in the state -- primarily landfills and wastewater treatment plants -- that use biogas produced onsite to generate electricity. For the most part, these plants have been excluded from this inventory, as they are not providing RNG for transportation customers. If, however, plant managers have indicated that they are actively pursuing the conversion of their operations from power generation to the provision of RNG for transportation, these projects have been included in this inventory.

Screening Projects for Inclusion in this Inventory

The authors have worked with stakeholders and industry experts to differentiate between "actual" or "real" projects and those that are (as of the time of this writing) too vague or insubstantial to include in this data base. Criteria that have been used to screen projects for incorporation in the study are enumerated below. Specifically, an RNG-production project qualified for inclusion if it:

- received grant funding or other incentives from a state or local government agency;
- received other debt or equity financing from private entities;
- secured feedstock and/or offtake agreements;
- entered into or completed CEQA review;
- applied for and received permits from relevant regulatory agencies;

[19]See pp. 13-14, "Renewable Sources of Natural Gas: Supply & Emission Reduction Assessment," An American Gas Foundation Study Prepared by ICF, December 2019.
[20]Ibid, p. 12. To provide a sense of the scope of this potential technical resource base, the ICF study says that, over the ten years between 2009-2018, the U.S. consumed an average of 15,850 tBtu/year. See p. 11.

- can substantiate that significant private resources have been expended for the development of the project; and,
- can demonstrate other attributes that indicate that the project is vested and in the process of development.

The projects that are included in this inventory do not have to demonstrate that they have achieved all of these criteria, but some combination of these attributes that gives both the authors and the developers justification to include the project in this report. It is believed that the project developers surveyed for this report have been conservative, and have excluded from this inventory projects that are only conceptual at the time of this research. In subsequent updates of this inventory, such conceptual projects may evolve to the point where it would make sense to include them in assessments of future in-state RNG production.

The Need for Confidentiality

To obtain data from most developers and existing RNG production facility operators, it was necessary to agree to keep their shared data confidential. As this inventory is focused on providing policy makers and industry stakeholder the aggregate, total current and future supply of in-state RNG, the authors agreed to keep individual company and project information confidential, in exchange for the ability to include each facilities fuel production information in the total. In some instances, when required by the developer/facility owner, non-disclosure agreements were executed. Thus, this study cannot and will not reveal the specific information associated with any single project, and will only present the cumulative fuel supply information.[21]

Temporal Presentation of the Aggregated RNG Production Data

To aid with planning, the study attempts to provide three primary temporal metrics (if the information is available):

- The total volume of in-state RNG that was being delivered to transportation end-users, and the weighted average CI of that RNG supply, on January 1, 2020;
- The volume of additional in-state RNG, and the impact of added RNG supply, on the cumulative energy-weighted average CI of the total RNG supply to that point in time. Such quarterly estimates of additional California supply and the changing CI value of the cumulative in-state supply is presented every quarter thru December 31, 2023; [22]
- The cumulative total of in-state RNG estimated to be delivered to transportation end users on January 1, 2024, and the average energy weighted CI of the aggregate RNG supply produced in the State of California.

The study cutoff of January 1, 2024 is not a hard deadline. Both the authors and industry advisors agreed that, if an RNG development project is "real" today, the project is likely to be delivering gas to customers within three and a half years. Although the date is somewhat arbitrary, it is informed by the extensive experience of many of the most successful RNG production project developers in the state. It was generally agreed among the several dozen parties that provided input to this inventory that, if a project is "real" today, it will be producing RNG for transportation end users within the proscribed time frame. In the course of this research, no developer sought to include a project that would be coming on line after January 1, 2024.[23]

[21]It is for this reason that we can not provide a list of names and locations of each of the 160 California-based RNG production facilities that this report projects will be online by January 1, 2024. For reasons unknown to the authors, several of the developers do not want, at this time, the names and locations of their projects to be made public. We are compelled to honor those requests, and thus chose not to publish a partial list. The authors will continue to seek permission to publish this list, and may amend this report in the near future.
[22]For most projects, the authors were able to obtain the projected date that the RNG would be brought to market. In those instances where such information was not available, it has been assumed that the RNG would be brought online at the end of the study period, January 1, 2024.
[23]The fact that no project is projected to come online after the study end date is testament to the "self-policing" that was conducted by RNG project developers. RNG project developers clearly understood the criteria for including a project in this assessment. Although there were several dozen additional projects that were brought to the attention of the authors, in all instances developers resisted seeking the addition of any potential project that did not meet the "test" established for inclusion.

Efforts Undertaken to Ensure the Inventory is Complete

To maximize the likelihood that this inventory is as comprehensive as possible, after roughly two months of research a preliminary list of all of the current and future RNG production projects was shared with more than a dozen RNG industry leaders, government agency specialists, fuel marketers, and others who are intimately familiar with the industry. These stakeholders were asked to review this list, which included only the information that was publicly available on the project (the name and its general location), and provide authors with their evaluation of this initial list of existing and future facilities. In addition, reviewers were asked to offer their views on whether all the projects in the preliminary inventory were still progressing. If reviewers knew of a project that was not on the list, they were asked to provide contact information to the authors so that the developers of the newly identified project could be contacted and asked if their data could be included in the inventory. This method provided valuable feedback to the authors and increased confidence that the register of in-state RNG production projects is complete.

Because of this approach, and the cooperation of most industry participants, the authors have a high degree of confidence that, as of the time of this writing, this inventory is comprehensive. This is, however, a dynamic industry, and that the data provided herein only presents a mid-2020 snapshot of the current and expected California-based RNG supply. During the 2nd half of 2020, many of the two dozen or so conceptual projects that were mentioned by developers during this research but not included in this assessment may mature to the point where it would be appropriate to include them in an update. In addition, given the substantial policy and financial incentives that exist today to capture fugitive methane and make it available for motor vehicle use, new RNG production projects are being announced on a regular basis. Finally, in October 2020 the California Department of Food and Agriculture (CDFA) will be announcing the awardees of the latest round of Dairy Digester Research & Development Program (DDRDP) grant recipients. The CDFA received applications for new dairy digesters totaling $47.3 million, and the farms that receive awards will no doubt increase the RNG supply projected for the beginning of 2024.

Presentation of the Data

The data have been collected in the energy units provided by their sources. There were four units of energy in which the data was provided. For consistency, the authors have taken the data provided by each developer and converted it into each of the three other units of energy measurements in which data was received. The four units of energy measurement include:

- Million British Thermal Units (MMBTU)
- Billion Cubic Feet (BCF)
- Gasoline Gallon Equivalent (GGE)
- Diesel Gallon Equivalent (DGE)

The authors of this study have found that different corners of the industry are comfortable with different energy metrics. Thus, to “speak the language” of as many stakeholders as possible, conversion factors were used to translate the units of energy that we received from sources in to these four metrics. The conversion factors were obtained from the models used by the ARB and other California agencies in modeling for GHG and criteria pollutant emissions. The factors that were used by this study can be found in Appendix 1.

Cumulative Carbon Intensity

In addition to the total projected in-state RNG supply, the authors believe it is important for policy makers and industry stakeholders to know the carbon intensity (CI) of the RNG supply from California RNG producers. Thus, the authors projected the average, energy-weighted cumulative carbon intensity of the California RNG supply, starting with the weighted average at the end of 2019, and continuing through every quarter between the beginning of 2020 through the end of 2023. As new California-based RNG has come online, we have calculated how the addition of this new gas impacts the cumulative energy-weighted CI score of California's RNG supply at the end of each quarter. This weighted CI value culminates in the estimated average, energy-weighted carbon intensity of all of California's transportation-bound RNG on January 1, 2024.

Where possible, GNA has used certified CI pathways. However, as the vast majority of the projects included in this study are not yet developed, they will not secure certified pathways until they can provide the ARB with data from at least three months of operations. Thus, to estimate the average carbon intensity of California's future RNG supply, we took the following steps:

- Utilized information from developers - If a developer is serious about a project, one of the first actions they are going to take is to perform a preliminary assessment of their RNG's probable CI value. Although most developers did not share their projected CI estimates, some did. When they did, their projected CI values were used.

- Used sector averages – Developer derived CI values were not available for the majority of projects. For these, the authors used an average of the certified CI scores from the most recent ARB Look Up Table. The authors performed this analysis for landfill gas, dairy manure, high solid anaerobic digestion, and wastewater RNG. The default Sector Average CI values that were used, are summarized in the table below.

Table 3: Average CI Values by Sector

Sector	Average CI
Landfill	44.37
Dairy	-277.73
HSAD	-11.30
Gasification	-87.50
Wastewater	25.33

As projects come online and obtain certified pathways, we will be able to update this model and increase the fidelity of estimated average energy-weighted carbon intensity of California produced RNG.[24]

Environmental Benefits

To provide policy makers and other stakeholders with a sense of the environmental impact of California sourced RNG, this study projects the GHG, criteria pollutant (NOx) and particulate matter reductions that will accompany the diversion of fugitive methane from the atmosphere and toward use in a medium or heavy-duty natural gas truck equipped with today's near zero emission (NZE) engines.

[24]For instance, on June 12, 2020 the Air Resources Board published six new proposed diary CI values for public comment. As all six of these new CI Pathways were for dairies included in this assessment, the authors decided to use the individual CI values for the six dairies as well as integrate these new CI's in to the dairy average. It is the author's assessment that these new dairy CI, although not yet "official", are likely better representations of the CI values that will be obtained by California dairies.

For the most part, the GHG emission reduction benefits have been taken directly from either the public record (DDRDP data) or from projections provided by developers. In some instances, the authors have had to estimate the GHG reduction benefit from the fuel production data coupled with the default CI value for that type of RNG.

For both NOx and PM reductions benefits, the authors have assumed that the RNG will be used in a new NZE-equipped natural gas truck and that those vehicles will be displacing a Model Year 2020 diesel truck. The figures provided herein, therefore, compare emissions factors for MY 2020 medium and heavy-duty vehicles taken from the EMFAC2017 (v1.0.2) Emissions Inventory. The analysis then assumes a 90% reduction in NOx emissions and a 100% reduction in diesel particulate emissions. It also assumes that NGVs, which are primarily equipped with spark-ignited engines, will incur a 10% fuel economy penalty (EER of 0.9).

It warrants mentioning that this methodology for estimating the NOx emission reduction benefits of today's natural gas trucks and buses likely severely underestimates the real-world reductions that these near zero emission engines deliver. The 90% NOx emission reduction factor used herein reflects the difference in the engine emission certification standards between a typical MY 2020 medium or heavy-duty diesel engine and their MY 2020 natural gas counterpart. There is increasing evidence, however, that in use diesel-fueled vehicles emit far greater levels of pollutants than their engine certification levels, while natural gas vehicles emit at or better than their certification levels. Numerous studies have been published in recent years that document that medium and heavy-duty diesel engines emit much more smog-forming gases in real world performance than the emissions levels these engines certified to in labs, particularly in urban duty cycles (i.e. slower speeds, idling, stop-and-go traffic, etc.).[25] Thus, diesel-fueled trucks and buses are much dirtier than assumed by air quality regulators. Simultaneously, some of these same studies have found that trucks equipped with the "near zero" emission natural gas engines (which have been commercially available since September 2015[26]) perform consistently better than their engine certification levels, and found that real-world emissions actually decreased in the kinds of urban driving cycles that expose more people, particularly in disadvantaged communities, to pollutants.[27]

Economic Benefits

This study provides a projection of the total investment, both public and private, in the 160 RNG production facilities that have been identified herein to be operational on January 1, 2024. To calculate the total investment, the authors used data provided by public sources (for instance, the DDRDP database includes both the value of the grant and the private match reported by the dairy digester developer) or figures provided by the developers. Using these sources, the authors were able to gather cost data on 129 out of 160 RNG production projects. Investment information was not available, however, for 31 of the projects. Thus, the capital investment information that is presented in incomplete, and underestimates the total public and private capital that has and will be flowing to these projects.

Caveats

There were several issues that confronted researchers as they worked to accumulate the data needed to provide an answer to the questions asked by this study. While none of the issues described herein significantly alter the conclusions, they warrant discussion.

[25]A sampling of these studies include Badshah et all., Current State of NOx Emissions from In-Use Heavy-Duty Diesel Vehicles in the United States, the International Council on Clean Transportation, November 2019; Sandhu et al., 2017, In-Use Emission Rates for MY 2010+ Heavy-Duty Diesel Vehicles, CRC On-Road Vehicle Emissions Workshop https://www.epa.gov/sites/production/files/2019-08/documents/crc-in-use-hdv-emission-rates-2017-03.pdf; Anenberg et al., 2017, "Impacts and mitigation of excess diesel-related NOx emissions in 11 major vehicle markets," Nature 545: 467-471 https://pubmed.ncbi.nlm.nih.gov/28505629/; Tan et al., On-Board Sensor-Based NOx Emissions from Heavy-Duty Diesel Vehicles, Environmental Science and Technology, 2019, Vol. 53, No. 9, pp. 5504-5511.

[26]See Leonard, et al., Gamechanger – Technical White Paper, Gladstein, Neandross & Associates, 2016, p. 70.

[27]Johnson, et al., Ultra-Low NOx Near-Zero Natural Gas Vehicle Evaluation ISX12N 400, College of Engineering-Center for Environmental Research and Technology, University of California, Riverside, April 2018; Li, C., Han, Y., Jiang, Y., Yang, J. et al., Emissions from Advanced Ultra-Low-NOx Heavy-Duty Natural Gas Vehicles,
SAE Technical Paper 2019-01-0751, 2019, doi:10.4271/2019-01-0751; Zhu et al., Characterizing emission rates of regulated and unregulated pollutants from two ultra-low NOx CNG heavy-duty vehicles, Fuel, Vol. 277, October 2020, 118119.

Reliance on Developer Projections

To arrive at a projection for future RNG supply, the authors had to rely on developers to provide their estimates of the anticipated production of their projects. For the most part we encouraged developers to be conservative in their projections, but in the absence of ability to independently verify information, this inventory has relied on information from interested parties. The authors were not in control of data that was shared by developers. The authors made every effort to compensate for possible exaggeration by thoroughly questioning developers and encouraging them to be realistic in the figures that they shared. Another control implemented to build in moderation is the fact that this study rarely presents nameplate RNG production capacity as the figure included in the study's estimate of aggregate production.

Projection vs Actual

The vast majority of the RNG that will be available for transportation use on January 1, 2024 will come from production facilities that are not yet operational. As will be noted in the findings, only 2.7% of the RNG consumed by California's natural gas vehicles comes from sources in the state. Thus, this study is, in essence, a survey of projections, albeit well informed projections. Ultimately, the actual RNG production will not be confirmed until each and every facility is up an operating for at least a year. Only then will stakeholders be able to evaluate the accuracy of the data provided for this study.

Project Fate

It is unlikely that every project that contributed to this inventory of future in-state RNG supply will succeed. Although every project included in this study cleared a screening process in order to be included in this database, experience indicates that some projects will inevitably fail – a permit application may be unsuccessful, a lawsuit may halt progress, financing may fall through, projected environmental credit revenue may be less than needed to ensure viability – and will not make it to through the development process to RNG projection. There are hundreds of things that must go right for a multi-million-dollar RNG production plant to succeed, and thousands of things that can go wrong. The uncertainties brought on by the COVID-19 crisis and the resulting economic and financial tumult only increase the likelihood that not every project included in this inventory will be completed.

Nonetheless, at the time of the publication of this report, the information contained herein reflects the authors' best, most accurate accounting of the RNG projects currently underway that enjoy the highest probability of success.

Dairy Sector Data

There are 137 dairies in this inventory. The authors received RNG production and GHG reduction information directly from the developers for 38 of the dairy projects (28%). Other public sources provided energy production/ GHG reduction estimates for approximately 20 more (15%) dairy digesters. For a variety of reasons (primarily sector competitive anxieties), the authors were not able to obtain direct RNG production data for approximately 60% of the dairy digester projects included in this inventory.

However, all of the dairy digester projects for which RNG production data were unavailable were recipients of a CDFA DDRDP grant. The DDRDP posts the projected GHG emission reduction benefits of each project. Under the CDFA Dairy Digester program, the majority of GHG emissions are attributed to reductions in fugitive methane emissions that are subsequently captured and directed to the transportation market. To estimate energy production from each project, the reported GHG reductions were translated to a CO2 equivalent mass of methane emissions using the CDFA program's global warming potential for methane of 25. Once mass emissions of methane captured were estimated for each project, the associated MMBTU of energy production was determined based on the heating value of the methane.

Findings

By January 1, 2024, there will be 160 RNG production facilities in California annually producing over 15.8 million MMBTU (119 million DGE) of fuel for the state's transportation sector. The breakdown by feedstock of this future production capacity is as follows:

Table 4: Projected Annual RNG Production by Sector, January 1, 2024

Sector	Percentage	MMBTU	SCF	GGE	DGE
Landfill	38.4%	6,087,775	5,935,084,199	51,745,235	45,729,776
Dairy	36.6%	5,797,281	5,628,428,291	49,191,380	43,564,503
HSAD	10.5%	1,669,325	1,628,800,738	14,193,660	12,538,192
Gasification	10.4%	1,650,000	1,601,941,748	14,000,663	12,399,162
Wastewater	4.0%	646,134	640,436,841	5,482,605	4,767,849
Total		**15,850,515**	**15,434,691,818**	**134,613,543**	**118,999,483**

Landfill gas projects will make up the largest proportion (38.4%) of in-state RNG supply at the beginning of 2024, followed closely by RNG from the dairy sector (36.6%). High solids anaerobic digestion (most often associated with the management of the organic portion of municipal solid waste), gasification, and biogas from wastewater treatment plants will comprise the balance (24.9%). At this time, we do not possess any evidence that a power-to-gas project (P2G) will be built in California in the time frame of this project and deliver RNG to the transportation sector.

Dairy digesters will far outnumber all other RNG production facilities combine. The projected breakdown of facilities by sector is as follows:

Table 5: California RNG Facilities in 2024 by Sector

Sector	# of Facilities
Dairy	137
Landfill	8
High Solid Anaerobic Digester (HSAD)	7
Wastewater Treatment Plant	7
Gasification of Dry Wood	1
Total	**160**

It warrants noting that gasification and landfill gas facilities are the most prodigious when it comes to the production of pipeline quality RNG. Most landfills in California already have much of the infrastructure in place to capture landfill gas, although at this time most landfills flare the biogas that they collect. Gasification is associated with the management of drier organic waste, such as construction waste, orchard clippings, and dead or dying trees from state or federal forests. Thus, both of these sectors are poised for significant growth over the next decade.

New In-State RNG Supply by Quarter

Table 6 below reflects both the quarter that new California-based RNG supply is projected to be coming to market, as well as the energy-weighted CI value of the cumulative California RNG supply at the end of each quarter. In the four years of this assessment (2020 thru 2023), in-state RNG production will increase from 3.8 million DGE by 115.2 million DGE to 119 million DGE, a >3000% increase.

Table 6: New In-State RNG Supply by Quarter; Cumulative Energy Weighted Carbon Intensity

Year	Quarter	Annualized Energy Production (MMBTU/year)	RNG added by end of the Quarter (MMBTU)	Annual Energy Production (DGE)	RNG added by end of the Quarter (DGE)	Energy-weighted average CI of total production within the quarter (gCO_2e/MJ)
2019	4	502,176	-	3,773,670	-	-193.95
2020	1	784,678	282,502	5,896,573	2,122,902	-133.63
	2	2,961,273	2,176,596	22,252,914	16,356,342	-133.55
	3	3,307,846	346,573	24,855,017	2,602,103	-147.64
	4	4,292,846	985,000	32,256,941	7,401,924	-148.19
2021	1	5,512,279	1,219,433	41,420,548	9,163,606	-176.84
	2	5,568,170	55,891	41,840,548	420,000	-174.62
	3	5,568,170	-	41,840,548	-	-174.62
	4	7,515,999	1,947,829	56,477,789	14,637,241	-201.34
2022	1	10,557,035	3,041,036	79,330,092	22,852,303	-130.56
	2	10,630,035	73,000	79,878,661	548,569	-131.57
	3	10,630,035	-	79,878,661	-	-131.57
	4	11,034,239	404,204	82,916,108	3,037,447	-136.93
2023	1	11,034,239	-	82,916,108	-	-136.93
	2	11,034,239	-	82,916,108	-	-136.93
	3	11,034,239	-	82,916,108	-	-136.93
	4	11,034,239	4,816,276	82,916,108	36,083,375	-136.93
For all 2024		15,850,515	15,348,340	118,999,483	115,225,812[28]	-101.74

One observation to note is when the ARB established the in-state RNG requirement for HVIP voucher recipients, there was only the capacity in California to produce 3.8 million DGE per year (enough to fuel roughly 435 natural gas trucks). Thus, at the end of 2019, in-state facilities provided only 2.1% of the state's total consumption of natural gas as a transportation fuel, or just 2.7% of the total RNG supply used by California vehicles. Inversely, it also means that out-of-state RNG supplies provided for 97.3% of California's RNG demand in 2019.

[28]This figure represents the new RNG production capacity that will be built in California between January 1, 2020 and January 1, 2024.

Weighted Carbon Intensity

Table 6 also calculates the average, energy weighted CI value of the new, projected California sourced RNG supply. On January 1, 2024, the average CI value will be -101.74 gCO2e/MJ. This figure compares very favorably to both the average, energy weighted CI for RNG (both CNG and LNG) consumed in California over the last seven years (2013 – 2019), which was 31.96 gCO2e/MJ, or the energy weighted CI for 2019, which was 35.49 gCO2e/MJ. By way of reminder, virtually all of the RNG consumed in California between 2013 and 2019 (over 560 million DGE) came from out of state.

At the beginning of 2020, the energy-weighted CI for in state RNG was almost twice as low as it is projected to be at the beginning of 2024. This is due to the impact of dairy RNG on the cumulative CI score. The increase in CI value over the study period is due to the influence of landfill gas (LFG) on average carbon intensity. The CI factor used for landfill projects in this study is 44.37 gCO2e/MJ. As detailed in Table 4, by the end of the study period the eight landfill gas projects that are projected to be delivering RNG to the California transportation sector will be supplying the plurality of in-state RNG. Most of these LFG projects will be coming online in the last two years of the study period. This new RNG from landfills drags the cumulative, energy weighted CI value closer to zero, and this is reflected in the diminishing CI value. As the dairy projects reported herein come online and receive certified CI values, it is likely that this energy-weighted average will improve.

The actual cumulative, energy weighted CI score on January 1, 2024 will likely to be better (lower) than the projected CI value of in-state RNG reported in this study (-101.74 gCO2e/MJ). There are several factors that support this prediction. First, the average CI value of California dairies is likely lower than the average CI factor used herein to estimate the average carbon intensity of dairy RNG.[29] Second, before the end of the year CDFA will announce funding for between 15 to 20 new dairy digesters, all of which are likely to be producing RNG before the end of the study period. Given the average RNG production from the 137 dairy digesters in this inventory, these newly funded dairy digesters are estimated to bring between 4.8 million to 6.4 million DGE of new dairy RNG to market, and push the California dairy RNG producers past the LFG sector to become the largest feedstock source of in-state RNG supply.[30]

Of course, these predictions could be offset by the addition of new landfill or wastewater RNG supplies not anticipated by this inventory. For now, however, this study projects that the average natural gas truck fueled with California-sourced RNG on January 1, 2024 with an energy-weighted average of -101.74 gCO2e/MJ, will roughly offset the GHG emissions of two average diesel trucks consuming diesel with an average CI of 100.82 gCO2e/MJ.

Economic Investment

As noted in the Methodology section, the study was able to secure cost data on 129 out of 160 in-state RNG production projects, or 80% of the facilities in this study. For those 129 existing and future RNG production facilities, nearly $1 billion will be invested in their development between now and 2024. The capital investment data that we were able to capture is summarized in Table 7 below.

Table 7: Total Project Investment

Public Funding Secured	Private Match	Total Investment
$223,835,745	$751,949,125	$975,784,870

[29]The dairy CI factor used for this study is -277.73 gCO2e/MJ. The average CI of the six Calgren dairies is -331.8 gCO2e/MJ.
[30]The RNG production from the average California dairy is projected to be 318,000 DGE/yr at the beginning of 2024. Fifteen to twenty new dairy digester projects may increase the sector's total in-state RNG production to 48.3 million to 49.9 million DGE. It may also increase the cumulative total of in-state RNG production to 123.8 to 125.4 million DGE.

Although it is a crude methodology, one way to estimate investment in the missing 31 projects would be to extrapolate the capital needed based on the average investment in the 129 projects for which data were obtained. This works out to be about $7.6 million per project. When applied to each of the 31 in-state RNG facilities for which we were unable to secure investment data, the total projected investment in RNG production facilities included in this inventory increases by $235 million. Thus, using this extrapolation, we can estimate that the total capital investment in the California-based RNG production facilities outlined in this study will be over $1.2 billion.

It is worth noting that the vast majority (77%) of investment into California-based RNG production -- which should also be viewed as investment in achieving the short-lived climate pollutant reduction goals of SB 1383 -- comes from the private sector. This is testament to the utility and effectiveness of the state's LCFS program and the market signals that it sends to investors.

Environmental Benefit

As should be expected, the potential environmental benefits of this new in-state RNG supply will be considerable. We assume that, beginning on January 1, 2024, the 119 million DGE of in-state RNG will be used to fuel new NZE natural gas trucks and buses. These vehicles will deliver at least the following emission reductions benefits, compared to a fleet of new diesel trucks.[31]

Table 8: Total Emission Reductions

Time Frame	Projected GHG Reduction (MTCO2e)	Projected NOx Reduction (tons)	Projected DPM Reductions (tons)
One Year	3,424,156	1,387	8.62
Ten Years	34,241,560	13,870	86.2
Fifteen Years	51,362,336	20,802	129.27

A Cost Effectiveness Analysis

This study was initiated to better understand the ramifications of ARB's policy to require NGVs seeking a HVIP voucher to fuel with in-state RNG. Now that stakeholders have a clearer insight into the current and future supply of California-produced RNG, and the environmental benefits that this supply of RNG could deliver to the state, it may be valuable to explore the potential cost effectiveness of utilizing the HVIP program to secure these GHG and criteria emission reductions. To illustrate, the authors have formulated the following scenario.

EMFAC 2017 assumes that the average California heavy-duty truck consumes 7,800 gallons of diesel fuel annually.[32] To calculate the energy equivalence for today's natural gas truck, this average fuel consumption for diesel has to be divided by the EER for heavy-duty NGVs, which is 0.9. Thus, the amount of fuel that a natural gas truck will consume to go the same distance as its diesel counterpart will be 8,667 DGE.

This assessment projects that there will be 119 million DGE of RNG produced in California by the beginning of 2024. If all of this RNG supply was to fuel a fleet of new natural gas trucks, it would be enough to fuel 13,731 trucks annually.

[31]See the description of Environmental Benefits herein, p.17 – 18. The baseline for comparison is a MY 2020 diesel truck with an engine that meet the current heavy-duty engine emission standard of 0.2 grams of NOx per brake horsepower hour.
[32]Statewide average fuel consumption for Class 7-8 truck categories in EMFAC 2017.

If the HVIP provided a $45,000 voucher toward the purchase of each of these new NZE heavy-duty natural gas trucks, it would cost the state $618 million. Assuming a fifteen-year life for each of these vehicles, this hypothetical fleet would generate 51.4 million metric tonnes of CO2e and 20.8 thousand tons of NOx reductions, at a cost of $12.03/MT of CO2e and $29,702 per ton of NOx.[33] For comparison, the cost effectiveness of emission reductions from the average heavy-duty battery electric truck that received a HVIP voucher on the 2019 wait list was $545.85/MT of GHG and $299,401/ton of NOx.[34] From any perspective, the cost effectiveness of the emission reductions that California would obtain from using HVIP to fund NGVs fueled with California RNG is very attractive.[35]

Conclusion

California seeks to simultaneously reduce its carbon footprint, meet national ambient air quality standards, improve energy resilience and promote a sustainable economy for its nearly 40 million residents. Any plan to meet these goals must begin with the state's transportation sector. California's transportation sector consumes 40% of the state's energy and is by far the largest source of greenhouse gases, smog-forming chemical compounds and toxic air contaminants. State policy makers have long prioritized reducing the use of diesel in transportation, as diesel exhaust is a known carcinogen that constitutes more than half of the airborne cancer risks in areas with intense use of heavy-duty diesel vehicles

To accomplish these goals, California needs a diverse and dynamic portfolio of strategies that not only maximizes the benefits to the goals outlined above but that also optimizes synergies with other essential social objectives, that include but are not limited to: protecting communities disproportionately impacted by environmental insults, shrinking the use of landfills for solid waste management, reducing and eliminating sources of contamination of receiving waters, and implementing strategies that reduce the wildfire fuel load in the state's parched forests. It also requires increased investment in California's economy, job creation and the ability of the state's businesses to help achieve these social and environmental goals. Throughout all of these critical initiatives, the state must find ways to not only boost the most cost-effective strategies, but also pursue policies that are faithful to the precepts of sustainability: reduce, recover, reuse and recycle.

In the next three and half years, this research indicates that over $1 billion in new RNG facilities will come on line, producing 119 million DGE of carbon negative fuel capable of fueling over 13,700 near zero emission NGVs that could provide carbon negative transit and transportation services to Californians. This climate-friendly fuel has the potential to cost effectively deliver millions of tons of GHG and thousands of tons of NOx reductions, as well as eliminate emissions of diesel particulates. Increased in-state production of RNG, which is the same as an investment in reducing short lived climate pollutants, is clearly in California's interest, but will only subtract from the state's pollution ledger if investments are made now in new, near zero emission natural gas trucks and buses.

[33]ARB staff uses a project life of 15 years for the calculation of NOx benefits and a three-year life for the calculation of GHG benefit. The three-year life is tied to staff assumptions regarding the term of the fuel contract. However, in this scenario the funded vehicles would be using California RNG for the life of the vehicle. See California Air Resources Board, Fiscal Year 2019-2020 Funding Plan on Clean Transportation Incentives - Appendix A: Emissions Reductions Quantification Methodology, pp. A-36-A37, https://ww2.arb.ca.gov/sites/default/files/2019-09/fy1920fundingplan-appa.pdf. For reference, in the May auction for the California Cap-and-Trade Program, the settlement price for an allowance (one metric ton of CO2e) was $16.68. See https://ww3.arb.ca.gov/cc/capandtrade/auction/results_summary.pdf

[34]Ibid. See Table A-30 for HVIP Annual Emissions Benefits on a Per-Vehicle Basis (p. A-31) and Table A-31: HVIP (waitlist) Average Incentive Cost (p. A-32). To provide a more accurate comparison, the GHG and NOx reductions for a HHD BEV were used, as was the incentive cost for a HHD BEV.

[35]At this time, the cost effectiveness limit for the state's oldest and most successful vehicle incentive, the Carl Moyer program, is $30,000 per weighted ton of emissions reduction, which included not only NOx, but also reductions in emissions of reactive organic gases (ROG) and particulate matter. See ARB, Appendix C: Cost-Effectiveness Calculation Methodology, 2017, p. C-2 thru C-5. https://ww3.arb.ca.gov/msprog/moyer/guidelines/2017gl/2017_gl_appendix_c.pdf

Appendix 1: Energy Conversion Factors

	One unit of:	MMBTU	SCF	GGE	DGE
Equals units of:	MMBTU	1.00	0.00103	0.12	0.1331
	SCF	970.87	1.00	118.05	137.05
	GGE	8.49	0.00847	1.00	1.16
	DGE	7.51	0.00730	0.86	1.00

(See "Fuel_Specs" worksheet within CA-GREET 3.0 model)