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CONSULTANT REPORT

Renewable Natural Gas in California

Characteristics, Potential, and Incentives: 2023 Update

Prepared for: **California Energy Commission**
Prepared by: **Verdant Associates**

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PREFACE

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ABSTRACT

From fires to floods, climate change has fueled an increase in severe weather events across the globe. California is at the forefront of tackling the ever-increasing climate crisis and, along with its greenhouse gas emission reduction goals, has passed legislation supporting the production and use of renewable natural gas.

In 2018, California Senate Bill 1440 (Hueso, Chapter 739) directed the California Public Utilities Commission (CPUC) to evaluate whether to establish goals or targets for renewable natural gas purchases by California's gas utilities. In November 2019, the CPUC issued the Assigned Commissioner's Scoping Memo and Ruling Opening Phase 4 of Rulemaking 13-02-008 addressing implementation of SB 1440. On December 6, 2019, the CPUC's Energy Division hosted a technical workshop to discuss SB 1440 implementation.

This report presents a snapshot of renewable natural gas in California, including sources of renewable natural gas within California, estimates of potential production, carbon intensities for different sources, federal and state incentive programs, and federal and state policies that may affect the future of renewable natural gas within California. This report is intended to help inform and frame other policy efforts such as the Integrated Energy Policy Report and be updated periodically to keep sources and data current.

Keywords: Anaerobic digester, biogas, BioMAT, biomass, biomethane, dairy, HSAD, landfills, LCFS, livestock, low carbon fuel standard, NEM, net energy metering, pipeline interconnection, REAP, RECs, renewable fuel standard, renewable natural gas, RFS, RNG, self-generation incentive program, SGIP, wastewater treatment plant, water resource recovery facility

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Introduction

Renewable natural gas is a renewable, lower-carbon-intensity substitute for fossil natural gas. It is composed of methane and other gases and is produced in a renewable manner when organic material is decomposed anaerobically (in the absence of oxygen) or through gasification or pyrolysis. This gas is then processed, cleaned, and injected into the natural gas system or used as a transportation fuel.

Renewable natural gas may be particularly attractive for use in sectors that are hard to electrify, such as industrial processes. Furthermore, it could reduce greenhouse gas emissions in buildings while avoiding the need to replace water heaters, furnaces, and other natural gas-fueled appliances with electric appliances. California is increasingly looking to RNG as a potential fuel to help decarbonize its energy supply. This report summarizes RNG sources, production potential, costs, and incentives in California.

Purpose and Scope

This report provides a comprehensive picture of renewable natural gas within California and is planned to be updated periodically. This report will provide policy makers and other stakeholders a source to support ongoing policy development and research.

The scope of this report includes:

- An overview of renewable natural gas.
- Descriptions of renewable natural gas production methods used at livestock farms (mostly dairies), wastewater treatment plants, landfills, biomass processing plants, and high solids anaerobic digestion facilities.
- An estimate of how many production plants exist in California.
- Estimates of the cost to produce renewable natural gas by facility type.
- A discussion of how renewable natural gas feedstock sources impact carbon intensity.
- A catalog of the available state and federal incentives for the production and use of renewable natural gas.

The report also summarizes the key findings of this research.

Approach

Verdant Associates (Verdant) researched the sources of renewable natural gas within California and estimates of the market and technical potential from in-state and out-of-state sources. Verdant also researched carbon intensities based on the source of renewable natural gas and federal and state incentive programs and policies that may affect the future of this fuel in California. The project team collected and integrated data from secondary sources such as published data from state agencies, published reports by other consultants, direct outreach to industry, and Verdant's analysis of available data. The synthesized data are intended to provide a snapshot of renewable natural gas within California that can be easily updated periodically.

Findings and Results

Figure 1 below highlights the different sources of renewable natural gas and describes the respective potential natural gas displacement, cost to produce, carbon intensities, and Low Carbon Fuel Standard incentives. This paper focuses on the following sources of biogas in California: livestock facilities, Water Resource and Recovery Facilities, landfills, biomass, and high-solids anaerobic discharge facilities.

- Livestock: Livestock facilities include dairies and swine farms, although in California, the primary source of RNG is in dairies.
- Water resource and recovery facilities (WRRFs), also known as wastewater treatment plants: The larger facilities (those that process more than 1 million gallons of water per day) are required to, at a minimum, collect and destroy the methane produced.
- Landfills: Similar to water resource and recovery facilities, California law requires most landfills greater than 450,000 tons of waste-in-place to collect and destroy methane produced by the landfill.
- Biomass: Biomass is generally defined as any organic matter used for fuel. Biomass is usually generated by forest residue, sawmill sources, crop residue, or wood demolition waste (urban), which are all types of biomass that can be decomposed using a process like gasification to produce methane.
- High-solids anaerobic discharge: These facilities process green waste (food scraps, yard clippings, and so forth) from municipal sources, breweries, or other food processing plants.

Figure 1: Comparison of Renewable Natural Gas Sources

	Livestock	WRRF	Landfills	Biomass	HSAD
Potential Displacement of California's Natural Gas Consumption					
	• Production Potential: 1 - 3% • Technical Potential: 4%	• Production Potential: <1% • Technical Potential: <1%	• Production Potential: 6 - 10% • Technical Potential: 15%	• Production Potential: 1 - 3% • Technical Potential: 11%	• Production Potential: 3 - 7% • Technical Potential: 17%
Cost to Produce RNG [$/MMBtu]					
	$25.50	$16.75	$13.00	$23.25	$30.75
Carbon Intensity Compared to the Baseline (Flaring or Venting) [gCO2e/MJ]*					
	-341	+28	+42	+13	-23
Reduction in Carbon over Natural Gas [gCO2e/MJ]					
	417	47	34	62	99
LCFS Incentive [$/MMBtu]					
	$53.85	$6.12	$4.40	$8.06	$12.79

***Carbon intensity for biomass is based on wood waste while potential also includes crop waste.**

Source: Verdant Associates. The specific sources of these numbers are cited throughout this report.

Renewable natural gas advocates cite the potential for this fuel to displace a portion of California's natural gas consumption as an important factor for decarbonizing fuel supply. Several reports have identified the production potential and technical potential of renewable natural gas. The production potential considers unique constraints for each potential feedstock based on factors such as feedstock accessibility and economics of production using that feedstock. The technical potential estimates the potential without these constraints. Some sources, like wastewater treatment plants, have limited technical potential for renewable natural gas production, while other sources, like landfills or high-solids anaerobic discharge facilities, may be able to displace 10 to 17 percent (respectively) of California's natural gas consumption.

Landfills and wastewater treatment plants have lower estimated renewable natural gas production costs (under $20 per MMBtu) versus the production costs for livestock and high-solids anaerobic discharge facilities, which range in the high $20s to low $30s per million British thermal units (MMBtu). High production costs can be a significant barrier, and incentives may be needed to encourage production.

Renewable natural gas produced at livestock farms and high-solids anaerobic discharge facilities can be a carbon-negative fuel source. In the absence of renewable natural gas production, methane, which occurs as a natural by-product at these facilities, would be vented to the atmosphere. Methane has 25 times more greenhouse gas potential than carbon dioxide. Therefore, capturing it for use as fuel will result in significant carbon savings. While renewable natural gas produced at other facility types is not carbon-negative like livestock and high-solids anaerobic discharge facilities, it still results in a reduction in carbon relative to the use of fossil natural gas. The carbon intensity of renewable natural gas, relative to fossil natural gas, produces a range from a 47 percent reduction for landfills to an 84 percent reduction for wood waste biomass facilities. For livestock and high-solids anaerobic discharge facilities, the production of renewable natural gas results in carbon reductions greater than 100 percent compared to fossil natural gas.

There are significant incentives available for renewable natural gas production, particularly if it is used as a transportation fuel. California's Low Carbon Fuel Standard program provides significant incentives based on the carbon intensity of the fuel. While producing renewable natural gas at livestock facilities may be expensive, the Low Carbon Fuel Standard credits can be three times higher than the cost to produce the fuel. Renewable natural gas incentives or credits can be increased if the Low Carbon Fuel Standard credits are stacked with other incentives like those from the federal Renewable Fuel Standard program.

Updates Since Last Report

This report is an update of the original report, CEC-200-2022-006, published in September 2022. The most substantial changes since that report are in the Low Carbon Fuel Standard market, where credit prices fell to less than half and the percentage of renewable natural gas from livestock (primarily dairies) increased substantially. Those and other notable updates from the original report include the following:

- Average Low Carbon Fuel Standard credit prices fell by more than half, dropping from $182 per metric ton in October 2021 to $86 per metric ton in December 2022.
- Livestock farms provided 37 percent of the renewable natural gas for the Low Carbon Fuel Standard in the second quarter of 2022, substantially higher than the 9 percent these facilities historically provided through the end of 2021.
- Thirty-six additional landfills installed (or were found to have installed) methane collection systems used for generation, pipeline injection, or both.
- Two additional biomass plants became operational, raising the total to 29 operational or pilot projects.
- The average federal Renewable Fuel Standard renewable identification number price rose to the highest prices seen by the program to date,
- The California Energy Commission's total historical 2020 natural gas baseline usage fell slightly from the forecasted 12,885 million (MM) therms down to 12,518 MM therms. However, the forecasted 2030 usage increased from 12,765 to 13,274 MM therms. See the revised California Natural Gas Usage in Figure 12.

CHAPTER 1: Introduction

California is at the forefront of tackling the ever-increasing climate crisis. As part of the state's stringent greenhouse gas (GHG) emission reduction goals, California has passed legislation to offer incentives for producing renewable natural gas (RNG). RNG is a renewable substitute for fossil natural gas. For this report, RNG is defined as methane and other gases formed renewably when organic material is decomposed anaerobically (in the absence of oxygen) or through gasification or pyrolysis, which is then processed, cleaned, and injected into the natural gas pipeline. RNG may be particularly attractive for use in sectors that are hard to electrify such as industrial processes. Furthermore, RNG can reduce GHG emissions in buildings without having to replace water heaters, furnaces, and other natural gas-fueled appliances. This report summarizes RNG sources, production potential, costs, and incentives in California to provide a basis for informing policy and decision makers.

Defining Renewable Natural Gas

The industry often uses the terms "biogas," "biomethane," and "RNG" interchangeably. This report uses the following definitions:

Biogas: Gas produced from an organic waste feedstock by one of the following processes:

- Anerobic decomposition of organic material, including codigestion.
- Noncombustible thermal conversion of any of the following materials:
  - Agricultural crop residues
  - Bark, lawn, yard, and garden clippings
  - Leaves, silvicultural residue, and tree and brush pruning
  - Wood, wood chips, and wood waste
  - Nonrecyclable pulp or nonrecyclable paper materials
  - Livestock waste
  - Municipal sewage sludge or biosolids

Biogas is not necessarily pipeline-quality gas. California laws, statutes, and programs such as CPUC Section 650,[1] the *Renewable Portfolio Standards (RPS) Eligibility Guidebook,*[2] and the

1 CPUC Section 650 is defined in California Senate Bill 1440 (Hueso, Chapter 739, Statutes of 2018). Biomethane Procurement. Available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1440.

2 Green, Lynette, and Christina Crume. 2017. *Renewables Portfolio Standard Eligibility Guidebook, Ninth Edition.* California Energy Commission. Publication Number: CEC-300-2016-006-ED9-CMF-REV. Available at https://efiling.energy.ca.gov/getdocument.aspx?tn=217317.

Biogas Market Adjusting Tariff (BioMAT) program[3] used to provide formal definitions of biogas, but the most recent versions have since removed the definition. The Self-Generation Incentive Program (SGIP) still uses the term "biogas" but provides no formal definition in the documentation. Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012) formally defines biogas as "gas produced from the anaerobic decomposition of organic material."[4]

Biomethane: Biogas that has been refined and processed and meets standards adopted under subdivisions (c) and (d) of Section 25421 of the California Health and Safety Code for injection into a common carrier pipeline. This definition means that it is pipeline-ready but has not necessarily been injected into the pipeline.

Renewable natural gas: As there is no formal current definition identified for RNG within California laws, statutes, and programs, this report defines RNG as biomethane that has been injected into a pipeline to replace natural gas. This definition is consistent with the description used by the United States Environmental Protection Agency (U.S. EPA), which states, "RNG is a term used to describe biogas that has been upgraded for use in place of fossil natural gas."[5] This is similar to the term "renewable gas," which includes hydrogen and is synonymous to the term "directed biogas" used by the SGIP.

Legislative and Policy Background

In 2018, Senate Bill (SB) 1440 directed the California Public Utilities Commission (CPUC) to evaluate whether to establish goals or targets for RNG purchases by California's gas utilities.[6] In November 2019, the CPUC issued the Assigned Commissioner's Scoping Memo and Ruling Opening Phase 4 of Rulemaking 13-02-008 addressing implementation of SB 1440. On December 6, 2019, the Energy Division hosted a technical workshop to discuss SB 1440 implementation. Senate Bill 1440 did not specify RNG cost-effectiveness metrics or benchmarks to compare RNG to other decarbonization options.

The CPUC has begun implementing SB 1440 with several decisions and policies including:

- D.20-08-035: Standard Renewable Gas Interconnection Tariff that adopted a gas quality and interconnection standard to protect human health and ensure pipeline integrity.
- D.20-12-031: Standard Renewable Gas Interconnection Agreement that defined the standardized contract between interconnectors and gas utilities (Pacific Gas and Electric

3 CPUC. Bioenergy Feed-in Tariff Program (SB 1122). Available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/rps/rps-procurement-programs/rps-sb-1122-biomat

4 California Assembly Bill 1900. Gatto. Renewable energy resources: biomethane. Available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201120120AB1900.

5 This description has the following footnote: RNG is a "term of art," and there is not at present a standard definition. This description has been developed by U.S. EPA's voluntary programs.

6 California Senate Bill 1440 (Hueso, Chapter 739, Statutes of 2018). Available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1440.

Company [PG&E], Southern California Gas Company [SoCalGas], San Diego Gas & Electric Company [SDG&E], and Southwest Gas).

- D.20-12-022: CPUC approved SoCalGas and SDG&E Voluntary Renewable Natural Gas Tariff that will provide gas utilities a pathway to sell RNG to their customers.

In addition, AB 1900 created an incentive program to aid RNG pipeline interconnection costs.[7] This program provides financial assistance to help RNG producers connect with the natural gas network.

Assembly Bill 3163 (AB 3163) defined biomethane and expanded the original definition from CPUC Public Utilities Code 650[8] to include biomethane from biomass that comes from additional forms of organic waste, including vegetation removed for wildfire mitigation.[9] The AB 3163 definition may allow for increased production of RNG from biomass. The AB 3163 definition does not include purpose-grown crops used to produce RNG.

Finally, the goal of SB 1383 is to reduce landfill disposal of organics by 50 percent by 2020 and 75 percent by 2025 compared to 2014 levels.[10] This abatement will reduce the emissions of short-lived climate pollutants, such as black carbon, fluorinated gases, and methane and, in doing so, improve organics recycling and beneficial uses of biomethane from solid waste facilities. This bill should increase the amount of RNG available within California.

Project Overview and Goals

This report provides an overview of RNG in California and builds off data that Verdant presented at the August 2021 Integrated Energy Policy Report RNG workshop. This report is a living document to be updated periodically to provide relevant stakeholders and policy makers with a comprehensive overview of RNG in California. It relies heavily on published data from a variety of sources referenced in footnotes throughout the report. Future updates will be published on the California Energy Commission (CEC) website.

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7 California Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012). Renewable energy resources: biomethane. Available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201120120AB1900.

8 The original definition in PUC 650 stated "'biomethane' means a biogas that meets the standards adopted pursuant to subdivisions (c) and (d) of Section 25421 of the Health and Safety Code for injection into a common carrier pipeline."

9 California Assembly Bill 3163 (Salas, Chapter 358, Statues of 2020). Energy: biomethane: procurement. Available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200AB3163.

10 California Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016). Short-lived climate pollutants: methane emissions: dairy and livestock: organic waste: landfills. Available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383.

CHAPTER 2: Characteristics of Renewable Natural Gas

Renewable natural gas can be produced by a variety of sources and methods. Unlike natural gas that is fossil-based, each RNG source has a unique production process, availability, and carbon intensity. These unique factors should be considered when sourcing RNG.

Biogas Production Methods

Biogas is created using several methods that vary based on the source of methane. Landfills undergo a specific anaerobic digestion process, where the landfill itself acts as the anaerobic digester, and the methane is then collected before it is released from the landfill. Other facilities like water resource recovery facilities (WRRF), often called wastewater treatment plants, livestock, and high-solid anaerobic digester (HSAD, also called municipal solid waste) facilities have an anaerobic digester where the methane is created. Biomass facilities undergo a separate gasification process that first creates a synthesis gas (syngas)[11] before creating methane. These three processes are highlighted in the subsections below.

Landfill Production

The process to convert landfill gas to biogas and then RNG is highlighted in Figure 2 below. At a minimum, the raw landfill gas must undergo a primary treatment that removes moisture and particulates before the resulting methane can be flared to meet air quality or local jurisdiction requirements. If the facility wishes to create biogas from the methane, the gas undergoes a secondary treatment that removes additional moisture and contaminants and then compresses it. Siloxanes, a by-product of the decomposition of plastics, are a key contaminant that must be removed, as discussed in a 2018 report by the California Council on Science and Technology.[12] California gas utilities have been prohibited from accepting RNG from landfills in the past, but AB 1900 began the process to allow this. For the gas to be converted into RNG, an advanced treatment removes additional impurities and compresses the gas further. At this step, waste gas that cannot be converted into RNG is flared. The remaining gas is compressed further and then is ready for pipeline injection.

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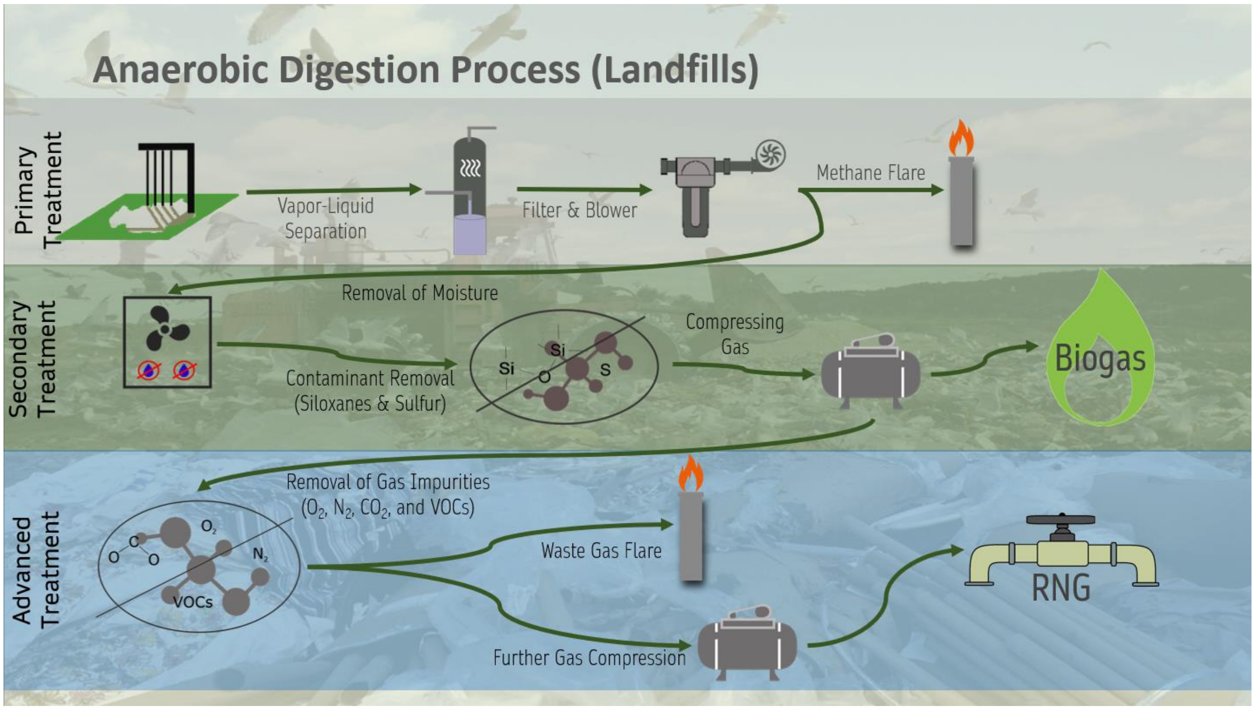
11 Synthesis gas, or syngas, is a fuel gas that is an intermediate product in the production of renewable natural gas via the gasification process. Syngas is composed primarily of the gases carbon monoxide and hydrogen.

12 *Biomethane in California Common Carrier Pipelines: Assessing Heating Value and Maximum Siloxane Specifications*, California Council on Science & Technology, June 2018. Available at https://ccst.us/reports/biomethane-in-california-common-carrier-pipelines-assessing-heating-value-and-maximum-siloxane-specifications/.

Figure 2: Anaerobic Digestion Process — Landfills

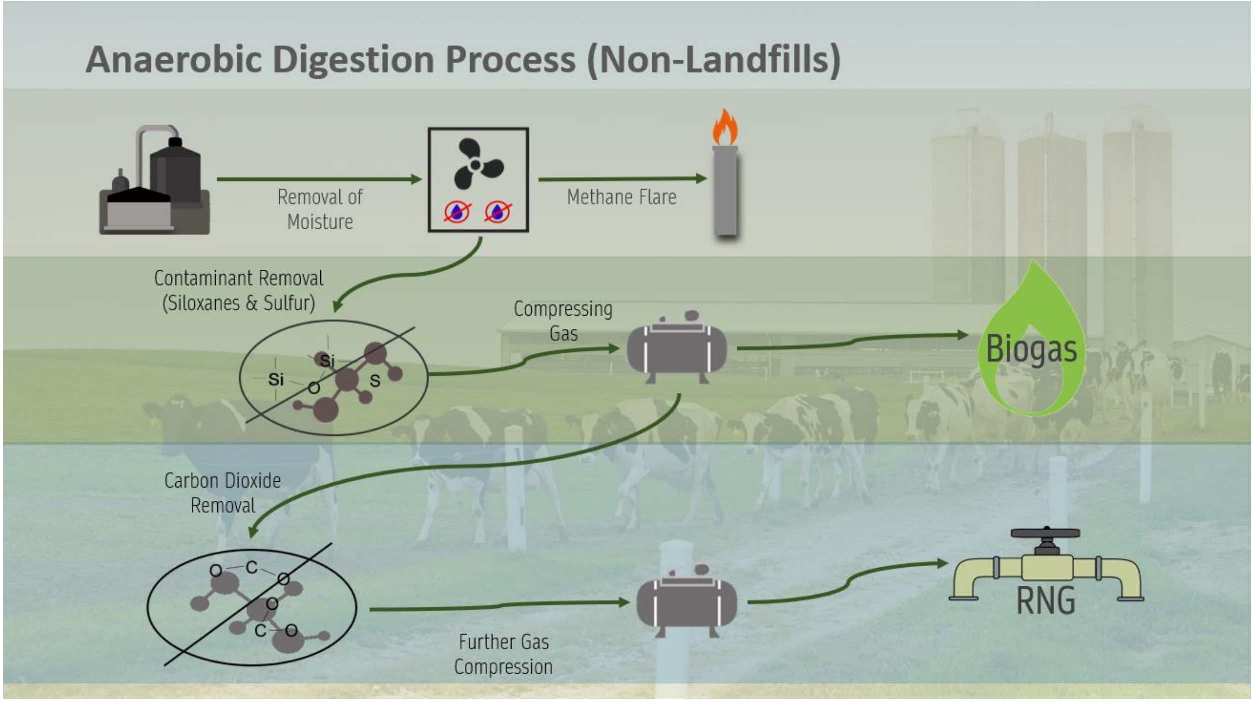


Source: U.S. EPA Renewable Natural Gas website

Nonlandfill Production at WRRF and From Livestock Manure

The anaerobic digestion process is slightly different for large livestock facilities, WRRF, and HSAD facilities than for landfills. The general process for anaerobic digestion for nonlandfill facilities is shown below in Figure 3. For these facilities, the first step after the gas leaves the digester is removing moisture. From here, many facilities choose to flare the methane, converting it into carbon dioxide and water. To create biogas, rather than flaring the methane, cleaning systems must be put into place to remove siloxanes and sulfur contaminants. These contaminants can damage equipment and pose safety concerns. Once this purification is complete, the gas must be compressed, and from there it is turned into useable biogas. If the facility wishes to create RNG, it must perform a more thorough scrubbing process, which removes carbon dioxide from the gas before compressing the gas to pipeline pressures and injecting it into a natural gas pipeline.

Figure 3: Anaerobic Digestion Process (Non-landfill Facilities)

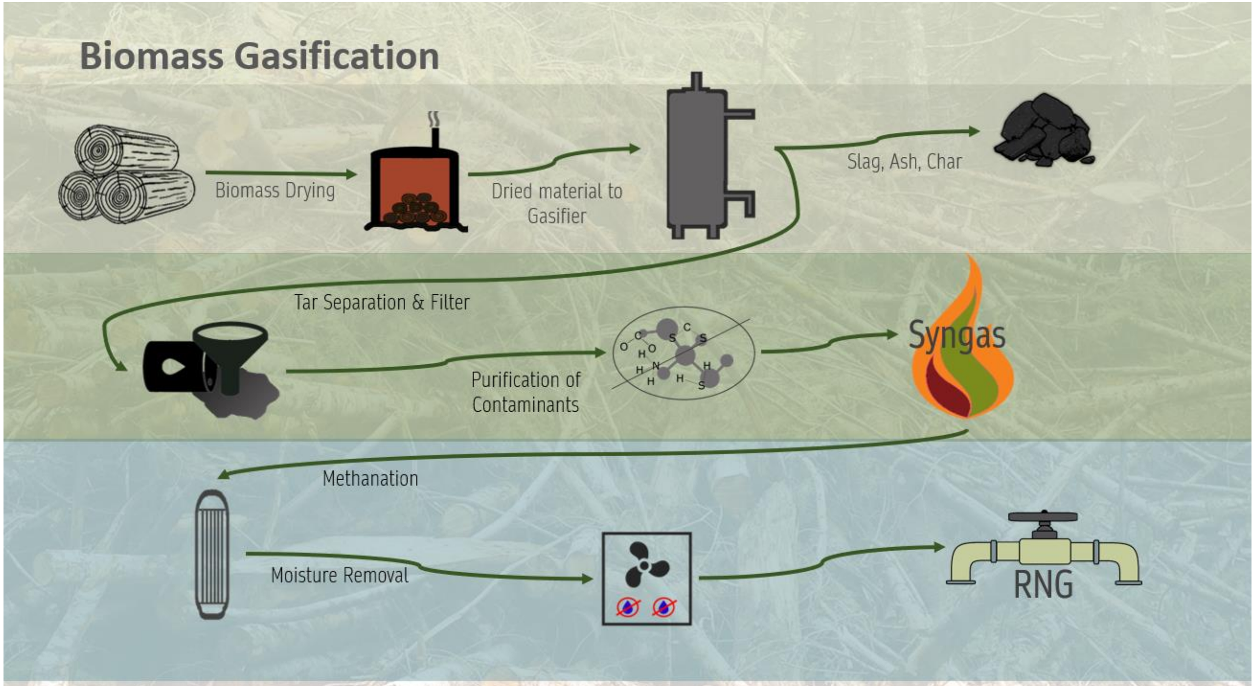


Source: U.S. EPA Renewable Natural Gas website

Biomass Production via Gasification

Renewable natural gas is produced from wood and crop waste biomass through gasification or pyrolysis. These processes are fundamentally different than anaerobic digestion. Figure 4 describes gasification for biomass. The biomass process first produces synthetic gas (syngas), which is composed of carbon monoxide and hydrogen. However, the creation of syngas requires large amounts of energy-intense processing to create usable fuel. The biomass needs to be dried before it enters the gasifier, where it is subjected to high temperatures and pressures in the presence of oxygen and steam. These high temperatures and pressures create chemical reactions that convert the feed into raw syngas, ash, and slag (the mineral residues of the feed). However, the raw syngas contains tar, dust, and other contaminants and must undergo a filter and treatment process before it can be considered usable syngas. For this syngas to be injected into the pipeline, it must then go through a methanation process, which converts carbon monoxide into methane through a chemical process. Finally, additional moisture is removed from the gas before it can be injected into the pipeline.

Figure 4: Biomass Gasification Process



Source: ICF. *Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment.* American Gas Foundation. December 2019

Baseline Types

A key factor in assessing the carbon impacts of RNG is what would have otherwise happened to the methane, or the baseline. Methane is a particularly potent GHG in the short term; a ton of methane has 25 times the global warming potential of a ton carbon dioxide based on weight.[13] State and federal laws require many RNG sources, such as landfills and wastewater treatment plants, to destroy any excess methane they produce by burning (flaring) it. This flaring greatly reduces the emissions impact of methane by decomposing it into carbon dioxide and water. Livestock facilities that process dairy and swine manure are not required to capture methane that is emitted from manure piles, so the baseline condition is that methane would vent to the atmosphere, causing significant GHG potential. Biomass facilities do not produce methane in the same way as other facilities and have a mixed baseline, with some venting and others flaring. In the absence of creating biogas, biomass would decay or be disposed of in several potential ways, including the following:[14]

- It may remain to decay in a forest, a field, or somewhere else open to the air. The decomposition in the presence of oxygen creates carbon dioxide rather than methane, resulting in a far less potent GHG impact.

13 Per 100-yr GWPs from the IPCC fourth assessment report (AR4). Available at: https://ww2.arb.ca.gov/ghg-gwps.

14 Low-Carbon Renewable Natural Gas (RNG) from Wood Wastes, Gas Technologies Institute, February 2019.

- It may be disposed of through burning, either intentionally in the case of agricultural waste or unintentionally in forest fires. This disposal could be considered equivalent to "flaring" and can have adverse air quality impacts.[15]
- It may be burned in biomass electricity-generating facilities. This combustion would also create carbon dioxide rather than methane, but these facilities are increasingly challenged to provide electricity at costs competitive with other renewable facilities.
- Finally, some biomass might otherwise be landfilled and, therefore, would have a flared baseline like other landfilled material.

Sources of Renewable Natural Gas

Figure 5 and the remainder of this section present an overview of the four primary sources of biogas in California: livestock facilities, WRRF, landfills, and biomass plants. Figure 5 also presents some of the impacts of RNG by source and describes the different sources, the associated California baseline methane requirement, ways that they breakdown organic matter, and the quantity of known systems operating within California. More details about the number and status of each of these different sources can be found in the subsections below.

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15 "Despite Tight Restrictions, Open Ag Burning Increases in the Valley." Valley Public Radio. Available at http://www.kvpr.org/post/despite-tight-restrictions-open-ag-burning-increases-valley.

California Wildfires and Acres for all Jurisdictions. Available at https://www.fire.ca.gov/our-impact/statistics.

Figure 5: Primary Sources of Biogas or RNG in California

	Livestock	WRRF	Landfills	Biomass
Description	Large dairies and swine farms collect and store manure to break down and later use as fertilizer.	Break down organic waste.	Methane is collected via pipes.	Organic material such as wood chips, orchard clippings, nut shells, urban/demolition debris used to produce syngas.
Baseline Methane Requirement	No requirement – typically vented (released into the atmosphere).	Required to destroy the methane through combustion or flaring.	Most landfills are required to destroy the methane through combustion or flaring.	No requirement – typically vented (released into the atmosphere.
Breakdown of Organic Matter	Anaerobic digestion.	Anaerobic digestion.	Anaerobic digestion.	Gasification and pyrolysis.
Quantity of Known Systems Operating in California	• 884 dairies in California • 77 creating biogas • 58 creating CNG • 27 creating RNG • 120 additional planned	• 242 WWTP in California • 154 known to have a digester to produce methane • 111 believed to make beneficial use of the gas • 5 creating RNG	• 300 landfills in California • 159 with methane collection • 87 using biogas to generate electricity • 5 creating RNG	• 24 biomass electrical plants in California • 3 onsite thermal generation • 0 known producing, collecting, and using biogas for RNG

Sources:

Livestock: U.S. Department of Agriculture 2017 Census, U.S. EPA AgSTAR Program, and California Department of Food & Agriculture Dairy Digester and Development Program.
WRRF: Tracking database from the California Association of Sanitation Agencies
Landfills: U.S. EPA Landfill Methane Outreach Program Database.
Biomass: Woody Biomass Utilization Group

Livestock

The United States Environmental Protection Agency (U.S. EPA) tracks methane sources and estimates the availability of methane from livestock facilities (dairies and swine) as part of its efforts to track sources of GHGs. The U.S. Department of Agriculture 2017 census estimates that there are 884 livestock facilities (dairies) in California that are candidates for anaerobic digesters.[16] This estimate is based on the U.S. EPA's determination that adding a digester is economically viable for dairies with 500 or more cows and for swine facilities with 2,000 or more hogs. However, other industry experts estimate that 1,500 or more cows would provide the economies of scale to make anaerobic digesters economically viable, which would reduce the number of dairies that can produce RNG in a financially sustainable manner. The 2017 agriculture census counted only 390 dairies with more than 1,000 cows and 163 dairies with more than 2,500 cows. The number of dairies with economically viable RNG production potential may be further reduced by the feasibility of pipeline interconnection; facilities that are far from natural gas pipelines would have to invest significant funds to build a pipeline or truck the gas to a pipeline.

Figure 6 displays the number of livestock facilities in California and associated current production status. The U.S. EPA tracks known digesters as part of the "AgSTAR: Biogas Recovery in the Agriculture Sector" program.[17] As of October 2022, the program found 91 agricultural digesters operating at dairies in California, with 71 of them creating compressed natural gas, of which 33 create RNG.[18] A significant number of additional digesters are under construction with assistance from the California Department of Food and Agriculture's Dairy Digester Research and Development Program, which provides grants for up to half the cost of the digester to a maximum of $3 million. As of December 2021, the program has planned for or allocated a total of nearly $200 million to 11,719 dairy digesters since 2014, and as of June 2022, 68 percent of the DDRDP projects have been completed.

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16 The 2017 U.S. Department of Agriculture census estimates four swine facilities with more than 2,000 hogs in California.

U.S. EPA. June 2018. *Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities*, EPA-430-R-18-006, https://www.epa.gov/sites/default/files/2018-06/documents/epa430r18006agstarmarketreport2018.pdf.

17 U.S. EPA. AgSTAR: Biogas Recovery in the Agriculture Sector. "Livestock Anaerobic Digester Database." Available at https://www.epa.gov/agstar/livestock-anaerobic-digester-database.

18 The number of facilities creating RNG is assumed, based on the number of facilities creating compressed natural gas (CNG) that cite a utility company which receives the data.

19 This figure is lower than the figure reported in the previous version of this report. The precise reasons are unclear, but the decrease may be the result of a handful of digesters being canceled before construction started.

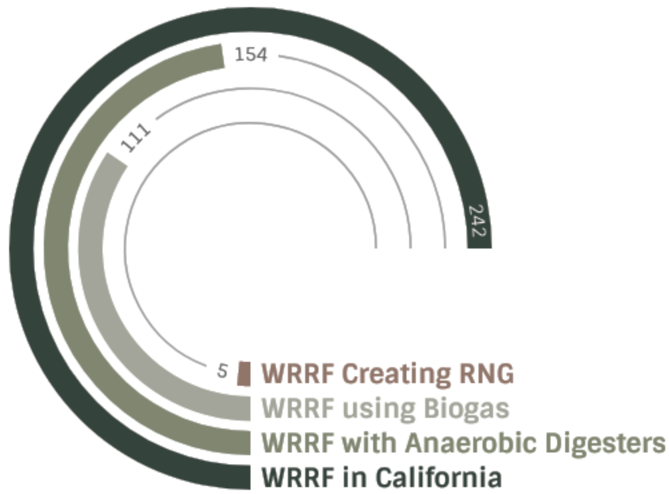
Figure 6: Large Livestock Facilities in California

Source: 2017 United States Department of Agriculture Census. The 884-facility total is based on the number of dairies with more than 500 cows. There are only 588 facilities with greater than 1,000 cows. The number of facilities creating biogas, CNG, and RNG comes from the U.S Department of Agriculture AgSTAR database (Accessed October 2022).
The acronym CNG in the figure is defined as "compressed natural gas."

Water Resource Recovery Facilities

Data from the California Association of Sanitation Agencies show there are 242 WRRF plants in California that process more than 1 million gallons of water per day, with an average flow of 12.5 million gallons of wastewater per day. Of this total, 154 plants are known to have a digester to help process waste and produce methane, and these, on average, process 18 million gallons of wastewater per day. Of the 154 plants with digesters, 111 are believed to make beneficial use of the gas with an average flow of 24 million gallons per day — the remaining 43 are believed to flare the gas to destroy it. Finally, five facilities are known to inject the fuel into the pipeline, and these process an average of 106 million gallons of waste-water per day. An additional 85 WRRF do not use digesters, and these facilities tend to be smaller with an average design flow of only 2.0 million gallons of wastewater processed per day.

Figure 7: Water Resource Recovery Facilities in California



Source: Tracking workbook provided by California Association of Sanitation Agencies

Landfills

California law requires most landfills with greater than or equal to 450,000 tons of waste-in-place to collect and destroy the methane produced by the landfill.[20] To process the methane into biomethane, the landfill must remove compounds from the breakdown of plastics, known as siloxanes, along with all sulfides (particularly hydrogen sulfide [H_2S]).

The U.S. EPA's Landfill Methane Outreach Program (LMOP) tracks landfills as potential sources of methane.[21] As part of that program, the U.S. EPA has recorded 300 landfills in California.[22] Landfills are noted as open or closed in the LMOP database, but even those that are closed may still have operational projects in place to collect methane. Of the 300 landfills in California, 159 have a methane collection system in place, but only 87 are listed as using methane for generation or pipeline injection or both. The remaining landfills with methane collection systems flare the collected methane or use it directly onsite for heating. The U.S. EPA also has requirements for emissions from landfills that each state must comply with.[23] There are 137 landfills in California that do not have a methane collection system in place. These tend to be smaller landfills with an average of roughly 385,000 tons of waste in place. (The average size of landfills with methane collection systems is about 12 million tons of waste.)

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20 California Code of Regulations. Article 4, Subarticle 6, Sections 95460 to 95476, Title 17.

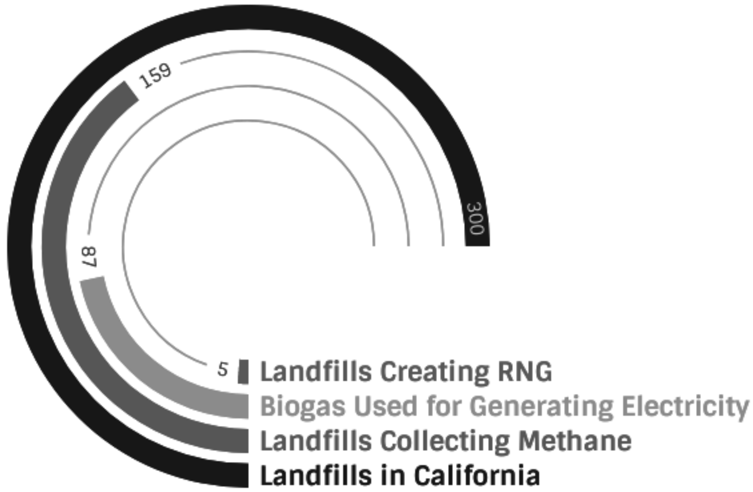
21 U.S. EPA Landfill Methane Outreach Program. Available at

https://www.epa.gov/lmop/about-landfill-methane-outreach-program.

22 U.S. EPA. Landfill Methane Outreach Program. Project and Landfill Data by State. Available at https://www.epa.gov/lmop/project-and-landfill-data-state.

23 U.S. EPA. 40 CFR Part 60 (EPA–HQ–OAR–2018–0696: FRL–9998–82– OAR) RIN 2060–AU33 Adopting Requirements in Emission Guidelines for Municipal Solid Waste Landfills. Available at https://www.federalregister.gov/documents/2019/08/26/2019-18233/adopting-requirements-in-emission-guidelines-for-municipal-solid-waste-landfills.

Figure 8: Landfills in California



Source: [U.S. EPA Landfill Methane Outreach Program Database](https://www.epa.gov/lmop/lmop-landfill-and-project-database), https://www.epa.gov/lmop/lmop-landfill-and-project-database. Updated August 2022.

The Landfill Methane Outreach Program database also tracks projects within each landfill. Eight additional landfills are either planning or constructing biomethane projects, and at least four of these are planning to implement pipeline injection to create RNG. Several of the facilities plan to use the biomethane onsite. All operational and planned projects except for two list the energy type as "vehicle fuel," with a single project using the biomethane onsite for generating electricity and the remaining project not specifying the project type.

Biomass

Biomass is generally defined as any organic matter used for fuel. Biomass is usually generated by forest residue, sawmill sources, crop residue, or wood demolition waste (urban), which are all types of biomass that can be decomposed using a process like gasification to produce methane.[24] As defined by AB 3163, California does not classify RNG produced from crops grown specifically for that purpose as renewable.

As described on the California Department of Forestry and Fire Prevention (CAL FIRE) website, "Woody biomass utilization — ways to use the excess woody material from the forest — is a major issue today for a number of reasons.

- Economic reasons: A market for biomass can help pay for forest treatments or provide income for landowners.
- Environmental reasons: Overly dense forests may create suboptimal habitat for many species and has the potential to go up in a catastrophic fire.

24 While some definitions of biomass may also include urban green waste, the project team's definition throughout this paper does not. Urban green waste is included with high-solids anaerobic discharge facilities.

- Energy reasons: Biomass is a form of stored energy that can be considered carbon neutral (with caveats). This has implications for climate change, as well as for our dependence on foreign oil.

"Finding ways to use the excess biomass in our forests has many benefits: it could help mitigate climate change, improve the health of our forests, decrease fire risk, provide income to forest landowners, create jobs, and obviate some of the need for fossil and foreign fuels."[25]

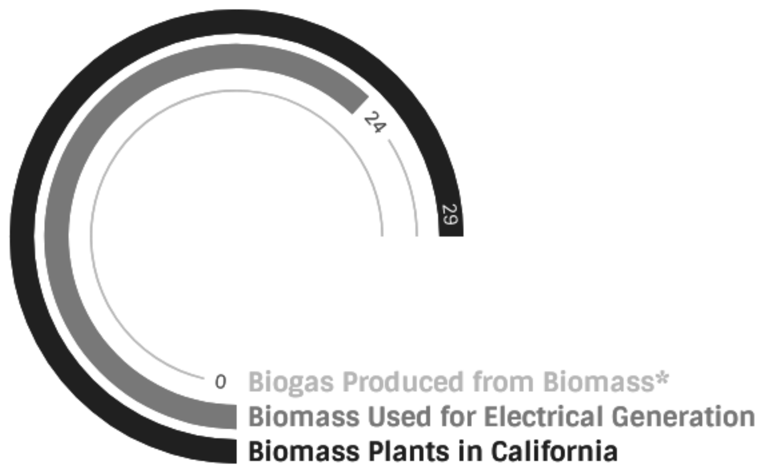
Methane created from biomass can be refined and upgraded into RNG or used for onsite electricity generation or thermal needs or both. Recent California legislation and the BioMAT program encourage using debris from forest cleanup and fire reduction efforts to help with forest management and reduce the chance or impact of wildfires. In addition, gasifier plants can use crop residues such as clippings from orchards and vineyards, or nut shells, to produce methane.

The University of California Agriculture and Natural Resources Woody Biomass Utilization group tracks biomass generation and processing plants in California.[26] There are 29 operational or pilot project biomass plants in California, most of which (24) use the biomass to produce electricity or mechanical power and useful thermal energy. An additional 10 plants are in development, 9 of which are expected to produce electricity for mechanical power (such as directly driving process machinery) and useful thermal energy combined, and 1 plant plans on using the biomass solely for liquid fuel, although no additional details are provided.

25 CAL FIRE. "Biomass: What Can We Do With the Excess Wood" Available at https://www.fire.ca.gov/what-we-do/natural-resource-management/wildfire-resilience/forest-stewardship

26 Woody Biomass Utilization. "Welcome to Woody Biomass Utilization." Available at https://ucanr.edu/sites/WoodyBiomass/.

Figure 9: Biomass Facilities in California



*** There is one project listed in the Woody Biomass Utilization Group data that produce biogas and are listed as operational. However, the symbol used to identify it on the map is listed as "idle," so it is not clear if this project is truly operational or not. A third project says it is a pilot project in development.**

Source: Woody Biomass Utilization Group. Available at https://ucanr.edu/sites/WoodyBiomass/.

The project team has not identified any biomass-sourced RNG produced within California. However, the inclusion of biomass as a source of biomethane in 2019 in AB 3163, combined with competition from increasingly cheaper renewables such as solar, may drive more biomass plants to produce RNG instead of electricity.

Other

HSAD facilities process green waste (food scraps, yard clippings, and so forth) from municipal sources and breweries or other food processing plants to create biogas. These sources are often categorized as municipal solid waste (MSW). The HSAD facilities use anaerobic digesters to reduce the amount of waste and, if desired, produce biogas for heating or generation. SB 1383 requires many of these MSW sources to reduce methane emissions.[27] However, these sources appear to provide significantly less biogas than the four sources identified above. In general, bigger is better due to economies of scale for projects collecting biogas to create usable biomethane.

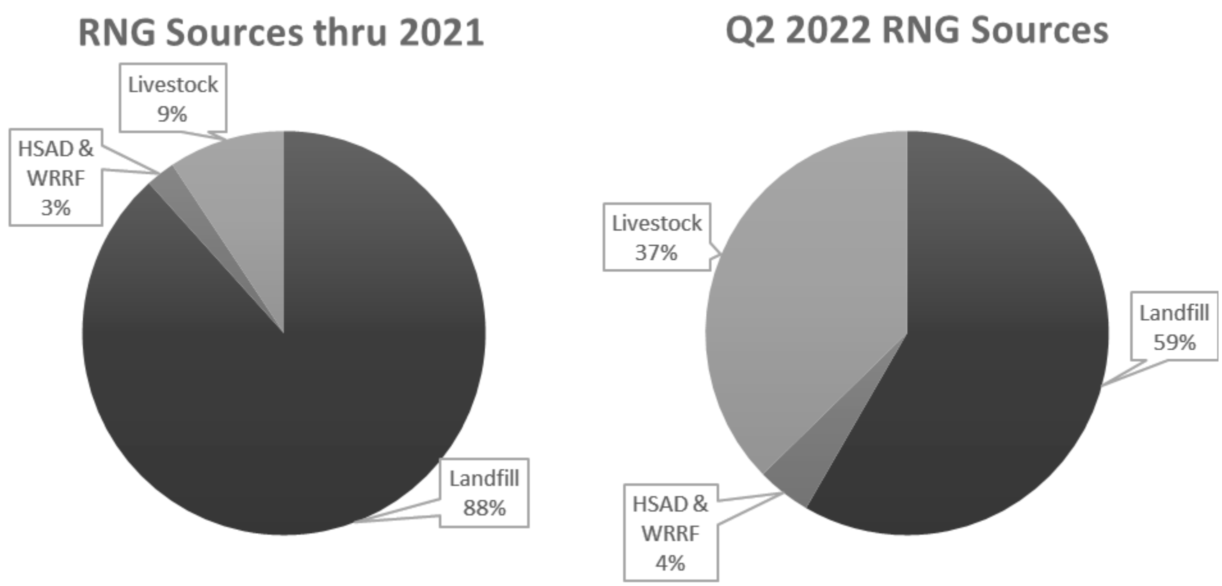
Volume of Renewable Natural Gas by Source

California's Low Carbon Fuel Standard (LCFS) began implementation January 1, 2011, with the goal of reducing California's greenhouse gas (GHG) emissions and other pollutants. As noted on the CARB website, "the LCFS is designed to encourage the use of cleaner low-carbon transportation fuels in California, encourage the production of those fuels, and therefore,

27 SB 1383, Lara. Short-lived climate pollutants: methane emissions: dairy and livestock: organic waste: landfills. Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383

reduce GHG emissions and decrease petroleum dependence in the transportation sector. The LCFS standards are expressed in terms of the 'carbon intensity' (CI) of gasoline and diesel fuel and their respective substitutes."[28] The LCFS established a market-based program that allows carbon-intensive fuel producers like refineries to buy credits from lower-carbon sources such as biogas. The carbon intensity can vary substantially by source, with dairies providing some of the greatest carbon reduction because of a high carbon equivalent baseline. Credits are based on the tons of carbon removed by use of a lower carbon fuel. The Low Carbon Fuel Standard (LCFS) tracks the total volume of renewable natural gas in diesel gallons equivalent (based on energy). The volume of renewable natural gas that generates LCFS credits is used as a proxy to the overall sources of renewable natural gas available in California since generating transportation credits via the LCFS is driving this market. Data for the LCFS are available from 2011 through June 2022. Landfill gas made up most of the RNG volume over the last decade, with only 9 percent of RNG volume coming from diaries or animal waste and 3 percent from high-solids or food waste. However, comparing the historical production to production in 2022 shows that the share of RNG created by livestock facilities has increased significantly — up to 30 percent of the overall RNG volume in Q1 of 2022 and 37 percent in Q2 of 2022.

Figure 10: Sources of Renewable Natural Gas in California



Source: "LCFS Quarterly Data Summaries Through Q2 2022." Available at

https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

In addition to the total volume of gas, the LCFS tracks the pathways, or the specific sources of fuel, by fuel type, facility location, feedstock, and carbon intensity (among other categories). This source is a proxy for the distribution of in-state versus out-of-state sources of RNG in

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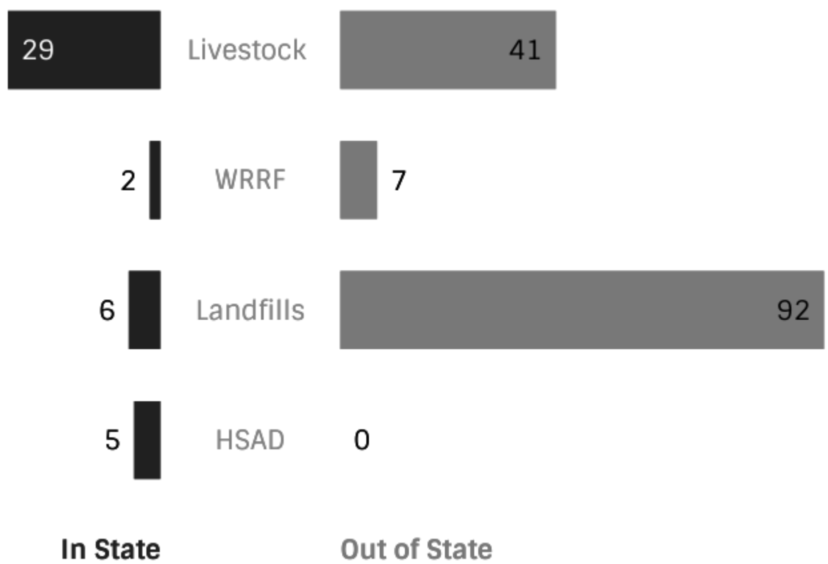
28 "Low Carbon Fuel Standard." Available at https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about.

California. Most RNG used in California comes from out-of-state sources, with landfill gas being the primary source.

Only 6 percent of landfill gas project (6 out of 92 total projects are in-state (Figure 11), and 41 percent of livestock facilities producing RNG are in-state (29 out of 70 total projects).

Figure 11: In-State vs Out-of-State Sources of Renewable Natural Gas in California



Source: "LCFS Pathway Certified Carbon Intensities Workbook" (updated 7/18/2022). Available at https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/current-pathways_all.xlsx. Represents sources with a fuel type of "Compressed Natural Gas."

Renewable Natural Gas Production and Technical Potential Estimates

The California Energy Demand Baseline Forecast[29] provides actual 2020 natural gas usage and forecasts by sector of natural gas usage for 2030, as displayed below in Figure 12. These totals exclude the natural gas used in large power plants to generate electricity. The historical natural gas baseline usage in 2020 was 12,518 MM therms. The forecasted 2030 usage increases about 6 percent by 2030 to 13,274 MM therms. The residential sector is the largest end user, making up about 38 percent of the natural gas usage in California. The industrial sector follows with about 25 percent. The mining and commercial sectors make up less than 20 percent each. Finally, the "other" category includes vehicles, TCU,[30] and agriculture, overall making up less than 1 percent of the natural gas usage in California.

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29 CEC. 2019 IEPR Workshops, Notices, and Documents. Docket #19-IEPR-01. "CED 2019 Baseline Natural Gas Forecast – Mid Demand Case TN-231608." Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=231608&DocumentContentId=63428.

30 TCU is a building segment representing transportation, communications, and utilities.

Figure 12: California Natural Gas Usage (MM Therms)

Source: 2021 Notice of Availability California Energy Demand Forecast. Docket #21-IEPR-03. "CED 2021 Baseline Natural Gas Forecast – Mid Demand Case TN-241226." Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=241226&DocumentContentId=75073
Note: The natural gas usage presented here excludes natural gas used to generate electricity in utility power plants.

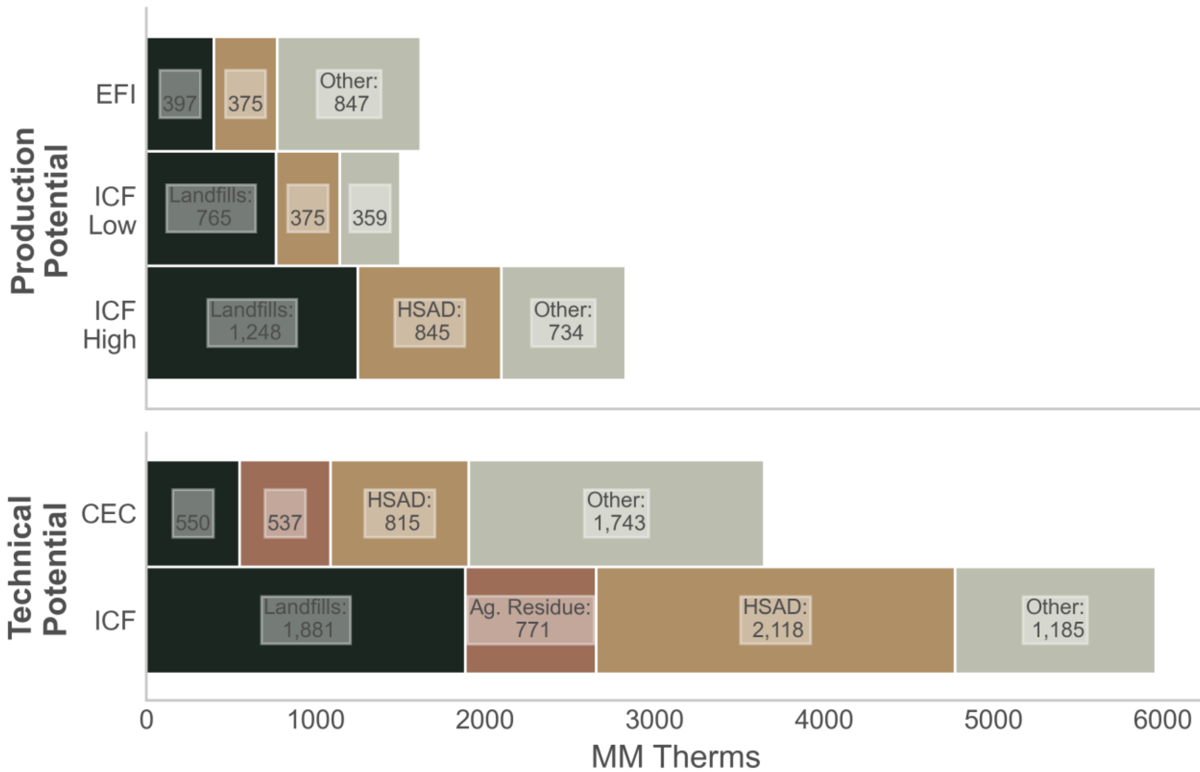
Figure 13 provides estimates of RNG potential in California from different sources. These range from a high of almost 6,000 MM therms down to 1,499 MM therms. Using these estimates, RNG has the potential to displace 12 to 23 percent of the natural gas usage in California based on production potential and up to 50 percent based on technical potential.

- "Production potential" includes two estimates that are based on a 2019 report by ICF and a report by EFI. The ICF report provided both low resource and high resource potential scenarios and considered unique constraints for each potential RNG feedstock, based on factors such as feedstock accessibility and the economics of RNG production using the feedstock.
- "Technical potential" is the maximum amount of RNG production that is achievable given system performance, topographic, environmental, and land-use constraints.[31] Technical potential is without regard to economic limitations so is often substantially

31 National Renewable Energy Lab. "Renewable Energy Technical Potential." Available at https://www.nrel.gov/gis/re-potential.html.

higher than any economically achievable potential estimates. Figure 13 includes results from two reports to illustrate the range of estimated potentials.

Figure 13: Range of Renewable Natural Gas Potential



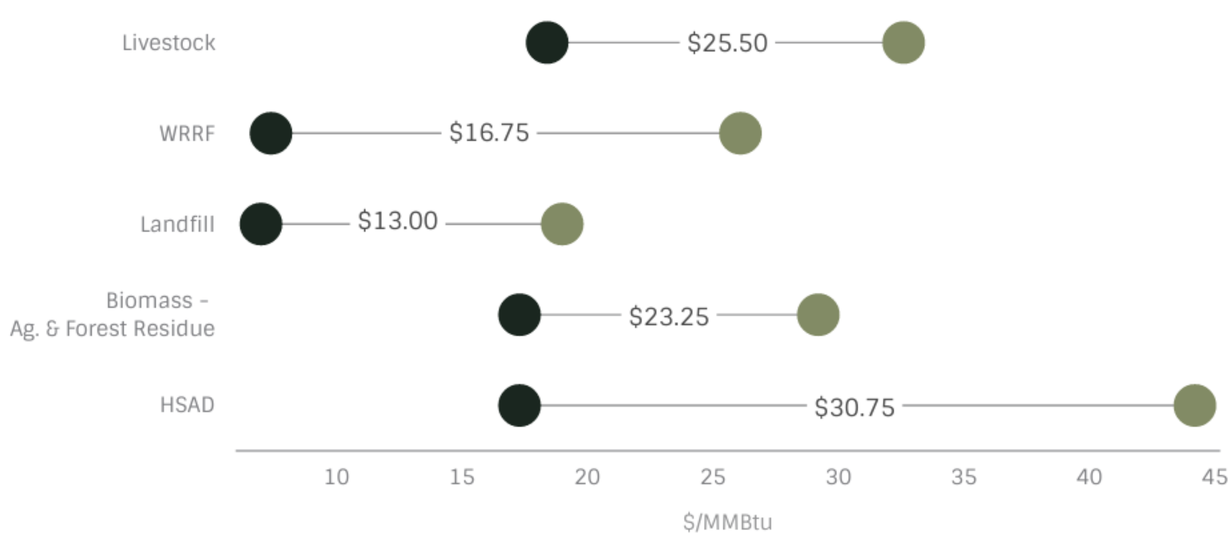
"Other" category includes WRRF, forestry and forest product residue, food waste, and livestock manure.

Source: ICF. *Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment*. American Gas Foundation. December 2019.
EFI: Energy Futures Initiative; *Pathways for Deep Decarbonization*, May 2019.
CEC: Rob Williams and Stephen Kaffka, UC Davis, presentation to the CEC on January 30, 2017.

CHAPTER 3:
Cost of Renewable Natural Gas

Figure 14 summarizes bottom-up estimates of RNG production costs based on facility types. These costs include the following parameters: facility size, gas conditioning and upgrades, gas compression, operational costs, feedstock costs (for thermal gasification), financing, interconnection, and project lifetimes. There are uncertainties surrounding the estimates, including large ranges in pipeline interconnection costs (from $200,000 up to $9 million). Despite these uncertainties, Figure 14 indicates that landfills and WRRFs represent the lowest estimated costs for the LCFS program.

Figure 14: Range in Expected RNG Production Costs ($/MMBtu)



Source: ICF. *Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment.* American Gas Foundation. December 2019.

While the figure above summarizes a basic understanding of the costs to produce RNG, these numbers are based on a single report. More research is needed to better understand RNG production costs and the ways that these costs are changing in addition to how incentives may be impacting the prices.

CHAPTER 4: Renewable Natural Gas Source and Carbon Intensity

Climate change concerns have directed public policy to increasingly implement programs and measures designed to reduce GHG emissions. As the share of electricity from renewable sources rises, the carbon intensity or GHG emissions associated with electricity use declines while the carbon intensity in natural gas remains constant.

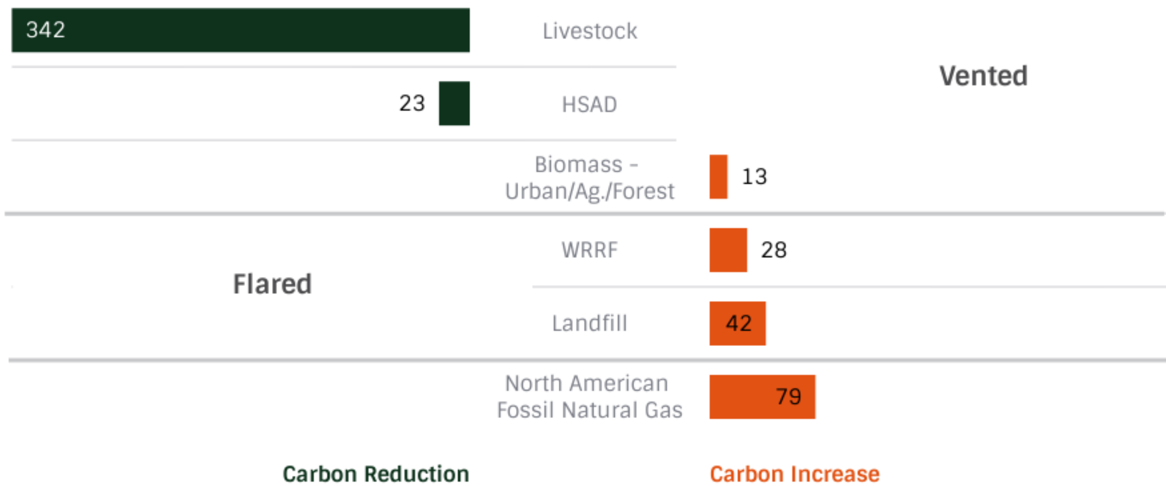
The carbon intensity of RNG depends on the type of facility from which it is sourced. Methane is a particularly potent GHG in the short term; a ton of methane has 25 times greater global warming potential than carbon dioxide (based on weight).[32] State or federal laws or both require many RNG sources, such as larger landfills and wastewater treatment plants, to destroy excess methane through flaring. Flaring usually destroys methane with fewer potentially harmful sulfur oxides (SOx) and nitrogen oxides (NOx) than combustion in engines or turbines because of a more controlled combustion process. One EPA study from 1995 found that flaring resulted in the lowest NOx emissions compared to internal combustion engines and boilers or gas turbines.[33] That report did not include fuel cells. As stated previously, flaring greatly reduces the GHG emissions impact of methane by decomposing it into carbon dioxide and water. However, flaring produces local emissions that are regulated differently than if the methane were burned in a generator. Dairy and swine farms are not required to capture methane from manure piles, so the methane would vent to the atmosphere, resulting in significant GHG emissions.

The LCFS has provided estimates of the carbon intensity (in units of grams of carbon dioxide equivalent per megajoules [gCO_2e/MJ]) of different production sources. As shown below in Figure 15, both livestock facilities and HSAD result in decreased carbon intensities, estimated at 338 gCO_2e/MJ and 20 gCO_2e/MJ, respectively. Other RNG sources listed in Figure 15 show positive carbon intensities, but all sources of biogas have a lower carbon intensity than fossil natural gas. The biogas produced from landfills, WRRF, and biomass reduce carbon intensities from 46 percent to 83 percent compared to the use of fossil natural gas. In the absence of RNG production, biogas created at most WRRF and landfill facilities would be flared, creating carbon dioxide and water. Methane flaring has a lower GHG potential than methane vented into the atmosphere. RNG produced from flared-baseline sources result in a lower carbon reduction than RNG from vented baseline facilities that are not required to destroy methane, such as livestock manure and HSAD facilities.

32 "GHG Global Warming Potentials." California Air Resources Board website. Available at https://ww2.arb.ca.gov/ghg-gwps.

33 Roe et. al. Methodologies for Quantifying Pollution Prevention Benefits From Landfill Gas Control and Utilization, EPA-600/R-96-089. Available at https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=30003X60.txt.

Figure 15: Carbon Intensity by Source (gCO_2e/MJ)



Source: Most vented and flared carbon intensities are sourced from the LCFS Pathway Certified Carbon Intensities workbook (updated 7/18/2022). The North American Fossil Natural Gas comes from the California Code of Regulation §95488.5. Lookup Table Fuel Pathway Application Requirements and Certification Process, Table 7-1. The biomass carbon intensity is sourced from Gas Technology Institute, Low-Carbon RNG From Wood Wastes, February 2019. All these values have 3.5 g/CO2e/MJ removed to reflect the lower compression needed for pipeline pressures vs. compressed natural gas pressures.

CHAPTER 5: Renewable Natural Gas Programs and Policies

Several federal and state programs are in place to offer incentives for the beneficial use of biogas and RNG. These incentives have many forms, such as grants, tax breaks, tax credits, and others. These include:

- **Transportation incentive programs** — California's LCFS and the federal RFS are market-based programs with the goal of reducing the carbon intensity of transportation fuels.
- **Biogas generation incentive programs** — The SGIP provides upfront and performance-based incentive payments for installing and operating renewably fueled onsite generation equipment. California's BioMAT program provides a feed-in tariff for biogas generation. RECs and NEM also offer opportunities for compensation to produce renewably generated electricity that is fed into the grid.
- **California Department of Food and Agriculture (CDFA)** – The CDFA provides grants to help offset the cost of anaerobic digester installation at dairies to expedite the production of biogas for beneficial use through its Dairy Digester Research and Development Program.
- **Federal tax credits** — The federal government offers tax credits on eligible renewable energy generating systems, including fuel cells[34] and microturbines[35].
- **Pipeline interconnection assistance incentives** — AB 1900 directed an incentive program to be offered to help cover biogas pipeline interconnection costs.

Table 1 presents more details on biogas programs.

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34 A fuel cell is a device that converts chemical energy into electricity.

35 Microturbines are a technology based on jet engines that use rotational energy to generate power. Microturbines can run on bio-gas, natural gas, propane, diesel, kerosene, methane, and other fuel sources

Table 1: Overview of Programs That Offer Incentives for the Beneficial Use of Biogas and RNG

Program Type	Program	Financial Incentive / Credit
Transportation	LCFS	LCFS Credit at $122/MT: $5-$56/MMBtu based on carbon intensity of the biogas.
Transportation	RFS	Renewable Identification Numbers (RINs) credits range from $17-38/credit for D3 and D5, 11.7 RINs/MMBtu of RNG.
Biogas Generation	SGIP	Twelve percent of the budget is allocated for Renewable Generation. Incentives at $2/W. A resiliency adder of $2.50/W is available.
Biogas Generation	NEM	Compensation for renewable electricity exported back to the utility, based on retail rate net of non-bypassable charges.
Biogas Generation	BioMAT	Feed-in-tariff: $127.72-$199.72/MWh to sell electricity directly to utility.
Biogas Generation	RECS	RECs are sold as a commodity in the marketplace. 1 REC = 1 MWh of renewable-generated energy.
Biogas Generation	REAP	Provides guaranteed loan financing and grant funding for renewable energy systems.
California Department of Food and Agriculture	CDFA Dairy Digester Research and Development Program	Grants for up to half of the cost of anaerobic digester installation ($2M/project max).
Federal Tax Credits	Investment Tax Credit (ITC) & Production Tax Credit (PTC)	ITC: 26 percent tax credit based on the fair market value of installed fuel cells or microturbines. PTC: Inflation-adjusted federal renewable energy production tax credit available for the first 10 years of operation.
Interconnection Assistance	Pipeline Interconnection Assistance	Grants for up to half of interconnection costs for dairies ($3M/project max, $5M for clusters).

Source: Verdant Associates using information from the following sources: LCFS program, EPA, SGIP Program Handbook, CPUC, PGE, NREL, USDA, CDFA, and Department of Energy.

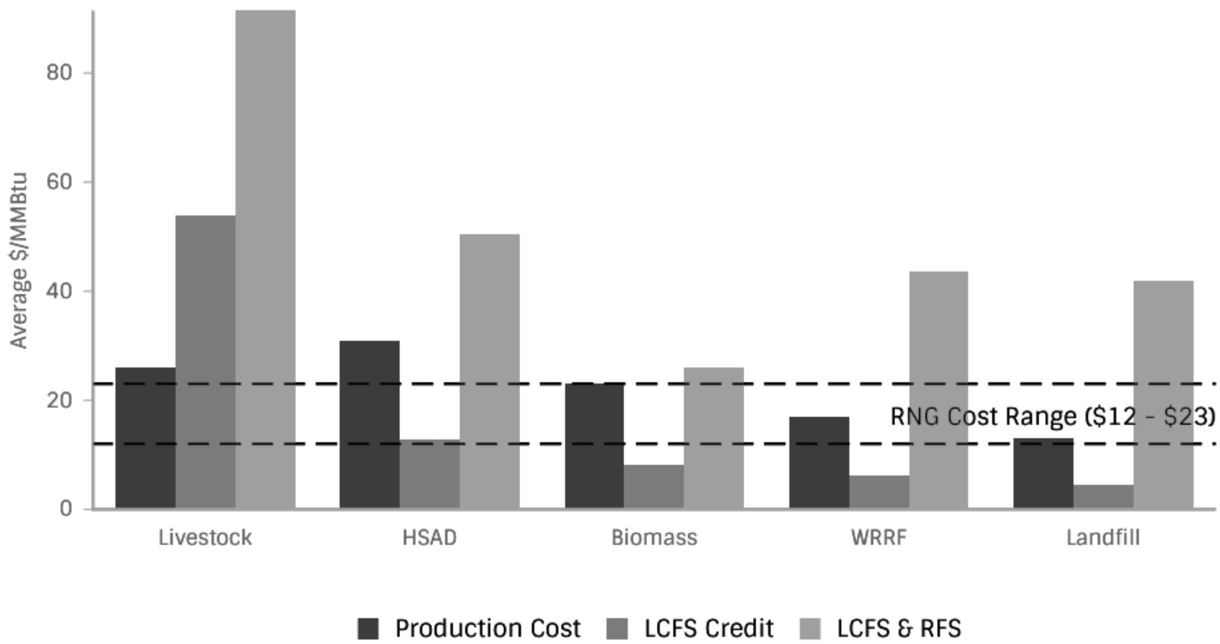
Transportation Incentive Programs

Several federal and state programs offer incentives for the beneficial use of biomethane through grants, tax breaks, credits, and other programs. These incentives also include transportation programs such as California's LCFS and the federal RFS. The LCFS and RFS are market-based programs with the goal of reducing the carbon intensity of transportation fuels. The demand driven by these programs competes with the supply of RNG available for stationary uses.

Figure 16 summarizes the cost of RNG compared with the potential value of LCFS and RFS credits. The LCFS credit values in the figure are based on an LCFS credit price of $126, which is the average credit price for 2022. The RFS price is estimated at $17.92 per MMBtu for biomass and $37.59 per MMBtu for other fuel sources. The RFS price for biomass is based off the average RIN price of Renewable Fuel Type D-Code 5 during the first half of 2022, while the RFS price for other sources is based off the average RIN price of Renewable Fuel Type D-Code 3 during the same period. More about the D-code can be found in the subsection below.

For Figure 16, the average RNG price is $12–$23 per MMBtu, but prices vary substantially depending on contract terms.[36]

Figure 16: Transportation Credits and RNG Supply



Source: The production price is sourced from the 2019 ICF Report. (See Figure 14) The LCFS credit is based on the carbon intensities by source, identified in Figure 15. The carbon intensity for biomass is sourced from Gas Technology Institute, *Low-Carbon Renewable Natural Gas (RNG) From Wood Wastes*, February 2019. The carbon intensities are converted to carbon reductions (by subtracting the natural gas carbon intensities, and then turned into credit by multiplying by the average credit cost of $122/metric ton[37] of CO_2eq, identified below in Figure 17. The RFS cost is based on the average of the RIN price during 2021, found through the U.S. EPA Annual RIN Sales Report.

Low Carbon Fuel Standard

California's LCFS began January 1, 2011, with the goal of reducing California's GHG emissions and other pollutants. The LCFS is designed to encourage the use of cleaner low-carbon transportation fuels in California and the production of those fuels and, therefore, reduce GHG emissions and decrease petroleum dependence in the transportation sector. The LCFS standards are expressed in terms of the carbon intensity of gasoline and diesel fuel and

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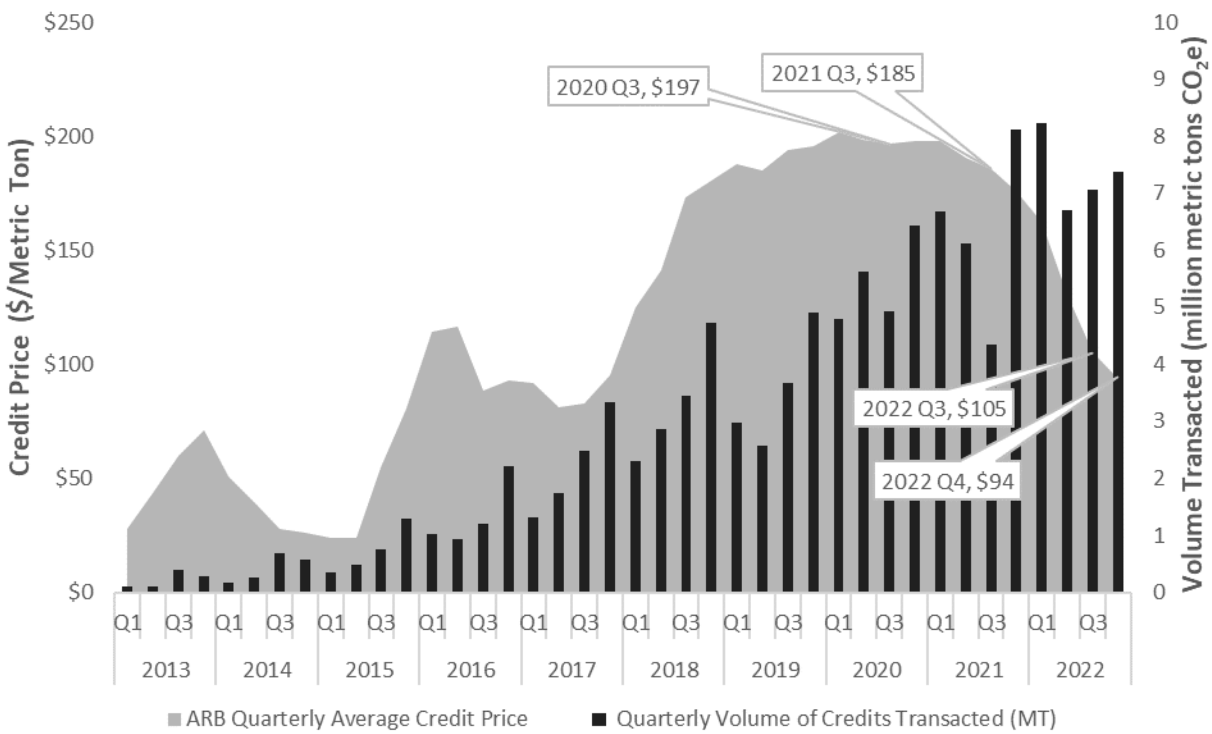
36 From a letter by Matt Tomich, president of Energy Vision 138 East 13th Street, New York, NY, 10003, dated July 11, 2019. This letter is included as Attachment A in Southern California Gas Company's (U904G) reply comments filed July 12, 2019, to Assigned Commissioner's Ruling Seeking Comments on Rulemaking 12-11-005 Implementation of SB 700 and Other Program Modifications. Available at https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M311/K114/311114276.PDF and https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M281/K395/281395627.PDF.

37 A metric ton is a unit of weight equal to 1,000 kilograms

respective substitutes.[38] The LCFS is a market-based program that allows carbon-intensive fuel producers like refineries to buy credits from lower-carbon sources such as biogas. As discussed above and as presented in Figure 15, the carbon intensity of RNG varies substantially by source, with RNG from dairies providing the greatest carbon reduction because of the high carbon emissions baseline. The LCFS credits are based on the tons of carbon removed by replacing the use of high-carbon fuels with lower-carbon fuels. Figure 17 shows the historical trend in LCFS credit prices. The price in 2019 and early 2020 averaged close to $200 per metric ton of carbon removed, while the price declined to $86 per metric ton in December 2022, or $94 per metric ton in Q4 2022. The average price per metric ton during in 2022 was $122.

Figure 17: Low Carbon Fuel Standard Historical Credit Pricing



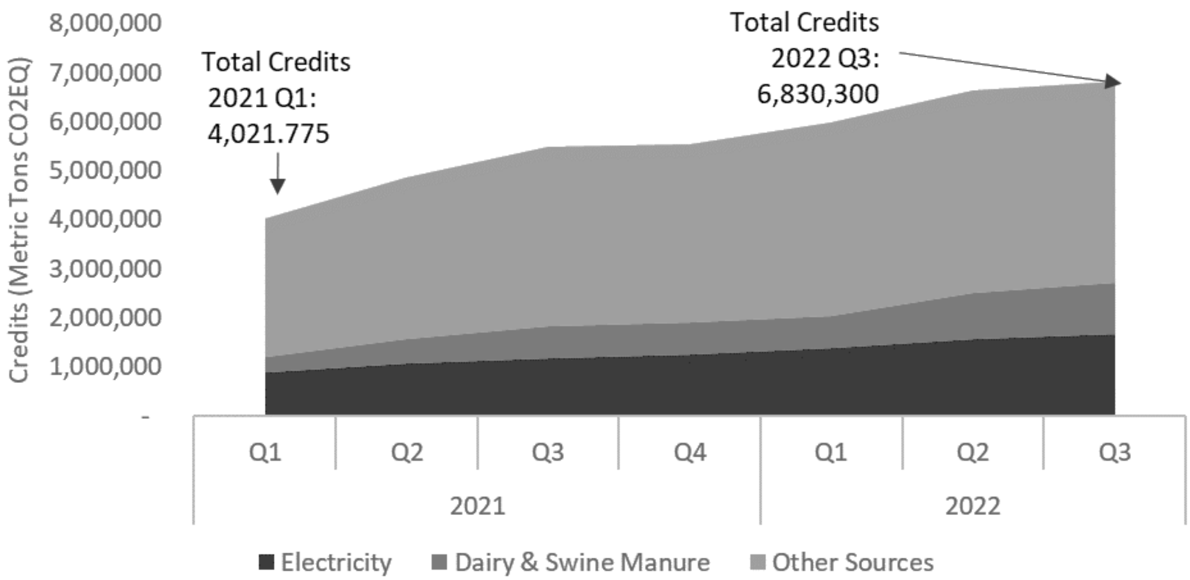
Source: "Monthly LCFS Credit Transfer Activity Reports." Available at https://ww3.arb.ca.gov/fuels/lcfs/credit/lrtmonthlycreditreports.htm.

The drop in LCFS credit prices from 2021 to 2022 appears to be driven, in part, by an increase in the supply of credits. Figure 18 shows the credits produced quarterly from 2021 through Q3 of 2022. In this time, the number of credits available increased by 70 percent from just more than 4 million in the first quarter of 2021 to nearly seven million in the third quarter of 2022. More than half of this increase can be attributed to additional renewable natural gas being delivered from dairy and swine manure and clean electricity being used for electric vehicle

38 California Air Resources Board. "Low Carbon Fuel Standard." Available at https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about.

(EV) charging. Some of that clean electricity is generated by dairies that are too far from pipelines for RNG injection to be economically feasible.

Figure 18: LCFS Credits Produced by Quarter



The LCFS assigns a carbon intensity value to each fuel type and sets a target of average carbon intensity for the transportation sector. Fuels with a carbon intensity above the target generate deficits based on the difference between the carbon intensity of the fuel and the target carbon intensity. Fuels with carbon intensity below the target generate credits based on the difference between the carbon intensity of the fuel and the target carbon intensity. Credits are then sold to firms that have accumulated deficits, and the market clears when the credit price equates the number of generated credits to deficits. In such a market, for a given credit price, credits can be thought of as a subsidy on low-carbon fuel and deficits can be thought of as a tax on high-carbon fuel.

Different RNG sources exhibit discrete ranges for the respective calculated carbon intensity, depending on whether the RNG was sourced from dairy gas, landfill gas, HSAD, or digestion in a wastewater treatment plant. Since the LCFS credit depends on the degree to which a fuel falls below the target carbon intensity, the effective subsidy per unit of RNG differs by source. Table 2 shows the average carbon intensities of the four sources of RNG, as well as fossil natural gas, diesel, and the 2021 LCFS CI target.[39] The authors emphasize that these values

39 Quoted from Jaffe et al, *Final Draft Report on The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute Contract No. 13-307*. Prepared for the California Air Resources Board and the California Environmental Protection Agency. Available at https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/13-307.pdf.

have 3.5 g/CO2e/MJ removed from vehicle fuel CIs to reflect the lower compression needed for pipeline pressures vs. compressed natural gas pressures.[40]

Table 2: LCFS Carbon Intensities and Prices for Compressed Natural Gas Fuel

Specific Source	Carbon Intensity [g CO2e/MJ]	LCFS Credit Benefit to RNG ($/MMBtu) at $122/MT
CA Comp. Nat. Gas via pipeline	75.71	$0
Livestock	-341.50	$53.85
HSAD	-23.40	$12.79
Biomass – Urban/Forest & Orchard Residue	13.30	$8.06
WRRF	28.26	$6.12
Landfill	41.65	$4.40

Source: Most carbon intensities are sourced from the LCFS Pathway Certified Carbon Intensities workbook (updated 7/18/2022). The North American Fossil Natural Gas comes from the California Code of Regulation §95488.5. Lookup Table Fuel Pathway Application Requirements and Certification Process, Table 7-1. The biomass value comes from Gas Technology Institute, Low-Carbon Renewable Natural Gas (RNG) From Wood Wastes February 2019.

The low LCFS credit values for some sources — especially from landfill gas, but also from biomass and WRRF — may provide an opportunity to deliver significant amounts of RNG for stationary sources. Furthermore, the relatively small percentage of these sites injecting RNG into pipelines (Figure 5) may indicate substantial potential for RNG pipeline injection. The carbon reduction from the use of RNG is the difference between the carbon intensity of the RNG vs. that of natural gas, as shown in Figure 19. As discussed, livestock facilities show the largest difference, with a carbon reduction of 417 g CO_2e/MJ. Both livestock and HSAD facilities have a vented baseline, meaning that they would otherwise vent methane into the atmosphere and make them carbon negative fuels. Biomass has a mixed baseline due to the following:

- Much of the biomass would otherwise decay aerobically in fields or forests, largely venting carbon dioxide rather than methane.
- Biomass may be burned, either intentionally in biomass generation facilities or as agricultural waste, or unintentionally in forest fires. Recent fires combined with a decrease in biomass facilities and lumber mills in California have led to an oversupply of potentially flammable forest waste that could take many years to process at current capacities.[41]

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40 The authors subtracted 3.5 g CO_2e/MJ to account for the lack of need to compress RNG to the higher pressures required for CNG than pipeline pressures. Standard value for compression to CNG per GREET 3.0 documentation. GREET 3.0 is a version of the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model, which is a tool that examines the life-cycle impacts of vehicle technologies, fuels, products, and energy systems.

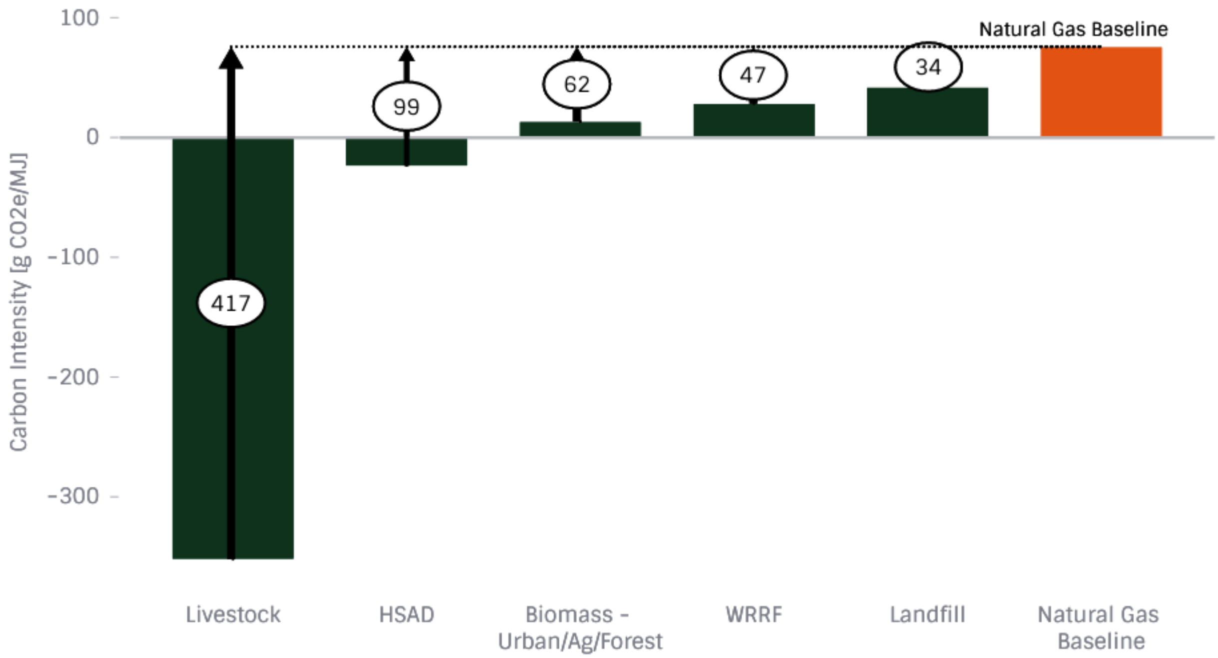
41 "'Fuel for the Next Fire' Why California Can't Unload the Trees That Worsen Wildfires," The Sacramento Bee, December 19. 2021. Available at https://sacbee.newspapers.com/search/?query=%27Fuel%20-%20for%20the%20-%20next%20fire%27%20-%20Why%20California%20can%27t%20unload%20the%20trees%20-%20that%20worsen%20its%20wildfires.

Furthermore, recent interest in forest thinning may produce still more biomass supply with no capacity to process.

- Some biomass would otherwise be landfilled.

Given these varying baselines, the carbon benefits from biomass are not as high as those for other sources with a vented methane baseline.

Figure 19: Average Carbon Reduction by Source Compared to Natural Gas Baseline



Source: Most carbon intensities are sourced from the LCFS Pathway Certified Carbon Intensities workbook (updated 7/18/2022). The North American Fossil Natural Gas comes from the California Code of Regulation §95488.5. Lookup Table Fuel Pathway Application Requirements and Certification Process, Table 7-1. The biomass value comes from Gas Technology Institute, Low-Carbon Renewable Natural Gas (RNG) From Wood Wastes February 2019.

Livestock facilities have a significantly greater emissions reduction due to the associated negative carbon intensity from eliminating methane that would otherwise be released to the atmosphere. Similarly, RNG from HSAD facilities have a negative carbon intensity as they also remove methane that would otherwise be vented. These greater reductions in carbon lead to generating more credits from the LCFS, which is based on dollars per metric ton of carbon removed.

Renewable Fuel Standard

Biogas producers can also participate in the federal RFS program. The same fuel can qualify for credits in the LCFS and RFS programs simultaneously to "stack" benefits. The RFS program was created under the federal Energy Policy Act of 2005, which amended the federal Clean Air Act. The Energy Independence and Security Act of 2007 further amended the federal Clean Air Act by expanding the RFS program. The U.S. EPA implements the program in consultation with U.S. Department of Agriculture and the U.S. Department of Energy. The RFS program is a national policy that requires a certain volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel, heating oil, or jet fuel.[42] Each fuel type is assigned a "D-code" — a code that identifies the renewable fuel type — based on the feedstock used, fuel type produced, energy inputs, and GHG reduction thresholds, among other requirements. The four categories of renewable fuel have the following assigned D-codes:

- **Biomass-based diesel (D-code 4):** Must meet a 50 percent life-cycle GHG reduction.
- **Cellulosic biofuel (D-code 3) or Cellulosic Diesel (D-code 7):** Must be produced from cellulose, hemicellulose, or lignin and must meet a 60 percent life-cycle GHG reduction.
- **Advanced biofuel (D-code 5):** Can be produced from qualifying renewable biomass (except corn starch) and must meet a 50 percent GHG reduction.
- **Total Renewable fuel (D-code 6):** Typically refers to ethanol derived from corn starch and must meet a 20 percent lifecycle GHG reduction threshold.

RINs are credits that obligated parties use to demonstrate compliance with the standard. Obligated parties must obtain sufficient RINs for each category to demonstrate compliance with the annual standard.

The RFS can provide incentives in addition to California's LCFS incentives. The value of RIN credits varies by fuel category. Most potential sources of biogas covered in this report qualify as cellulosic biofuel, or D-code 3. The D-code D5 covers most biomass sources. The EPA annually sets the volumes of renewable fuel required for each fuel category as part of a rulemaking process. RINs are used to track RFS compliance by assigning a RIN to each gallon of renewable fuel produced or imported. A RIN is a credit equivalent to a gallon of fuel ethanol, and there are 11.7 RINs per MMBtu of natural gas. Figure 20 below shows the average annual RIN price per MMBtu over the last decade. The average price during 2021 shot up significantly to the highest prices seen by the program to date, and while D5 fuels flattened out through the first half of 2022, D3 fuels continued to rise even further.

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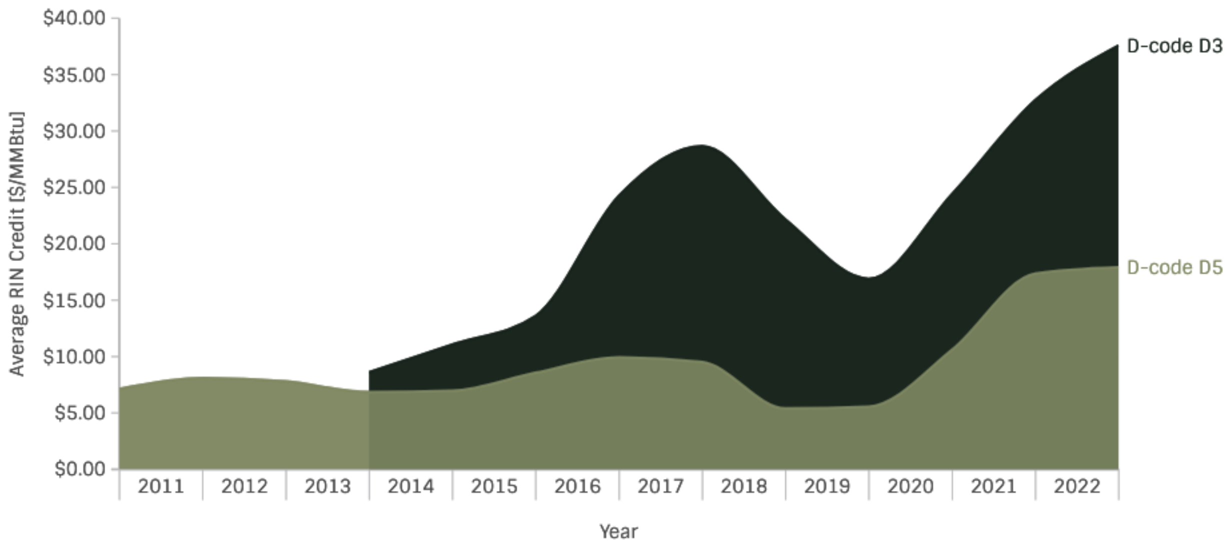
42 U.S. EPA. Renewable Fuel Standard Program. "Overview for Renewable Fuel Standard." Available at https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard.

Figure 20: Federal RIN Prices Over Time



Source: The RFS cost is based on the average of the RIN price during 2021 for D-codes D3 and D5, identified through the U.S. EPA Annual RIN Sales Report. These data run through June 2022.

These credits do not vary based on carbon intensity as LCFS credits do. On a $/MMBtu basis, RFS credits can be substantially larger (for landfills) or smaller (for livestock facilities) than LCFS credits.

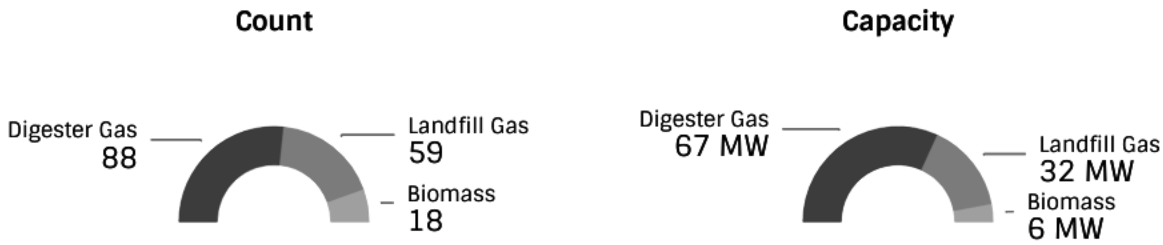
Biogas Generation Incentive Programs

Self-Generation Incentive Program

Since SGIP's inception in 2001, it has provided financial incentives for the installation of distributed generation technologies. Until 2017, the onsite generation could be fueled by either natural gas or renewable biogas. However, in 2017, the program began requiring a portion of the fuel to come from a renewable source, and beginning in 2020, 100 percent of the fuel had to be biogas. The SGIP incentives are split 50/50 between an upfront payment and a five-year performance-based incentive. The performance-based incentive is based on the expected output of the onsite generation equipment when operating at an 80 percent capacity factor for those five years for nonrenewable natural gas fueled projects.

Figure 21 shows the breakdown of completed SGIP biogas-fueled projects by biogas fuel with regards to project count and rebated capacity since the program's inception. Overall, the most prevalent type of biogas for SGIP projects is digester gas, which makes up roughly half of completed biogas projects and 69 percent of rebated capacity (consisting of 88 projects and 67 MW of capacity). Landfill gas makes up roughly a third of SGIP biogas in terms of completed projects and capacity. The biomass gas represents the smallest share of SGIP biogas projects, consisting of 18 projects and 6 MW of capacity, and it is not clear from the SGIP tracking system what the biomass inputs are for these projects.

Figure 21: Completed Gas Generation Project Count and Capacity by Biogas Type, 2001–Mid-2022



Source: Self Generation Incentive Program Tracking Data (10/20/2021)

Net Energy Metering

California's net energy metering (NEM) policies, beginning in 1995 with the original NEM tariff or "NEM 1.0," have encouraged the adoption of customer-sited renewable resources like solar photovoltaic (PV) systems, fuel cells, renewable and biogas fueled generation, and distributed wind. NEM tariffs incentivize the installation of customer-sited renewable resources by compensating NEM customers for energy that is produced and exported to the grid.

California's NEM policies are one of a handful of tools available from the CPUC to encourage the adoption of customer-sited renewable resources. California's SB 656[43] required every electric utility in the state, regardless of whether the entity is subject to the jurisdiction of the CPUC, to develop a standard contract or tariff providing for NEM. Senate Bill 656 allowed NEM customers to be compensated for the electricity generated by an eligible customer-sited renewable resource and fed back to the utility over an entire billing period. The bill also required California utilities to make the NEM tariff available to eligible customers on a first-come, first-served basis until the time that the total rated generating capacity in each utility's service area equaled 0.1 percent of the utility's peak electricity demand forecast for 1996.

On February 5, 2016, the CPUC issued Decision (D.) 16-01-044, which created the NEM successor tariff, known as "NEM 2.0." [44] The NEM 2.0 program went into effect in SDG&E's service territory on June 29, 2016, in PG&E's service territory December 15, 2016, and in SCE's service territory July 1, 2017. The program provides customer-generators full retail rate credits for energy exported to the grid and requires them to pay charges intended to align NEM customer costs more closely with non-NEM customer costs. Customer-generators taking service under NEM 2.0 must pay a one-time interconnection fee, pay nonbypassable charges, and transfer to a time-of-use (TOU) rate. On December 15, 2023, the CPUC adopted another successor tariff, known as "NEM 3.0," which went into effect on across all IOU territories on April 15, 2023. NEB 3.0 made several changes to the program, including updating the price signals and compensation for solar and solar plus battery storage customers.

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43 California SB 656, Alquist. February 22, 1995. Available at

http://www.leginfo.ca.gov/pub/95-96/bill/sen/sb_0651-0700/sb_656_bill_950804_chaptered.html.

44 CPUC Decision Adopting Successor to Net Energy Metering Tariff. February 5, 2016.
Available at https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M158/K181/158181678.pdf.

Bioenergy Market Adjusting Tariff

California provides the Bioenergy Market Adjusting Tariff (BioMAT) to incentivize biogas-fueled electricity generation. This program was created by SB 1122[45] and follows up to the Feed-in tariff (FiT) for the RPS program.[46] The BioMAT is a feed-in tariff program for bioenergy renewable generators less than 5 MW in size. The BioMAT program offers up to 250 MW to eligible projects through a fixed-price standard contract to export electricity to California's three large investor-owned utilities (IOUs). Electricity generated as part of the BioMAT program counts towards the utilities' RPS targets and the utilities own the Renewable Energy Credits (RECs) for the energy produced. Small-scale bioenergy projects can be procured in three categories:

- **Category 1:** Biogas from wastewater treatment, municipal organic waste diversion, food processing, and codigestion — **110 MW**
- **Category 2:** Dairy and other agricultural bioenergy — **90 MW**
- **Category 3:** Bioenergy using by-products of sustainable forest management (including fuels from high hazard zones effective February 1, 2017) — **50 MW**[47]

BioMAT provides a feed-in-tariff of $127.72/MWh to $199.72/MWh to sell electricity directly to the utility, as shown below in Figure 22. The program is modeled largely after the existing Renewable Market Adjusting Tariff (ReMAT), which implements SB 32[48] for all renewable generators. The available contract price started at $127.72/MWh in Period 1 (February 2016) and the power purchase agreement (PPA) can have 10, 15, or 20-year terms. Once the PPA is executed, the contract price is fixed over the delivery term. Available prices have the potential to adjust every two months and are set according to market acceptance and market depth on a statewide basis.[49]

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45 California SB 1122. Rubio. September 27, 2012. Available at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201120120SB1122.

46 From CPUC Decision 14-12-081 December 18, 2014 " The initial FiT legislation, Assembly Bill (AB) 1969 (Yee), Stats. 2006, Ch. 731, created a program for procurement of RPS-eligible electricity produced at plants up to 1.5 megawatts (MW) in size at public water and wastewater treatment plants.

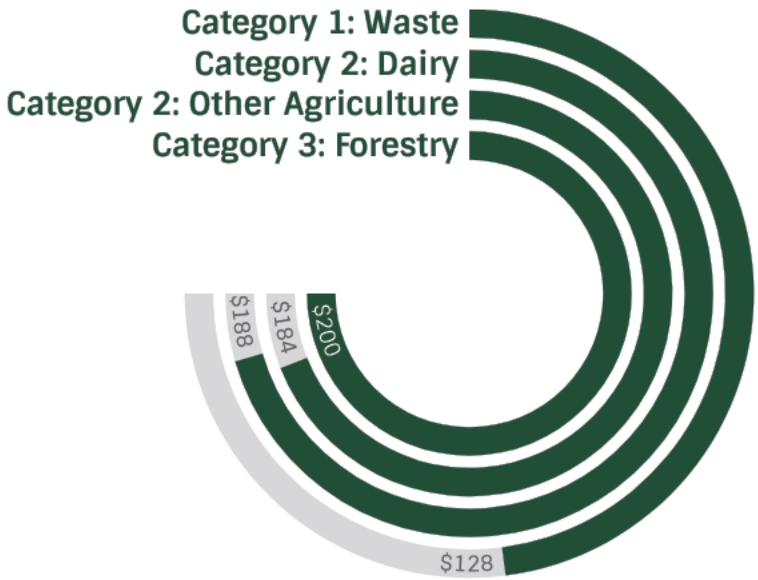
47 CPUC. Bioenergy Feed-in Tariff Program (SB 1122). Available at

https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/rps/rps-procurement-programs/rps-sb-1122-biomat.

48 California SB 32. Amended April 8, 2021. Building Decarbonization Requirements. Cortese and Stern. Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB32.

49 PG&E, SDG&E, SCE. Bioenergy Market Adjusting Tariff (BioMAT) Public Webinar. November 20, 2015. Available at https://www.pge.com/includes/docs/pdfs/b2b/wholesaleelectricsuppliersolicitation/BioMAT/BioMAT_JointIOUWebinar_FINAL.pdf.

Figure 22: BioMAT Feed-In Tariffs by Category



Source: IOU-specific BioMAT Feed-in Tariff participation webpages.
PG&E: https://pgebiomat.accionpower.com/biomat/home.asp
SCE: https://scebiomat.accionpower.com/biomat/home.asp
SDG&E: https://sdgebiomat.accionpower.com/biomat/home.asp

Renewable Energy Credits

RECs can provide additional incentives for renewable generation. Utility customers generating energy from biogas or other renewable sources may be eligible to create RECs that can be traded to individuals or organizations needing or wanting to offset emissions from other sources. As described by the U.S. EPA, a REC *"…represents the property rights to the environment, social, and other non-power attributes of the renewable electricity generation. RECs are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource."*[50] The creation and trading of RECs must be verified via a third party.

RECs can be used to support voluntary (like green tariffs or corporate sustainability goals) or compulsory (like RPS) green energy programs. Utility green tariff programs allow customers to switch to new tariff rates to procure renewable energy via the utility. The value of RECs varies significantly by state and can be volatile given fluctuations in renewable energy supply, demand, and evolving legislative or regulatory goals. Community choice aggregator (CCA) green power programs are driving an increase in the REC market in California. California's REC market is tracked by the Western Renewable Energy Generation Information System (WREGIS), which also creates the certificates for every REC generated. The WREGIS certificates (or RECs) are used to demonstrate compliance with state RPS policies and serves 14 states and two Canadian provinces. For reference, in mid-June 2019, the price SCE paid for

50 "Renewable Energy Certificates (RECs)," https://www.epa.gov/green-power-markets/renewable-energy-certificates-recs.

RECs was $0.018 per kWh, which is significantly lower than the prices paid by LCFS and BioMAT.

If participating in BioMAT, these RECs are owned by the utility. If generating outside BioMAT, these RECs often accrue to the owner of the generator.

Rural Energy for America Program

The United States Department of Agriculture provides grants and loans for renewable energy systems in rural areas through the Rural Energy for America Program (REAP). The grants can cover 25 percent of total eligible project costs of renewable energy systems, up to a maximum of $500,000.[51] REAP is restricted to rural small businesses or farms, so these grants are unlikely to be used by landfills or WRRF, which are usually owned by municipalities or corporations. These grants require a separate application process that can be somewhat cumbersome but can aid in making use of biogas from some dairies for generation.

California Department of Food and Agriculture

The California Department of Food and Agriculture (CDFA) Dairy Digester Research and Development Program is funded by the California's Greenhouse Gas Reduction Fund. The Dairy Digester Research and Development Program is a competitive grant program that provides funds to assist in the installation of anaerobic digesters at dairies to produce biogas for beneficial use. The program provides grants for up to half of the project cost with a maximum of $2 million per project.[52]

From 2014 through 2022, the program has provided a total of $195.5 million to 117 dairy digesters. Table 3 provides a summary of the projects.

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51 U.S. Department of Agriculture Rural Development. Rural Energy for America Program, Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants. Available at

https://www.rd.usda.gov/programs-services/energy-programs/rural-energy-america-program-renewable-energy-systems-energy-efficiency-improvement-guaranteed-loans.

52 California Department of Food and Agriculture 2020 Dairy Digester Research and Development Program. February 3, 2020. "Frequently Asked Questions". Available at http://www.cdfa.ca.gov/oefi/ddrdp/docs/2020_DDRDP_FAQ.pdf.

Table 3: CDFA Dairy Digester Research and Development Program Projects

Year	Number of Projects Funded	Use(s)	Total Funding
2015	6	Electricity Generation	$11.1 million
2017	16	Biogas for Transportation Fuel	$30.7 million
2018	40	Biogas for Transportation Fuel*	$68.0 million
2019	44	Biogas for Transportation Fuel*	$68.6 million
2020	12	Biogas for Transportation Fuel	$16.5 million

*One project in 2018 and two projects in 2019 plan to use fuel cells to generate electricity onsite and sell this electricity for EV charging to receive LCFS credits without injecting into a pipeline.
** The Budget Act of 2021 allocated $80 million to CDFA for its dairy and livestock methane reduction program for Fiscal Years 2021–22 and 2022–23. Funds have not yet been awarded.
Source: California Department of Food and Agriculture. Updated June 3, 2022. Dairy Digester Research and Development Program. *DDRDP Project-Level Data of Executed and Funded Grant Projects*, Available at https://www.cdfa.ca.gov/oefi/DDRDP/docs/DDRDP_Project_Level_Data.pdf.

As shown in Table 3 above, most digesters installed with assistance from the Dairy Digester Research and Development Program produce biogas for transportation and, therefore, participate in both the state LCFS and federal RFS markets. Three recent projects plan to generate electricity with a fuel cell that is used to provide electricity for EV charging. Generating electricity for the purpose of EV charging allows these projects to still participate in the LCFS, but the amount of credits generated is relatively low since the electric grid is the baseline instead of high-carbon-emitting dairies. Having the electric grid as the baseline instead of a dairy effectively lowers the LCFS credit by two-thirds, but by selling electricity instead of gas, these projects do not need to compress the gas to pipeline pressures and do not need to connect to a natural gas pipeline. These same projects could have chosen to participate in the SGIP or BioMAT programs instead but chose to participate in the market-based LCFS.

Federal Tax Credits

The investment tax credit provides a credit on federal taxes for any entity installing renewable fueled generation. This credit is based on a percentage of the fair market value of the installed equipment and will decrease incrementally in subsequent years per federal law. To take advantage of this credit, the owner must have federal tax liability. Currently, the investment tax credit is available at a 26 percent rate for fuel cells, and at a 10 percent rate for microturbines and other combined heat and power systems. Credits for other nonfueled systems are available at differing rates.

The federal renewable energy production tax credit is an inflation-adjusted per-kilowatt-hour tax credit. This is currently available for landfill gas, closed-loop and open-loop biomass projects, and waste-to-energy systems, along with several other non-biogas related technologies. The tax credit is available for the first 10 years of operation and currently provides a credit between $0.026 and $0.13 per kilowatt-hour.

Pipeline Interconnection Assistance Incentives

Assembly Bill 1900 (Gatto, Chapter 602, Statutes of 2012) established an incentive program to aid biogas projects with interconnecting to the natural gas distribution network. Among other things, it required the CPUC to adopt standards that specified the concentrations of constituents of concern that are found in biogas, and to adopt monitoring, testing, reporting, and recordkeeping protocols to ensure the protection of human health and to ensure the integrity and safety of the pipelines and pipeline facilities. Moreover, on December 18, 2017, the CPUC issued Decision (D.) 17-12-004, which established the necessary framework to direct natural gas corporations to implement not less than five dairy biogas pilot projects to demonstrate interconnection to the common carrier pipeline system and allow for rate recovery of reasonable infrastructure costs pursuant to SB 1383.

The State of California provides financial reimbursements to offset biogas developer pipeline interconnection costs. Under AB 2313, these reimbursements can be up to 50 percent of the interconnection costs or $3 million per project, whichever is lower. If a project involves a cluster of dairy farms, the reimbursements can be up to 50 percent of the interconnection costs or $5 million, whichever is lower. Reimbursements for biogas interconnection costs are implemented by the CPUC decisions and policies and carried out by regulated investor-owned gas utilities.[53]

It should be noted that according to the CPUC's Renewable Natural Gas Web page, incentives for this program are unavailable. While there appears to be an additional $51 million in incentives remaining, these incentives are all reserved, and the fund is oversubscribed by $15.5 million.[54]

Combining Incentives and Revenues

As discussed in this chapter, California and the federal government provide several incentives to promote the beneficial use of biogas. Some of these programs are complimentary and allow participants to "stack" incentives while others are mutually exclusive. Table 4 summarizes which programs can be used together and which cannot.

53 "PG&E's Biomethane Frequently Asked Questions." Available at

https://www.pge.com/en_US/for-our-business-partners/interconnection-renewables/interconnections-renewables/biomethane-faq.page?ctx=large-business.

54 "CPUC Renewable Natural Gas." Available at https://www.cpuc.ca.gov/renewable_natural_gas/.

Table 4: Incentive Capability Cross Reference

PROGRAM	LCFS	RFS	SGIP - ONSITE	SGIP - DIRECTED	NEM	BIOMAT	RECS	FEDERAL TAX CREDITS	CDFA DDRDP	USDA REAP	INTERCONNECTION ASSISTANCE
LCFS		**Y**	**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**N**	**Y**
RFS	**Y**		**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**N**	**Y**
SGIP - ONSITE	**N**	**N**		**N**	**Y**	**N**	**Y**	**Y**	**N**	**Y**	**N**
SGIP - DIRECTED	**N**	**N**	**N**		**Y**	**N**	**Y**	**Y**	**Y***	**N**	**Y***
NEM	**N**	**N**	**Y**	**Y**		**N**	**Y**	**Y**	**N***	**Y**	**N***
BIOMAT	**N**	**N**	**N**	**N**	**N**		**N**	**Y**	**Y***	**Y**	**Y***
RECS	**N**	**N**	**Y**	**Y**	**Y**	**Y**		**Y**	**Y**	**Y**	**Y**
FEDERAL TAX CREDITS	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**		**Y**	**Y**	**Y**
CDFA DDRDP	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**		**Y**	**Y**
USDA REAP	**N**	**N**	**Y**	**N**	**Y**	**Y**	**Y**	**Y**	**Y**		**N**
INTERCONNECTION ASSISTANCE	**Y**	**Y**	**N**	**Y**	**Y***	**Y***	**Y**	**Y***	**Y***	**N**	

*Only applicable for selling/buying RNG through the gas network

Source: Verdant Associates using information from the following sources: LCFS, RFS, SGIP, CPUC, EPA, CDFA, USD, and Department of Energy.

In general, the beneficial use options for producers of biogas fall into either selling biogas through the gas distribution network for use elsewhere (and potentially getting LCFS/RFS credits or selling for use by the utility or a directed biogas generator) or for onsite generation (with assistance from SGIP/NEM or the BioMAT program).

Other Policies

Other California policies and legislation may further impact RNG in California. In addition to the aspects of California SB 1440 (already discussed), CPUC Decision D.20-12-022 (December 2020) approved the Voluntary Renewable Natural Gas Tariff. This tariff allows SoCalGas and SDG&E to offer a natural gas mix containing RNG to their customers, like the green energy packages offered by many electric utilities. These tariffs would need to procure at least 50 percent of the RNG from in-state or out-of-state sources that are delivered to California to comply with California Public Utilities Code 651(b)(3)(B) and carbon intensities must be verified with the same modified version of the GREET model used to calculate carbon intensities for the LCFS program.[55] These RNG tariffs may increase the demand for RNG, thereby driving additional supply.

Another piece of legislation, California SB 1383,[56] has the goal of reducing the landfill disposal of organics 50 percent by 2020 and 75 percent by 2025, based on 2014 levels. The purpose is to reduce the emissions of short-lived climate pollutants, such as black carbon, fluorinated gases, and methane, and in doing so, improve organics recycling and beneficial uses of biomethane from solid waste facilities.

SB 1383 is implemented through several methods, such as:[57]

- **Collection and recycling:** Organic waste collection is provided to all residences and businesses. These organic materials must be recycled through facilities that create biofuel and electricity through anaerobic digestion, or composting facilities that make soil amendments.
- **Procurement requirements:** Local governments are required to use recycled organic material products, such as mulch, compost, and renewable energy.
- **Food recovery:** Edible food is donated to help feed Californians (almost 25 percent) without enough to eat.
- **Capacity planning:** Counties are leading collaborative planning for necessary organic waste recycling and food recovery capacity, which will divert organic waste away from landfills.
- **Enforcement:** Jurisdictions will lead their own inspection and enforcement program, with CalRecycle providing compliance evaluations of jurisdictions.
- **Recordkeeping requirements:** Records are required to demonstrate compliance with the law.

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55 California Air Resources Board. LCFS Life Cycle Analysis Models and Documentation. Available at https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation

56 California SB 1383, Lara. September 19, 2016. Short-lived climate pollutants: methane emissions: dairy and livestock: organic waste: landfills. Available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383.

57 CalRecycle. California's Short-Lived Climate Pollutant Reduction Strategy. Available at https://www.calrecycle.ca.gov/organics/slcp.

Implementation of SB 1383 may increase the available RNG by diverting organic waste from landfills to other processing facilities that can produce additional RNG such as WRRFs.

In 2019, Carollo Engineers, Inc., produced a report titled *Co-Digestion Capacity Analysis for the California State Water Resources Control Board*,[58] which analyzed codigestion capacity at municipal waste-water treatment facilities in California. The study estimated that between 3.4 and 4.5 million short wet tons per year of food waste would be suitable for digestion at California WRRFs by 2030. The analysis suggested that without any infrastructure modifications, at least seven of California's WRRFs have the excess capacity to handle approximately 118,000 short wet tons per year, or 3.5 percent of the projected food waste. However, if these seven facilities were modified, such that their overall system capacity would match their excess digestion capacity, they would be able to handle from 850,000 to 2.2 million additional short wet tons per year of food waste diverted from landfills, representing 25–64 percent of the recoverable and digestible food waste in 2030.

Finally, AB 3163[59] expanded the definition of biomethane to include gas produced from biomass that comes from additional forms of organic waste, including vegetation removed for wildfire mitigation. This may expand the production of RNG from biomass. Note that crops grown for the purpose of producing RNG are not included in this definition.

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58 Carollo Engineers, Inc. June 2019. *Co-Digestion Capacity Analysis Prepared for the California State Water Resources Control Board under Agreement #17-014-240*. Available at https://www.waterboards.ca.gov/climate/docs/co_digestion/final_co_digestion_capacity_in_california_report_only.pdf.

59 California Assembly Bill 3163, Salas. September 30, 2020. Energy: biomethane: procurement. Available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200AB3163.

CHAPTER 6: Summary of Findings

Encouraging RNG production has the potential to contribute to California's progress toward a low-carbon future. Based on research by ICF, RNG has the production potential to displace 12 to 23 percent of the non-power-plant natural gas usage in California and up to 50 percent based on technical potential.[60] Figure 23 summarizes the differences in each of these RNG sources, including potential natural gas displacement, estimated cost to produce, carbon intensities, and LCFS incentives.

Figure 23: Comparison of RNG Sources

	Livestock	WRRF	Landfills	Biomass	HSAD
Potential Displacement of California's Natural Gas Consumption	• Production Potential: 1 - 3% • Technical Potential: 4%	• Production Potential: <1% • Technical Potential: <1%	• Production Potential: 6 - 10% • Technical Potential: 15%	• Production Potential: 1 - 3% • Technical Potential: 11%	• Production Potential: 3 - 7% • Technical Potential: 17%
Cost to Produce RNG [$/MMBtu]	$25.50	$16.75	$13.00	$23.25	$30.75
Carbon Intensity Compared to the Baseline (Flaring or Venting) [gCO2e/MJ]*	-341	+28	+42	+13	-23
Reduction in Carbon over Natural Gas [gCO2e/MJ]	417	47	34	62	99
LCFS Incentive [$/MMBtu]	$53.85	$6.12	$4.40	$8.06	$12.79

*Carbon intensity for Biomass is based on wood waste while potential also includes crop waste

Note: WRRF refers to Water Resource Recovery Facility and HSAD refers to High-Solids Anaerobic Digestion
Source: The sources of these numbers are cited throughout this report.

While there are many livestock facilities and the associated carbon reduction opportunity is significant compared to the natural gas baseline, the total potential for RNG at livestock facilities only represents 1 to 4 percent of the current California non-power-plant natural gas energy usage. Furthermore, these facilities have a much higher estimated cost associated with the production of RNG.

Landfills have the potential to displace 6 to 15 percent of the non-power-plant natural gas consumption in California and have an average cost of production that is about half that of

60 ICF. *Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment.* American Gas Foundation. December 2019.

livestock facilities. Landfills, however, have a carbon emissions reduction that is only 8 percent of the carbon emissions reduction achieved from livestock facilities.

While HSAD facilities are not counted as a major source of biogas in California today, there are several findings which indicate an opportunity for sourcing 3 to 17 percent of the non-power-plant natural gas consumption from these facilities. Like livestock facilities, the average estimates of the cost to produce RNG currently make HSAD the most expensive source of RNG, however it is also a carbon negative source, making it a high-carbon-reduction opportunity with significant potential. The changes to California’s waste management driven by SB 1383 make this source a more likely RNG candidate in the future.

GLOSSARY

Acronym	Definition
AB	Assembly Bill (AB) – Refers to a piece of legislation (federal or state) that passed the assembly
BioMAT	Bioenergy Marketing Adjusting Tariff (BioMAT) – Program to incentivize biogas fueled electricity generation
CDFA	California Department of Food and Agriculture (CDFA) – California agency which manages the Dairy Digester Research and Development Program
CODIGESTION	Codigestion refers to the simultaneous anaerobic digestion of multiple organic wastes in one digester.
CPUC	California Public Utilities Commission (CPUC) – The California state agency regulating public utilities
GHG	Greenhouse gas (GHG)—Any gas that absorbs infrared radiation in the atmosphere
HSAD	High-Solids Anaerobic Digester (HSAD) – Anaerobic digester which handles high-solids biomass, like feed stocks, food waste, and yard clippings
LCFS	Low Carbon Fuel Standard (LCFS) – California program incentivizing low carbon fuels
MSW	Municipal Solid Waste (MSW) – Home, school, or business trash that is used and thrown away by consumers such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries.
NEM	Net Energy Metering (NEM) – California provides customer-generators full retail rate credits for energy exported to the grid
PYROLYSIS	Pyrolysis is a thermochemical process that entails the heating of organic material at high temperatures in the absence of oxygen. Biomass pyrolysis produces fuels such as charcoal, bio-oil, renewable diesel, methane, and hydrogen.
REAP	Rural Energy for America Program (REAP) – Program run by the United States Department of Agriculture which provides grants and loans for renewable energy systems in rural areas
RECs	Renewable Energy Credits (RECs) – A federal program which allows utility customers generating energy from biogas or other renewable sources to trade the benefit of on the REC markets to aid in compliance with state or other renewable portfolio standards.
RFS	Renewable Fuel Standard (RFS) – Federal program incentivizing renewable fuels
RNG	Renewable Natural Gas (RNG) – Biomethane that is injected in the natural gas pipeline
RPS	Renewable Portfolio Standards (RPS) – Renewable electricity policies designed to increase the use of renewable sources of electricity generation
SB	Senate Bill (SB) – Refers to a piece of legislation (federal or state) that passed the federal or state senate

SGIP	Self-Generation Incentive Program (SGIP) – California program which, among other things, incentivizes renewable fuels for onsite generation
U.S. EPA	United States Environmental Protection Agency (U.S. EPA) – The federal agency tasked with environmental protection
WRRF	Water Resource Recovery Facility (WRRF) – Also known as waste-water treatment plants