

# Renewable Natural Gas

The RNG Opportunity for Natural Gas Utilities



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This report reflects the analysis and judgment of the MJB&A authors only and does not necessarily reflect the views of the DSI companies.

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## Executive Summary

As customers increasingly demand renewable energy sources, natural gas local distribution companies (LDCs) are evaluating the opportunity to integrate renewable natural gas (RNG) resources into their fuel supply. Increased use of RNG would enable LDCs to lower the carbon intensity of their fuel supply while diverting waste streams, encouraging local economic development, and adding additional sources of supply. In addition, when compared to flaring or generating electricity on-site, integrating RNG into LDC pipelines can result in local air quality benefits. When properly treated, RNG can be used interchangeably with traditional natural gas, providing fossil fuel displacement benefits across a range of industries and end uses. While RNG has been produced and used in the U.S. for decades, utilities and policymakers are increasingly exploring an expanded role for RNG.

The opportunity for expanded use of RNG is significant, with a recent study estimating the technical potential of RNG from existing sources in the U.S. could satisfy ten percent of the natural gas distributed nationally. However, due to the high costs associated with upgrading RNG and bringing it to market, the majority of potential supplies of RNG have not been developed. While a number of policies are helping promote RNG resource development for use in the transportation and power generation sectors, to date, these policies have not been directed at increasing the use of RNG in the natural gas distribution segment for delivery to customers for heating and appliances.

### **Renewable natural gas from a range of existing sources has the potential to meet ten percent of natural gas demand.**

Most RNG produced today originates from diverted waste streams such as landfills, animal manure, and waste water treatment plants. It can also be produced from plant materials such as forest and agriculture waste. Estimates of the amount of RNG that could be produced in the U.S. vary, but show that meaningful amounts of customer demand for natural gas could be met with RNG. The high end of a range of potential RNG volumes from an American Gas Foundation study is equal to ten percent of the natural gas delivered to U.S. customers in 2015. RNG potential varies regionally, and areas with large RNG feedstock resources have the potential to achieve higher percentages of RNG. A study by the University of California Davis shows that California resources could provide enough RNG to fuel current natural gas demand from the state's transportation sector four times over. The development of emerging technologies, such as power-to-gas, that break down water to create RNG could expand the RNG resource base in the future, allowing RNG to supplant even greater volumes of traditional natural gas.

### **The existing natural gas distribution network can be used to deliver renewable fuel.**

Natural gas customers – from individual home owners to major corporations – are increasingly interested in reducing their environmental impact. RNG allows natural gas users to reduce the impact of their gas consumption and allows utilities to complement existing renewable electricity offerings with a renewable gas product. Incorporating RNG into natural gas supply provides an opportunity to reduce greenhouse gas (GHG) emissions while utilizing the existing natural gas distribution system. Replacing traditional natural gas with RNG in many cases provides a greater climate benefit than electrification of end-uses. Additionally, RNG can be substituted for traditional natural gas in any application, whereas electrification is not possible or even beneficial on a lifecycle basis for all current natural gas applications. Beyond interest in strategies to reduce the carbon intensity of natural gas, RNG development can add new sources of supply and provide an economic benefit to regional economies.

### **Policies to reduce the carbon intensity of electricity and transportation fuels are the primary drivers for RNG today, but RNG can also be used to heat homes and businesses.**

The primary existing drivers of RNG development are policies and incentives to decarbonize the transportation and power generation sectors. Federal and state programs, such as the Renewable Fuel

Standard (RFS) and California's Low Carbon Fuel Standard (LCFS), provide a monetary credit to RNG that is used as a transportation fuel. Similarly, many state electric renewable portfolio standard (RPS) programs allow RNG to generate renewable energy credits (RECs) when it is used to produce electricity. However, there are very few programs that allow RNG to generate credits when it is used to heat homes and fuel household appliances. As such, most RNG produced in the U.S. is used in the transportation and power generation sectors. With new incentives, RNG use in the natural gas distribution sector, where end-use combustion is often more efficient compared to the transportation and electric sectors, would likely increase.

### **Financial and regulatory barriers currently limit RNG use in the distribution segment**

Despite RNG's large potential resource base, a range of barriers currently limit RNG production and use in natural gas distribution systems. The primary barrier is economic. After RNG is produced, it must be processed to meet specific standards, designed to protect health and infrastructure, before it can be introduced to the distribution network. RNG production facilities must also be physically connected to the distribution system via pipeline. The costs associated with these efforts are usually too great to be borne by RNG producers, and cannot be covered by utilities subject to least-cost requirements. Regulatory requirements related to the quality of RNG represent another challenge. Currently, RNG quality is handled on a project-by-project basis without an established standard. Aside from recently established rules in California, the lack of clear and consistent regulations governing RNG quality standards creates uncertainty for project developers.

### **Policymakers can provide certainty to project developers and reduce barriers to RNG projects.**

Natural gas utilities, policymakers, and regulators have several options to increase the utilization of RNG and realize some of its potential environmental and economic benefits. As a first step, RNG gas quality standards could be established to provide LDCs and RNG producers with regulatory certainty. This would assure LDCs that the RNG they receive is fully interchangeable with the traditional natural gas on their systems and make clear to producers how to treat their RNG. Utilities can also encourage RNG production by purchasing RNG from producers, investing in RNG infrastructure, or offering voluntary RNG programs to customers. To enable this investment, regulators could consider taking factors beyond cost into consideration. For example, regulators could consider the ability of RNG to contribute toward GHG reductions and the local or regional economic benefits of RNG investments. When these factors are considered, as is currently allowed in California and British Columbia, regulators are more likely to approve investment in RNG projects. Finally, policymakers could consider options that assign a value to the environmental attributes of RNG consumed by end users outside of the transportation and power generation sectors. This would incentivize using RNG in the natural gas distribution segment and recognize the environmental benefits of RNG supplied by LDCs to all customers rather than for only specific end uses.

## Introduction

Recognizing the environmental and economic benefits of RNG, natural gas utilities and customers are increasingly interested in developing and using RNG. However, many policy makers and the general public remain uninformed on the basics of RNG and its potential benefits. This white paper provides an overview of RNG; summarizes current RNG policies, market drivers, and barriers; and describes potential regulatory and policy changes that could be made to support the integration of greater volumes of RNG into the natural gas distribution system.

## Renewable Natural Gas 101

RNG is produced by processing and cleaning methane-rich gas, also referred to as biogas, from waste streams to create a pipeline-quality gas that is fully interchangeable with traditional natural gas. All natural gas of similar composition, whether it is renewable or traditional, emits the same amount of GHG emissions when combusted in the same process. Because the climate impact of methane is greater than that of carbon dioxide (CO<sub>2</sub>), eliminating methane emissions from waste streams yields a net life-cycle GHG reduction when that methane is combusted in lieu of traditional gas, rather than being emitted to the atmosphere or flared.

Table 1 shows the calculated carbon intensities (CIs), under California's Low Carbon Fuel Standard (LCFS), of traditional natural gas, RNG produced from solid waste, cow manure, wastewater treatment plants, and food waste. As shown, compared to traditional natural gas, net life-cycle GHG emissions from RNG are at least 40 percent lower, with some feedstocks providing net-negative GHG emissions. The primary factor driving carbon intensities is whether the methane, if not processed to RNG, would otherwise be flared or emitted to the atmosphere.

**Table 1** California LCFS Carbon Intensities

Gas Source	Carbon Intensity (g CO <sub>2</sub> e/MJ)
California Natural Gas (Traditional)	78.37
Landfill Gas	46.42
Dairy Digester Gas	-276.24
Wastewater Treatment	19.34
Municipal Solid Waste (MSW)	-22.93

Source: California Air Resources Board

Today, RNG is primarily produced using one of two processes: anaerobic digestion (AD), or thermo-chemical conversion. In the AD process, microorganisms break down organic material in a zero-oxygen environment, producing methane and carbon dioxide. AD is most often used to produce methane from feedstocks with high moisture contents, such as animal manure and wastewater. AD also naturally generates methane at landfills, where organic waste is slowly broken down over time.

Thermo-chemical conversion involves heating feedstocks at high temperatures to break down the material at the molecular level without combustion. The resulting hydrogen and carbon monoxide gases are then converted to methane and carbon dioxide using a process called methanation. Thermo-chemical conversion is usually used to produce methane from low-moisture feedstocks such as woody biomass, crop residuals, and dedicated energy crops.

The gases produced by both AD and thermo-chemical conversion are known as biogas, and can be purified to become RNG. In addition to methane, both processes generate CO<sub>2</sub> and other trace constituents. While raw biogas can be used directly for on-site electricity generation or burned to produce process heat, raw biogas is not of pipeline quality and must be cleaned of various constituents and/or upgraded to a higher

heating value before it can be called RNG. After processing to meet gas quality specification requirements, the gas becomes RNG and can be safely injected into natural gas pipelines, and used for all of the same purposes as traditional natural gas.

Two additional processes, power-to-gas and artificial photosynthesis, can also be used to produce RNG. Rather than creating RNG using biogenic feedstocks, these processes convert water to hydrogen, which can then be combined with CO<sub>2</sub> to create methane. Power-to-gas uses renewable power to split water into oxygen and hydrogen. Artificial photosynthesis does the same, but uses sunlight rather than electricity to split water molecules. While these technologies are still under development, they could be used to produce significant amounts of RNG in the future.

## Existing RNG Resources

Most of the RNG produced today comes from landfills, livestock manure digesters, and wastewater treatment plants. While information on some of these projects is reported to EPA, there is no source of centralized data on U.S. RNG production, complicating efforts to estimate current U.S. supply. Two major sources of data are EPA's AgSTAR<sup>1</sup> program and Landfill Methane Outreach Program (LMOP).<sup>2</sup> AgSTAR provides information on biogas recovery systems at manure management facilities, while LMOP provides information on methane recovery at landfills. These programs share information on relevant technologies, financing opportunities, and current and potential projects. Data from both programs shed light on where RNG is being produced today, what it is being used for, and the GHG emissions mitigated by RNG projects.

Landfills are currently the largest source of RNG in the U.S. EPA's LMOP currently lists 654 operational landfill gas energy recovery projects at 599 landfills. Across the landfills reporting data on landfill gas (LFG) collected, average daily biogas production is 1.7 million standard cubic feet per day (MMscf/d). This figure does not include excess gas beyond the capture and processing capacity of each project, meaning total gas production is actually higher. The average biogas methane content among reporting facilities is 49.3 percent. The LMOP estimates that U.S. LFG projects currently reduce direct methane emissions to the atmosphere by 130.6 million metric tons (MMT) carbon dioxide equivalent (CO<sub>2</sub>e) per year. The LMOP has also identified an additional 416 landfills that are candidates for LFG projects. EPA estimates that these projects could produce an additional 246 MMscf/day of biogas and yield nearly 36 MMT CO<sub>2</sub>e per year in methane reductions. Further, 57 percent of these landfills already have gas capture systems in place but flare all of their gas. Figure 1 shows the number of landfills with LFG energy recovery projects by state. California has by far the most landfills with projects in place at 70, followed by Michigan at 39, and North Carolina at 36.

Currently, three-quarters of collected LFG is used to generate electricity that is used onsite, sent to a nearby industrial or institutional facility, or sold onto the local grid. About 16 percent of LFG is used for direct heating onsite or nearby, and only about 7 percent of currently captured landfill gas is processed and upgraded to RNG for use as a transportation fuel, or for injection into the local natural gas pipeline network. The LMOP estimates that electricity generation projects using LFG have a total capacity of 2,190 MW. LFG is directly used by nearby facilities for a wide range of purposes, including combustion in a boiler for heating and process steam, sludge drying at waste treatment facilities, and kiln heating at brick and cement plants. EPA estimates that LFG projects produce 311 MMscf/d of biogas that is used in direct heating or is upgraded to RNG.<sup>3</sup> The fact that many landfills are located near large population centers means there are potential

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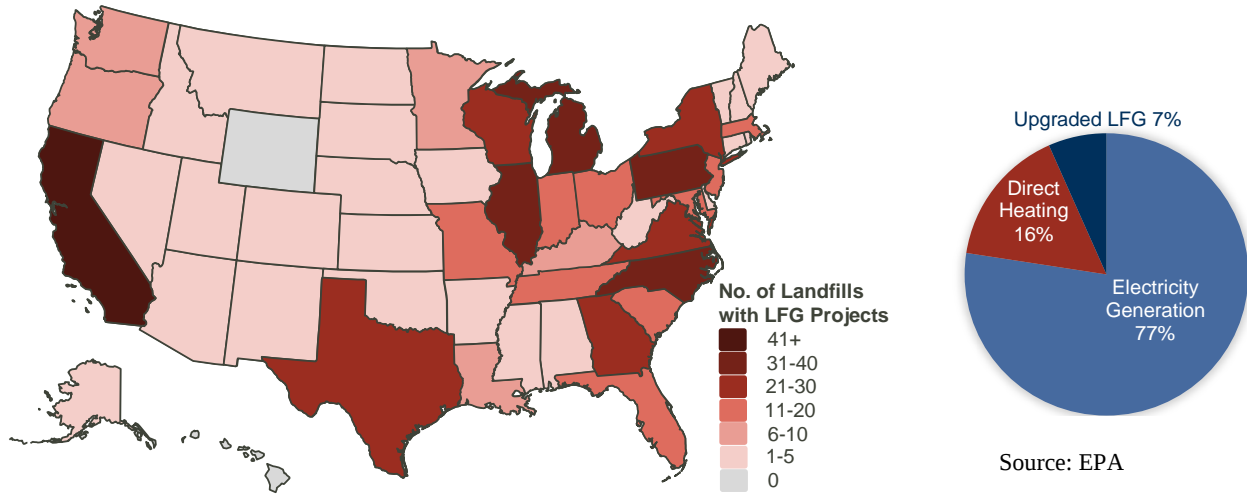
<sup>1</sup> More information available at: <https://www.epa.gov/agstar>

<sup>2</sup> More information available at: <https://www.epa.gov/lmop>

<sup>3</sup> Landfill projects that use gas for direct heat, or upgrade their LFG to RNG, report the volume of gas collected, but not all projects generating electricity report collected gas volume. EPA therefore provides totals for gas collected for direct heat and upgraded LFG projects but not for electricity projects. Instead, the cumulative impact of electricity projects is represented by their total electric generating capacity.

nearby markets to drive demand for upgraded LFG. Proximity may also limit infrastructure costs for RNG interconnections.

**Figure 1** Landfill Gas Projects by State and End Use



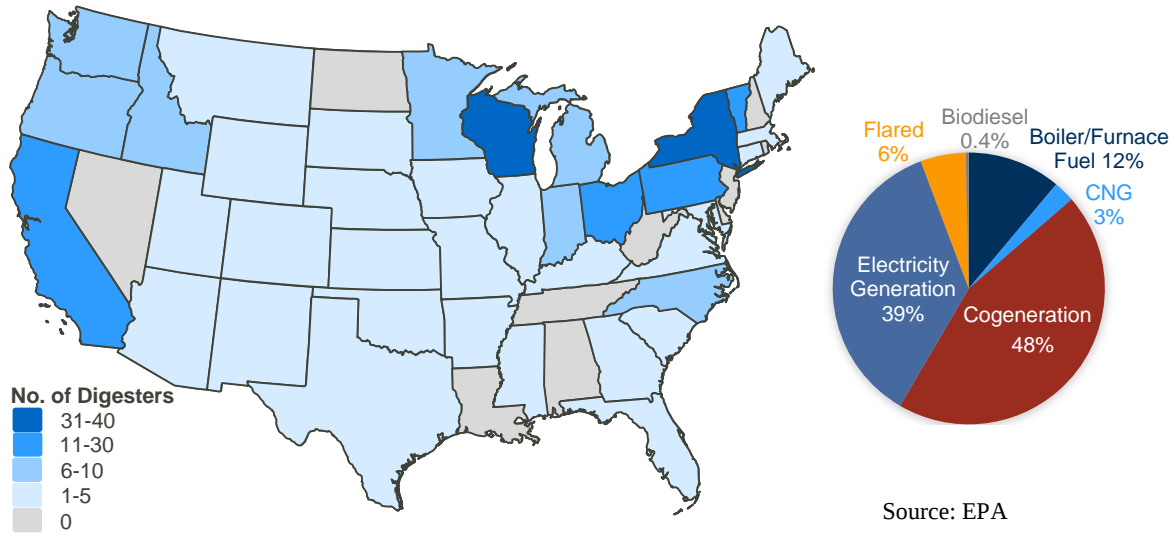
EPA’s AgSTAR program maintains a database of existing bio-digesters across the U.S. According to this database, there are significantly fewer digesters in the U.S. than LFG projects, with a total of 242 active digesters. These digesters also generate less biogas than most landfills, with the average digester producing 302,223 cubic feet of gas per day.<sup>4</sup> In 2015, energy generation from digesters at U.S. livestock farms was approximately equivalent to 981 gigawatt hours (GWh) of electricity, and biogas production avoided methane emissions equal to 2.5 MMT CO<sub>2</sub>e. AgSTAR’s database shows that digesters are concentrated along the eastern, north-central, and western U.S., with several large operations in other parts of the country. Figure 2 shows the number of manure digesters by state. The potential RNG supply from digesters is largely untapped, with AgSTAR estimating that biogas recovery systems are technically feasible at over 8,000 large livestock operations in the U.S.

Methane from manure digesters is used in many of the same ways that landfill gas is used, including for electricity generation and for direct or process heating. However, because large farms are often located far from population centers, installing natural gas or electric lines to existing grids can be prohibitively expensive. As such, many farms with bio-digesters have installed cogeneration plants that enable them to use their own gas onsite, to produce electricity and heat for their own use. Cogeneration, or combined heat and power (CHP), systems use gas to generate electricity and capture heat that would normally exit the exhaust stack for a useful purpose, such as space heating. These systems allow farms to reduce methane emissions, save money, and use methane in a highly efficient manner. A number of waste digesters also co-digest other material with manure, such as agricultural waste, food waste, and process water from dairy and slaughterhouse operations. The addition of these materials boosts methane production and provides a beneficial use for wastes that if otherwise disposed of could lead to additional methane emissions to the atmosphere, and present other waste management challenges. Some facilities flare their digester gas, reducing its climate impact but wasting a potential resource. The pie chart in Figure 2 shows how biogas from digesters is used, as reported by AgSTAR.

<sup>4</sup> Based on the facilities that reported production data.

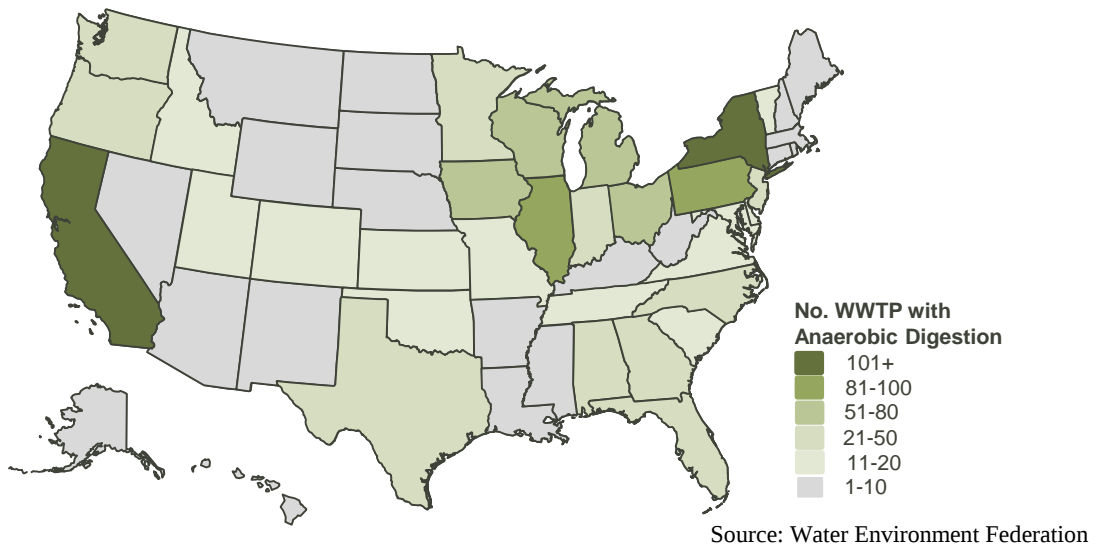


**Figure 2** Manure Digesters by State and End Use



Wastewater treatment plants (WWTP) are the third major source of biogas in the U.S. While less data is available on biogas from WWTP compared to landfills and manure digesters, a coalition of wastewater organizations estimates that of the approximately 16,000 WWTP in the U.S., 1,268 use anaerobic digestion (see Figure 3).<sup>5</sup> Many of the facilities that generate biogas have excess digester capacity and could boost biogas production by adding other feedstocks, such as food waste, to their digesters. Gas produced at WWTP is used in many of the same ways as gas produced at landfills and manure management systems, including for CHP (a large amount of heat is used in the wastewater treatment process), electricity generation, and upgrading to RNG for injection into the natural gas pipeline network. Systems that do not beneficially use biogas, or that generate excess gas, typically flare it. Similar to landfills, WWTP tend to be located near large population areas, providing a nearby market for RNG, and potentially reducing infrastructure buildout requirements.

**Figure 3** Wastewater Treatment Plants with Anaerobic Digestion by State



<sup>5</sup> Water Environment Federation. *Biogas Data*. Available at: <http://www.resourcerecoverydata.org/biogasdata.php>

Other potential feedstock sources for production of RNG include woody biomass, crop residuals, food waste, and energy crops. As discussed above, some of these feedstocks can be added to anaerobic digesters that primarily process other materials to boost biogas production. However, because forest materials, crop residuals, and dedicated energy crops have lower moisture contents, they are generally converted into biogas using thermo-chemical conversion processes, not anaerobic digestion.

## Potential RNG Supply

Although U.S. RNG supply is difficult to calculate, total potential supply can be estimated using data on RNG feedstocks. The National Renewable Energy Laboratory’s (NREL) most recent analysis of RNG potential, published in 2014, estimated an annual potential supply of 15,988,000 tons of methane, or over 756 billion cubic feet (bcf), from biogenic feedstocks.<sup>6</sup> The study estimated RNG potential from four anaerobic digestion feedstocks: landfills, WWTP, animal manure, and industrial, institutional, and commercial (IIC) organic waste. Table 2 shows the potential for each feedstock.

**Table 2** NREL Estimate of Anaerobic Digestion Biogas Potential

Source	Methane Potential (thousand tons/year)	Methane Potential (bcf/year)
Landfills	10,586	500.8
WWTP (wastewater treatment plant)	2,339	110.7
Animal Manure	1,905	90.1
IIC (industrial, institutional, and commercial) Organic Waste	1,158	54.8
Total	15,988	756.4

Source: NREL

The NREL study does not estimate RNG potential from other feedstocks such as lipids and lignocellulosic biomass (forest materials, crop residuals, energy crops), so supply is potentially higher than NREL’s estimate. A different study by the American Gas Foundation (AGF) did estimate potential RNG supply produced from lignocellulosic feedstocks via thermal gasification (TG, a form of thermo-chemical conversion). That study found TG of these resources could produce between 612 and 1,563 bcf of RNG per year (AGF’s estimate of RNG from AD ranged from 324 to 844 bcf/year).<sup>7</sup>

The high range of potential RNG estimates from the AGF study total roughly 2.4 trillion cubic feet (tcf) per year. This is equal to almost ten percent of U.S. natural gas deliveries, which in 2015 totaled over 25 tcf. Looking at individual sectors, potential RNG could supply about half of residential gas demand and is more than 60 times greater than 2015 consumption of natural gas for use as a vehicle fuel. However, it is important to note that actual RNG supplies will come with increasing costs to fully achieve these technical potentials. RNG also faces competition for feedstock from other fuels. Lignocellulosic feedstocks can be directly burned to generate electricity, or used to produce liquid fuels via distillation or TG (e.g., corn converted into ethanol) as alternatives to RNG production. The type of fuel derived from various feedstocks is driven by economics and market demand, discussed below, and actual biogas production and utilization is therefore lower than potential production.

<sup>6</sup> Saur, G. and Milbrandt, A. National Renewable Energy Laboratory. “Renewable Hydrogen Potential from Biogas in the United States”. July 2014. Available at: <http://www.nrel.gov/docs/fy14osti/60283.pdf>

<sup>7</sup> American Gas Foundation. The Potential for Renewable Gas: Biogas Derived from Biomass Feedstocks and Upgraded to Pipeline Quality”. September 2011. Available at: <http://www.eesi.org/files/agf-renewable-gas-assessment-report-110901.pdf>

Other analyses have estimated potential RNG supply at regional levels. In 2010, National Grid estimated that across Massachusetts, New Hampshire, New York, and Rhode Island, the annual technical potential for RNG was 268 bcf, or enough to supply 16 percent of the region’s total natural gas supply.<sup>8</sup> As shown in Table 3, this jumps to a quarter of total demand if gas used for power generation is not included. National Grid projects that developing the region’s full RNG potential would reduce CO<sub>2</sub> emissions by 15.6 million tons per year.

**Table 3** National Grid State-Specific RNG Potential Estimates

State	Technical RNG Potential (bcf/year)	Potential as a Percentage of Total Demand	Potential as a Percentage of Total Demand w/o Power Generation
Massachusetts	39	10%	18%
New Hampshire	23	35%	100%
New York	193	17%	25%
Rhode Island	13	15%	35%
Total	268	16%	25%

Source: National Grid

A June 2016 study by the University of California Davis analyzed California’s potential RNG supply. The study estimated that California’s landfills, manure digesters, wastewater treatment plants, and municipal solid waste digesters have the technical potential to produce up to 90.6 bcf/year.<sup>9</sup> This estimate could meet 23 percent of California’s residential natural gas demand in 2015, and provide four times the amount of natural gas delivered to the transportation sector that year.<sup>10</sup> However, the report notes that total RNG production will vary based on the value of incentives and other economic factors.

## Barriers to RNG Development

Project economics currently present the largest barrier to wider development and integration of RNG resources. While it is often economic to use biogas on site to produce process heat, or even to generate electricity for export to the grid, interconnecting RNG production facilities with the natural gas distribution system is typically more expensive than on-site use. The first interconnection cost is related to conditioning the raw biogas to meet minimum heating value and other quality specifications for pipeline gas. The methane content of raw biogas is usually between 50-60 percent, depending on its source, compared to 90 percent or more for traditional natural gas. The heating value and Wobbe number (a combustion interchangeability metric) of raw biogas is therefore often lower than that of traditional natural gas, making upgrading necessary before it can be injected into the gas distribution system.<sup>11</sup> Maintaining minimum and consistent heating values is key to ensuring gas quality and appropriate combustion. Lowering and

<sup>8</sup> National Grid. “Renewable Gas – Vision for a Sustainable Gas Network”. 2010. Available at: [https://www9.nationalgridus.com/non\\_html/NG\\_renewable\\_WP.pdf](https://www9.nationalgridus.com/non_html/NG_renewable_WP.pdf)

<sup>9</sup> Myers Jaffe, Amy. “The Feasibility of Renewable Natural Gas as a Large-Scale, Low-Carbon Substitute”. University of California Davis. June 2016. Available at: <https://www.arb.ca.gov/research/apr/past/13-307.pdf>

<sup>10</sup> Based on volumes of residential and transportation sector deliveries reported in EIA Form 176. Available at: [https://www.eia.gov/cfapps/ngqs/ngqs.cfm?f\\_report=RP1](https://www.eia.gov/cfapps/ngqs/ngqs.cfm?f_report=RP1)

<sup>11</sup> Blending biogas with propane or butane to increase heating value could cause problems for RNG used as a vehicle fuel.

fluctuating heating values can negatively impact end-user equipment, affecting the performance (and potentially damaging) of everything from residential gas stoves to natural gas combustion turbines.

As with traditional gas, biogas must be treated to ensure it is clean enough for injection into the pipeline network. This process is typically combined with the heating value upgrading process. Depending on the feedstock, raw biogas can contain constituents that may pose health risks and damage pipelines and end-use equipment. In 2007, the Gas Technology Institute (GTI) began a technical evaluation of what would be required to incorporate RNG into existing natural gas infrastructure, and developed guidance documents for RNG derived from manure management, landfills, and wastewater treatment plants.<sup>12</sup> This evaluation included an analysis of possible RNG constituents and their impacts. Potential constituents such as arsenic and toluene are unhealthy to breathe, regardless of whether the gas is leaked or combusted. Hydrogen sulfide poses a health risk, and is also corrosive and can damage pipelines. Siloxanes, which are found in biogas from landfills and wastewater treatment plants, can produce silica deposits when combusted, which impact engine performance and damage microturbines.<sup>13</sup> In addition to these potential constituents, gas characteristics such as temperature, water content, and particulate content can contribute to pipeline corrosion and accumulations on pipeline walls, and can reduce the effectiveness of gas odorants.<sup>14</sup> Processing equipment must be installed to test for and remove unwanted gas constituents, to conform RNG to the standards of the accepting pipeline.

The cost of upgrading the methane content and cleaning raw biogas can vary based on the biogas makeup and volume, but is typically capital intensive, requiring long-term project financing to be cost-effective. In addition to the capital costs for developing equipment, annual costs are incurred to maintain treatment systems. Operating costs could run into the tens or thousands of dollars per year per RNG production site.<sup>15</sup> It is important to note that traditional natural gas may also contain a wide range of potentially dangerous constituents, including benzene, toluene, ethylbenzene, xylenes (BTEX) and other hydrocarbons that are not present in RNG and must be removed during processing.

The final major infrastructure requirement for RNG projects is the interconnection that brings RNG from the producer to the natural gas distribution network. The cost of the physical interconnection will vary based on the producer's location, but may be very high for rural dairy or feedlot operations located far from natural gas pipelines. Total gas monitoring/cleaning and interconnection costs in California are estimated to be between \$1.5 and \$3.5 million per site, depending on facility size and location.<sup>16</sup> Interconnection cost estimates for other states are considerably lower, between \$75,000 and \$500,000.<sup>17</sup>

The cumulative costs of gas treatment and interconnection facilities are potentially challenging to the economic viability of RNG development projects. These costs are often too high for RNG producers to absorb, and utilities cannot invest in most RNG infrastructure without regulatory approval. Utility

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<sup>12</sup> The GTI documents are available at: [http://www.gastechnology.org/market\\_results/Pages/Dairy-Biomethane-Guidance-Documents.aspx](http://www.gastechnology.org/market_results/Pages/Dairy-Biomethane-Guidance-Documents.aspx)

<sup>13</sup> GTI. "Conduct a Nationwide Survey of Biogas Cleanup Technologies and Costs". June 2014. Available at: [http://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1110\\_2/aqmd-contract-13432-final-report-2014---revised.pdf?sfvrsn=2](http://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1110_2/aqmd-contract-13432-final-report-2014---revised.pdf?sfvrsn=2)

<sup>14</sup> GTI. "Guidance Document for Introduction of Dairy Waste Biomethane". September 2009. Available at: [http://www.gastechnology.org/news/Documents/BiomethaneGuidanceDoc/Pipeline\\_Quality\\_Biomethane\\_FINAL\\_TAS\\_K\\_3\\_REPORT.pdf](http://www.gastechnology.org/news/Documents/BiomethaneGuidanceDoc/Pipeline_Quality_Biomethane_FINAL_TAS_K_3_REPORT.pdf)

<sup>15</sup> The Public Utilities Commission of the State of California, Decision Regarding the Costs of Compliance With Decision 14-01-034 and Adoption of Biomethane Promotion Policies and Program, Decision 15-06-029 June 11, 2015. "CPUC Decision 15-06-029" Available at:

<http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M152/K572/152572023.PDF>

<sup>16</sup> Ibid

<sup>17</sup> Ibid

commissions are responsible for protecting ratepayers and therefore generally operate on least-cost principles. Because the costs of purchasing RNG and investing in related infrastructure are greater than the costs of providing service with traditional natural gas, utility commissions generally do not grant rate recovery for RNG-related costs. Customer demand for a low-carbon product and regional climate goals and policies are two key drivers for promoting RNG. Programs in California and British Columbia, described later in this paper, provide examples of utility commissions allowing LDCs to recover costs associated with RNG investments in order to advance other policy objectives by promoting the development of RNG resources.

## State Regulatory Frameworks

Establishing stable financing and regulatory certainty is key to advancing the development of RNG resources. While states are in various stages of creating incentives for RNG, California has led the way in developing a regulatory framework to provide protections and confidence for both RNG producers and LDCs which could be instructive as policymakers assess potential actions for their own jurisdictions.

In 2012, California adopted AB 1900, which required the Public Utility Commission (PUC) to set gas quality standards for biogas injected into the state's natural gas pipelines in order to protect human health and pipeline integrity and safety. The bill also required the California PUC to adopt policies that promote the in-state production and distribution of RNG. The adoption of RNG quality standards is an important foundational measure that provides LDCs with assurance that the gas they receive is safe and will not damage their infrastructure. These standards give RNG producers and LDCs regulatory certainty and protect LDCs and their customers from the potential risks posed by raw biogas described earlier in this paper.

Following the finalization of gas quality standards in January 2014, which set concentration limits for 17 RNG constituents, the California PUC initiated a proceeding to determine who should bear the costs of meeting the standards. This proceeding outlined the costs associated with cleaning, upgrading and injecting RNG into natural gas pipelines. In June 2015, the PUC ruled that biogas producers are responsible for all those costs, but also found that those costs are an obstacle to the state's goal of promoting RNG production, and established an incentive program to help defray them. The program makes a total of \$40 million available to biogas producers. Individual projects are eligible for a one-time payment equal to 50 percent of interconnection costs, up to a maximum of \$3 million for non-dairy cluster projects and \$5 million for dairy cluster projects that include three or more dairies. Further, the PUC was directed to consider factors beyond costs when determining whether or not to allow rate recovery for LDC investments in RNG interconnection facilities.<sup>18</sup>

## Market and Policy Drivers

The primary existing drivers of RNG development are federal and state policies and incentives to decarbonize the transportation and power generation sector. No policies currently exist to promote RNG use in the residential, commercial, or industrial sectors. Other efforts include voluntary programs that foster development with financial and technical assistance. Regulatory mandates and voluntary customer choice programs for RNG are also beginning to emerge and could become a driver of RNG production in future years.

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<sup>18</sup> See California Assembly Bill No. 2313. Available at: [https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\\_id=201520160AB2313](https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB2313)

## Federal Drivers and Policies

The primary federal economic incentive for RNG development is the Renewable Fuel Standard (RFS). The RFS requires a certain volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel, heating oil, or jet fuel used in the U.S. each year. Mandated volumes are set annually for four renewable fuel categories: biomass-based diesel, cellulosic biofuel, advanced biofuel, and total renewable fuel. These eligible fuels generate Renewable Identification Numbers (RINs), which can be bought and sold separate from the fuel itself. Refineries and fuel suppliers attain compliance by either blending quantities of renewable fuel into the transportation fuel supply or obtaining enough RINs to meet specified volume obligations.

Under the RFS, RNG from landfills, municipal wastewater treatment facility digesters, agricultural digesters, and separated MSW digesters, as well as RNG from the cellulosic components of biomass processed in other waste digesters, currently provides the highest RIN value (approximately \$24/Mcf based on 2016 values). RNG from waste digesters qualifies as an advanced biofuel, which is not as valuable as cellulosic biofuels. For both fuel categories, gas can be in the form of compressed natural gas (CNG) or liquefied natural gas (LNG) used to power vehicles, or electricity generated using biogas used to power electric vehicles.

Other federal incentives related to biogas include the Renewable Energy Production Tax Credit (PTC). This PTC provides qualifying resources with monetary credits for each unit of electricity produced. Only generation facilities using landfill methane that commenced operation by year-end 2016 are eligible for the current credit, which is set at \$0.012/kWh. While not an incentive, EPA's recently finalized New Source Performance Standards (NSPS) for municipal solid waste landfills may drive an increase in RNG production. The rule requires landfills constructed or modified after July 17, 2014 to install controls if they emit more than 34 metric tons of non-methane organic compounds per year. Separate guidelines set the same requirement for existing landfills. Although flaring methane is an option under both rules, landfill operators may find it more profitable to put the collected LFG to use on-site, or to upgrade it to RNG and deliver it to the natural gas pipeline.

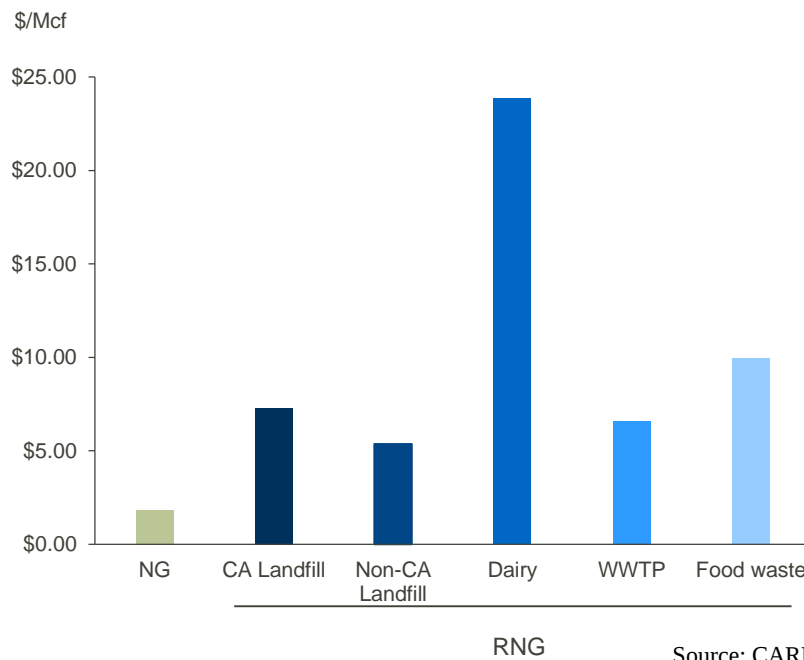
## State Drivers and Policies

State-specific RNG policies vary widely across the U.S., with some states taking significant action to promote RNG production and use. One leading state is California, which has implemented a number of regulations that benefit RNG as part of its wider GHG reduction strategy. Two California rules affecting RNG are the Low Carbon Fuel Standard (LCFS) and the GHG cap-and-trade program.

The LCFS requires refineries and fuel suppliers in California to reduce the carbon intensity of its transportation fuels ten percent by 2020. Transportation fuels must meet an annual carbon intensity target that decreases each year. Refineries and fuel suppliers can meet these targets by mixing in fuels with lower CI into the overall supply or purchasing credits. Fuels with CI below the target level (based on a lifecycle analysis) are able to generate credits. Under the rule, RNG is considered a low carbon fuel and can generate credits (see Table 1 for the carbon intensity values used to calculate the credits). Figure 4 shows the estimated average LCFS credit (\$/Mcf) that could be generated by every thousand cubic feet of natural gas or RNG used as transportation fuel in 2017, based on the recent LCFS credit value of \$89/metric ton CO<sub>2</sub>. This added value can help offset the costs associated with developing and interconnecting RNG resources. Note that while traditional natural gas also generates credits under the LCFS, RNG can generate substantially more credits per unit of gas.

Under California’s cap-and-trade program, GHG emission sources and certain fuel suppliers, including natural gas utilities, are required to hold allowances equal to their annual GHG emissions. Many entities covered under the regulation must purchase allowances at quarterly auctions.<sup>19</sup> However, qualifying biogas is exempt from compliance obligations under the program. Further, the program allows biogas control systems for manure management on dairy cattle and swine farms to generate GHG offsets, which can then be sold. However, given recent allowance prices (\$12.73/metric ton CO<sub>2</sub>), the economic incentive to generate LCFS credits is much greater than the incentive to use RNG to generate GHG offsets under California’s cap-and-trade program.

**Figure 4** Estimated LCFS Incentives by Fuel Source (January 2017 Credit Prices)



Source: CARB, MJB&A Analysis

As a result of the federal and state incentives described above, the majority of RNG produced today that is not used on-site to generate process heat is used in the transportation sector or to generate electricity. Both of these markets provide added value that offsets the higher costs of RNG production relative to fossil natural gas.

In September 2016, SB 1383 was signed into law in California, requiring the state to significantly reduce emissions of methane and other short-lived climate pollutants. The bill requires the California Air Resources Board (CARB) to establish energy infrastructure development and procurement policies needed to encourage dairy biomethane projects by the beginning of 2018, as well as develop a pilot financial mechanism to reduce the economic uncertainty associated with the value of environmental credits for biogas. The bill also requires the California PUC to direct investor-owned LDCs to implement at least five dairy biogas projects that interconnect to the natural gas pipeline system by January 1, 2018. The bill allows LDCs to recover the costs associated with developing the pipeline infrastructure for these projects through rates. Providing utility rate recovery provides for the development of projects that otherwise may not have been financially

<sup>19</sup> Natural gas utilities are currently allocated allowances by the California Air Resources Board to ensure that the cap-and-trade program does not result in sudden increases to ratepayer bills. Utilities must use any value associated with the allowances for the benefit of ratepayers.

attractive. Actions such as California’s efforts to lay a regulatory framework for RNG and then implement incentives and mandates for RNG development provide LDCs and RNG producers with confidence to develop RNG resources. State clean fuel standards such as California’s LCFS also encourage RNG development by creating a market that specifically values the environmental benefits of renewable fuels.

While all of the above-mentioned policies help create markets for RNG production, they do not treat all uses of RNG equally. For example, the same RNG that generates LCFS credits and RINs when used as a transportation fuel and RECs when used to generate electricity receives no credit when used for heating buildings and fueling appliances.<sup>20</sup> As shown in Table 4, omitting incentives for space heating and other appliances means incentives are not available for one of the most efficient uses of RNG.

**Table 4** Fuel Efficiencies of Natural Gas End Uses

Energy Use	Fuel Efficiency
Natural Gas Space Heating (natural gas boiler)	90-98.5%
Electric Power Generation (electricity from natural gas combined cycle)*	48%
Combined Heat and Power (natural gas)	60-90%
Transportation (natural gas light-duty vehicle)	18-25%

\* Includes six percent electric transmission and distribution line losses. This is the best available electric generation efficiency, which is higher than U.S. average efficiency.

### Voluntary Utility Programs

To overcome the economic challenges of using RNG in the natural gas pipeline system, LDCs have explored using voluntary programs designed to allow customers to elect to purchase RNG. While voluntary programs are being developed by several utilities, British Columbia’s FortisBC has offered a voluntary RNG program since 2011 that allows customers to pay more to blend RNG into their fuel supply. Similar to voluntary renewable energy programs, the actual RNG molecules do not flow to participating customers, but FortisBC works to ensure that RNG volumes equal to participating customer demand is injected into their system. Customers pay a higher gas supply rate depending on their selected RNG percentage. While these higher rates help offset the higher supply costs of RNG, they do not cover the entire difference. To fill this gap, the British Columbia Utilities Commission allows FortisBC to distribute the remaining program costs across non-participating customers. FortisBC also has regulatory approval to recover costs associated with any infrastructure related to RNG, such as gas treatment and interconnection equipment at RNG production facilities. This regulatory structure addresses the costs that present the greatest barriers to bringing RNG onto natural gas distribution systems.

### LDC Interest in RNG

More than twenty states, including California, Massachusetts, Minnesota, New York, Oregon and Washington, have established economy-wide GHG reduction targets and are making progress towards achieving them through a suite of programs and policies. Some states have long-term GHG reduction goals of 80 percent reduction from 1990 levels by 2050. As states work to achieve these long-term goals, GHG emission reductions will be necessary from all industries, including reducing the carbon intensity of the natural gas delivered to LDC customers. For example, California aims to reduce GHG emissions to 40 and 80 percent below 1990 levels by 2030 and 2050, respectively. As shown in Figure 5, California’s 2050 GHG emissions from all fossil fuels will need to be less than half the emissions natural gas alone produced in

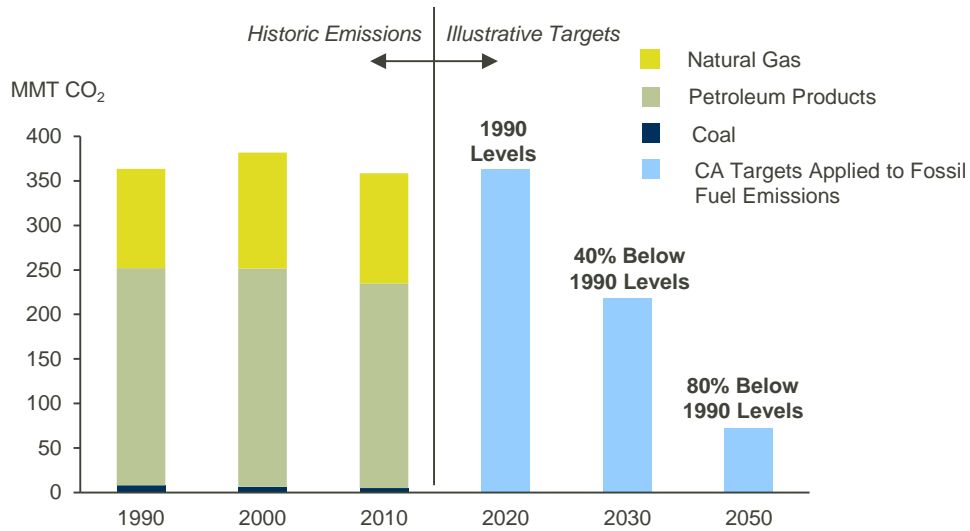
<sup>20</sup> RNG does have value outside of the transportation and electric sectors under California’s cap-and-trade program, reducing an LDC’s compliance obligation when substituted for traditional gas.



2010. GHG reduction targets in other states present similar challenges. Reducing the carbon intensity of a primary energy source like natural gas requires changes to the source of the fuel itself, and RNG is the primary near-term source of lower lifecycle GHG natural gas. LDCs are therefore interested in advancing RNG development as a means to provide low-carbon solutions for their customers to meet climate goals and prepare the industry for a low-carbon future.

While decarbonization of the electric grid and electrification of sources now fueled by natural gas would reduce GHG emissions for many end-uses, it is important to recognize that electrification is not possible or even beneficial on a lifecycle basis for some natural gas applications. In fact, in almost all combustion applications, RNG can provide climate benefits comparable to or in excess of even a highly decarbonized grid.

**Figure 5** California GHG Emissions and Targets



Source: EIA, MJB&A analysis

Additionally, some natural gas customers cannot replace natural gas with electricity. Table 5 shows that more than 40 percent of all natural gas in 2015 was delivered to commercial and industrial end users. While this gas was used for numerous purposes, some commercial and industrial customers require natural gas for process heat (e.g., certain cement and steel producers), and cannot replace it with electricity.

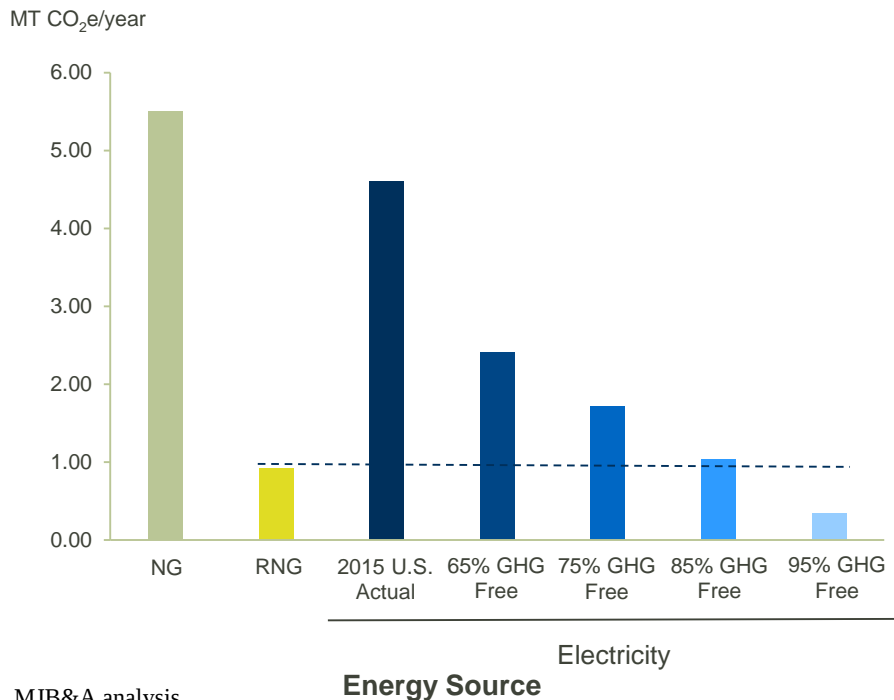
**Table 5** U.S. Natural Gas Deliveries by Customer Segment (2015)

Customer Type	Volume Delivered (Mscf)	Percent Total
Residential	4,609,669,883	18%
Commercial	3,198,797,217	13%
Industrial	7,534,589,246	30%
Electricity Generation	9,689,827,433	39%
Vehicle Fuel	39,348,210	<1%

Source: EIA

Further, using RNG in the residential sector could provide climate benefits even when electricity has been largely decarbonized. Figure 6 shows that using RNG to fuel appliances in a typical U.S. home generates fewer GHG emissions on a lifecycle basis compared to using electricity even when the grid is over 75 percent carbon free.<sup>21</sup> Currently, the most aggressive state electric renewable portfolio standards require 50 percent renewables by 2030. While technology innovation will likely speed the integration of renewables going forward, RNG can provide significant climate benefits today.

**Figure 6** Annual GHG Emissions from Appliances at a New Home

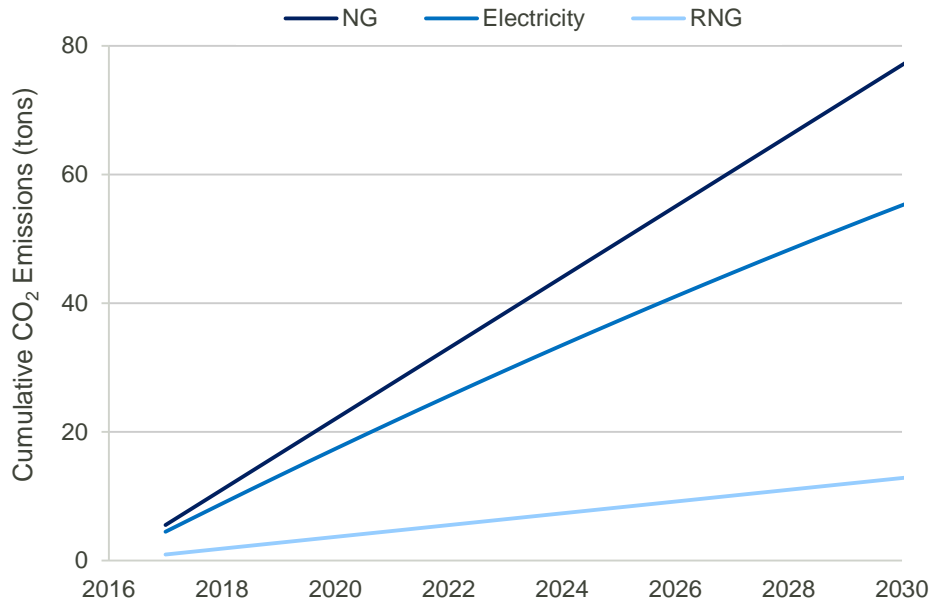


Source: AGA, MJB&A analysis

The cumulative GHG benefits of integrating RNG in the residential sector today are shown in Figure 7. Using the annual energy use for a new home and assuming the electric supply moves from 33 percent GHG-free resources in 2017 to 50 percent GHG-free resources in 2030, a single home using RNG would generate roughly one quarter the CO<sub>2</sub> emissions of a home using electricity.

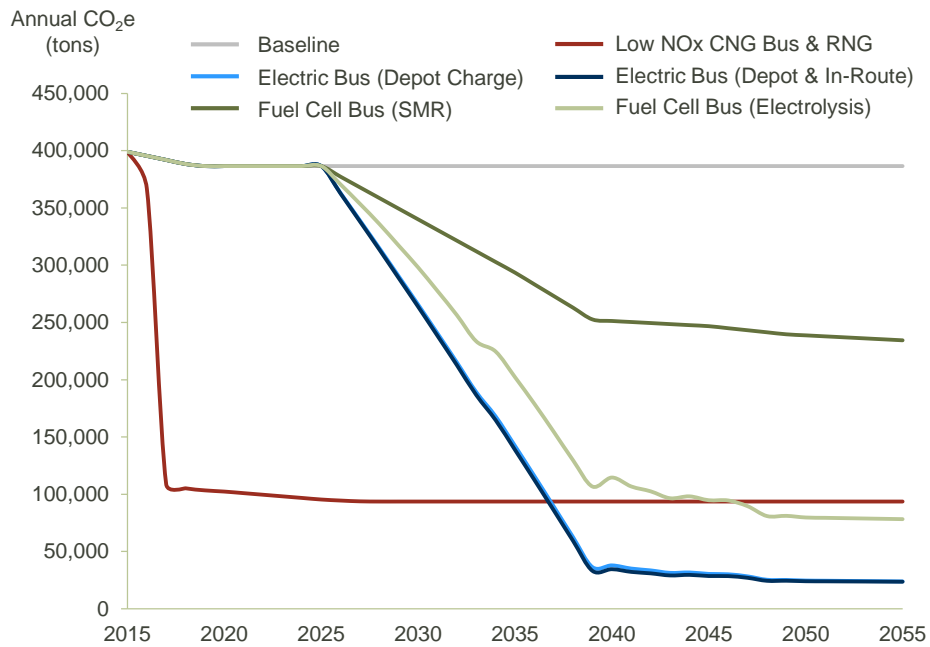
<sup>21</sup> This analysis includes energy for space and water heating, cooking and clothes drying. The natural gas case assumes a natural gas furnace with 80 percent efficiency. The electric case assumes an air source heat pump with HSPF rating of 7.7 btu/watt-hour. Net energy requirements for each case (MMBtu/yr) are from a 2015 American Gas Association Study (EA 2015-05). RNG carbon content based on LCFS data using gas from a California landfill.

**Figure 7** Cumulative Annual CO<sub>2</sub> Emissions for a Household Using Different Fuels



Source: AGA, MJB&A analysis

**Figure 8** Projected Annual Fleet GHG Emissions Using Different Fuels



Source: Ramboll Environ U.S. Corporation, MJB&A

Note: The analysis assumed that GHG emissions from electricity generation in California would be 262 g/kWh in 2015, falling to 109 g/kWh in 2050. 2015 emissions are actual average values, based on EIA data. Projected future emissions are based on zero-carbon electricity generation in California increasing from 46% today to 78% in 2050, in accordance with state goals. Fleet-wide deployment of electric buses is assumed to be uneconomical until 2025.

Immediate GHG reductions can also be gained by using RNG in the transportation sector. Figure 8 shows the GHG impact of replacing a large fleet of transit buses currently fueled with traditional natural gas with landfill-sourced RNG and other low-carbon fuels.<sup>22</sup> While electrification provides deeper GHG reductions when fully implemented, fleet-wide electrification will likely not be practical until the mid-2020s or later due to the high cost of electric buses. In contrast, swapping traditional natural gas for RNG could be done today on natural gas-fueled buses without the need for changes to the fleet, providing instantaneous GHG reductions at a lower cost than electrification. The climate benefit is even greater when fleets are converted from diesel to RNG. Additionally, as lower carbon varieties of RNG, such as dairy manure and diverted organic waste become available, the lifecycle GHG savings for RNG-fueled buses might exceed the emissions reductions from electric buses.

In addition to reducing GHG emissions, LDCs are interested in developing RNG resources as means to generate local jobs and economic activity, new sources of supply, and divert waste streams. In National Grid's 2010 analysis, developing the four-state region's RNG potential would result in \$6.75 billion in capital investment and create 2,500 to 8,900 jobs.<sup>23</sup> Using RNG also provides utilities with the opportunity to add new supplies with a locally-sourced fuel that is currently burned off or directly released to the atmosphere.

Customer demand is another factor driving the development of RNG resources. As a growing number of companies pursue corporate environmental targets, RNG provides the opportunity to reduce GHG emissions from natural gas use. Many utilities already offer renewable electricity products, and customer demand for a matching low-carbon gas product has been driver of the voluntary LDC RNG programs described above.

The development of RNG resources can also lead to improvements in local air quality. While combustion of biogas at landfills, manure digesters, and WWTPs reduces GHG emissions, it results in the emission of pollutants that affect health and contribute to ozone formation. Compared to on-site combustion, upgrading biogas to RNG can reduce emissions of criteria pollutants. A recent study by the University of California Davis and EPA of biogas sources in California found that compared to biogas flaring, upgrading biogas to RNG reduced local, on-site emissions of nitrogen oxides (NO<sub>x</sub>), particulate matter (PM), volatile organic compounds (VOCs), and sulfur oxides (SO<sub>x</sub>) by 90 percent or more.<sup>24</sup> The study found that local emissions from on-site electricity production varied depending on the technology used, but most technologies produced significantly more on-site emissions than RNG upgrading. For example, the most common method of on-site electricity production – the use of reciprocating engines – was found to produce 8 times more NO<sub>x</sub> and almost 13 times more PM than biogas upgrading.

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<sup>22</sup> Ramboll Environ US Corporation, M.J. Bradley & Associates, LLC, Zero Emission Bus Options: Analysis of 2015-2055 Fleet Costs and Emissions of New Transit Vehicle Technologies and Advanced Technology Implementation (OP33203093), submitted to: Advanced Transit Vehicle Consortium Los Angeles, California, September 29, 2016. Available at: <https://records.metro.net/documents/223/download>

<sup>23</sup> In the National Grid whitepaper, jobs are high level estimate of positions related to manufacturing, construction, maintenance and operation levelized over a 25-year project life.

<sup>24</sup> University of California Davis and U.S. EPA. "Evaluating the Air Quality, Climate & Economic Impacts of Biogas Management Technologies." September 2016. Available at: [http://biomass.ucdavis.edu/wp-content/uploads/2016/11/EPA600R-16099\\_BiogasTech\\_Sept2016.pdf](http://biomass.ucdavis.edu/wp-content/uploads/2016/11/EPA600R-16099_BiogasTech_Sept2016.pdf)

## Policy Considerations

As policymakers evaluate options to respond to customer interest and support the development of a state or regional RNG market, they may consider the following.

First, clear gas quality and interconnection standards for RNG are critical policies to provide assurances to LDCs and their customers, inform project developers of gas quality requirements, and identify interconnection construction, operation, and cost responsibilities. Standards that align with best practices, are consistent, clearly justified, and understandable to LDCs, project developers, policymakers, the public, and other stakeholders can provide critical support for this resource.

Next, policymakers may also consider the role of LDCs in the RNG market. For example, policymakers could evaluate the potential for voluntary natural gas customer offerings that allow customers to pay a premium for RNG. This could create a demand signal to the RNG market, help offset the higher cost of RNG development, and allow natural gas customers the opportunity to offset their carbon footprint by using RNG. When assessing voluntary customer programs for RNG, policymakers could consider local and state climate goals and policies rather than relying solely on a least-cost analysis. Policymakers could also consider potential targets and incentives for RNG project development that provide LDCs with rate recovery for the necessary interconnection and other associated infrastructure investments. This approach could help kick start the RNG market and reduce costs.

Finally, policymakers could consider policies and programs that assign a financial value to the renewable attributes of RNG supplied by LDCs to all customers rather than for only specific end uses. This added value could help RNG producers offset the high costs of interconnecting with the natural gas pipeline system. However, as a method to promote RNG production, RNG supply mandates such as renewable gas standards may not be appropriate in all regions and should only be implemented in regions with sufficient potential RNG resources, and after RNG standards are established.

## Conclusion

RNG can provide environmental and economic benefits including: greenhouse gas emission reductions, local jobs, and economic development. RNG is a local fuel source and makes use of resources that would otherwise be flared or emitted directly to the atmosphere. There are enough potential RNG resources to meet meaningful volumes of natural gas demand across the U.S. Once it is processed and cleaned, RNG is pipeline-quality gas that is fully interchangeable with traditional natural gas. While some states are actively promoting RNG resource development, additional policy actions may be necessary to overcome cost barriers. As state policymakers consider strategies to achieve their energy, economic, and environmental objectives, they should include policies and programs that support the development of the RNG market.