White Paper

Design Principles for a Renewable Gas Standard

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Executive Summary

California continues to seek programs and policies that can reduce greenhouse gas (GHG) emissions cost-effectively to help meet 2030 targets. Renewable natural gas (RNG) has the potential to reduce GHG emissions significantly. Despite the success of RNG in the transportation fuels market—representing more than 60 percent of natural gas used as a transportation fuel in 2016—the programs in place do not provide the price and supply certainty that is required for larger volumes of RNG to be deployed. Starting in 2013, advocacy groups have introduced the concept of a Renewable Gas Standard (RGS) in the state legislature. The principles of an RGS are straightforward and mimic renewable portfolio standards, a common policy tool to introduce a renewable energy procurement requirement for electricity providers. In other words, an RGS would require RNG be delivered and measured against some benchmark, such as a carbon-based reduction or volumetric target. In this white paper, ICF explores the following questions:

- What is the regulatory and policy context that supports RNG today?
- Is there enough RNG supply to satisfy a Renewable Gas Standard?
- What are the costs associated with RNG production?
- What are the key considerations in the development of a Renewable Gas Standard?

1. Regulatory and Policy Context for Renewable Natural Gas

California continues to lead the nation in the development of cutting-edge programs that reduce harmful GHG emissions. In 2016, the legislature passed Senate Bill 32, directing the California Air Resources Board (CARB) to ensure that statewide emissions are reduced to at least 40 percent below 1990 levels by 2030. Natural gas use is a significant source of the GHG emissions that these regulations are targeting: current use exceeds 2 trillion cubic feet (tcf) annually for electric power, industrial applications, space and water heating, and in the transportation sector (see Exhibit 1 below).

EXHIBIT 1. NATURAL GAS DEMAND IN CALIFORNIA BY END USE

End Use	Share of Demand
Electric Power	45%
Industrial	25%
Residential Heating	21%
Commercial Heating	9%
Transportation	1%

The Cap-and-Trade program is CARB's main policy to reduce GHG emissions. It works in tandem with complementary measures, such as the Low Carbon Fuel Standard (LCFS) program, to help the state meets its reduction targets. The Cap-and-Trade market and the LCFS program encourage the use of RNG in place of fossil-derived natural gas. RNG can also be used to comply with the state's Renewable Portfolio Standard (RPS). State-level incentive programs like the Self-Generation Incentive Program (SGIP) also incentivize RNG consumption. Similarly, there are federal-level drivers for RNG use, most notably the Renewable Fuel Standard (RFS2), administered by the U.S. Environmental Protection Agency (EPA).

Cap-and-Trade Program. Under the Cap-and-Trade Program, CARB sets a limit (cap)—that declines by approximately 3 percent each year--on major sources of GHG emissions from regulated sectors. Regulated parties can trade permits (allowances) to emit GHGs, purchase carbon offset credits (offsets), or reduce their GHG emissions. CARB holds quarterly auctions for allowances, and parties are also allowed to bank allowances to protect themselves against shortages and price swings in the market. Offsets can be generated by qualified projects that reduce or sequester carbon emissions, but are currently limited to providing 8% of a regulated party's compliance obligation. If regulated parties do not meet CARB's compliance standards, they must provide four allowances for every ton of emissions not covered by the compliance deadline.

LCFS Program. California's LCFS is designed to be a flexible, market-based mechanism to reduce GHG emissions from transportation fuels, like gasoline and diesel, on a lifecycle basis. The LCFS was established in 2007 through a Governor's Executive Order Governor's Executive Order and requires those who produce petroleum-based transportation fuels to reduce the carbon intensity (CI) of their fuels by 10 percent by 2020. The LCFS applies to transportation fuel that is sold, supplied, or offered for sale in California and obligates any regulated party that produces those transportation fuels, like oil refineries and other distributors, to comply with these CI reductions. The program is administered by CARB and is implemented using a system of credits and deficits. Transportation fuels that have a higher carbon intensity than the compliance standard yield deficits, and fuels that have a lower carbon intensity (such as RNG) generate credits. Regulated entities who generate deficits must offset them by purchasing credits. In 2016, nearly 87 million diesel gallon equivalents of RNG were consumed in California, representing more than 60 percent of the natural gas consumed in the transportation sector.

California RPS. The California RPS requires that all retail sellers of electricity in California--including publicly owned utilities (POUs), investor-owned utilities, electricity service providers, and community choice aggregators--derive at least 33 percent of retail sales from eligible renewable energy resources by December 31, 2020, and 50% of retail sales by 2030. Eligible renewable energy technologies include certain biomass resources, including agricultural products, landfill gas, and municipal solid waste. Biogas and biomass projects represent less than two percent of planned and installed capacity in the RPS market.

Self-Generation Incentive Program. The SGIP is administered by the California Public Utilities Commission (CPUC) and provides incentives to support existing, new, and emerging distributed energy resources. Biogas can be used in eligible technologies such as fuel cells, internal combustion engines, and microturbines. Biogas can be used from on-site production sources, or sourced from another in-state producer and injected into the common carrier pipeline—this is referred to as directed biogas. An adjustment to the program required that the directed biogas come from a source within the Western Electricity Coordinating Council (WECC) region, or a source interconnected with a pipeline system located within the WECC region, making it a rare occurrence; only one directed biogas project has been deployed since 2011. The rebated capacity of projects using biogas since SGIP's inception is 80 MW.

Renewable Fuel Standard. The RFS2 mandates biofuel volumes that must be blended into transportation fuel each year from 2006 to 2022. The program was developed as part of the Energy Policy Act (EPAct) of 2005 and revised/updated by the Energy Independence and Security Act (EISA) in 2007. The program is structured with four nested categories: renewable biofuels, advanced biofuels, biomass-based diesel, and cellulosic biofuels. Each category has its own volume requirement, or Renewable Volume Obligation (RVO), and renewable identification number (RIN) type. In 2013, RNG was determined to be an eligible fuel; most forms of RNG are considered cellulosic biofuels and earn the highest value RINs in the market, referred to as D3 RINs.

Senate Bill 1383 (Lara, Chapter 395, Statues of 2016)

In September 2016, the California legislature passed and Governor Brown signed Senate Bill 1383, requiring CARB to approve and implement a comprehensive strategy to reduce Short Lived Climate Pollutants (SLCP) including methane, hydrofluorocarbons, and black carbon. The strategy development to reduce emissions of SLCPs began in 2014 with the passage of SB 605 and the strategy was approved in March 2017. Among SB 1383's key targets are: reduce methane by 40%, hydrofluorocarbon gases by 40%, and anthropogenic black carbon by 50% below 2013 levels by 2030; develop strategies and incentives to increase production and use of renewable gas; reduce landfill disposal of organics; and target dairy and livestock sector methane to help achieve reduction goals. There are three main components of SB 1383:

1. **Adopt regulations, if feasible and cost-effective.** CARB is directed by SB 1383 to work with the California Department of Food and Agriculture (CDFA) to adopt regulations to reduce the methane emissions from livestock and diary manure management operations by up to 40% below 2013 levels by 2030. The regulations developed will take effect on or after January 1, 2024 if CARB determines they are technically and economically feasible and cost effective. CARB will also have to determine if the regulations minimize and mitigate potential leakage
2. **Develop a pilot financial mechanism.** CARB, in concert with the CPUC and the California Energy Commission (CEC), will establish infrastructure development and procurement policies for renewable gas from livestock and dairy manure. These policies will include a pilot financial mechanism to reduce the economic uncertainty of credits from dairy-related projects producing low-carbon transportation fuels. By January 1, 2018, the CPUC, in consultation with CARB, will direct gas corporations to implement "no less than five" manure projects to "demonstrate interconnection to the common carrier pipeline system." The gas corporations will be allowed, for the purposes of the pilot projects, to recover in rates the reasonable cost of the pipeline infrastructure developed for the pilot projects.
3. **Reduce landfill disposal of organics.** To control methane emissions from landfills, SB 1383 sets a statewide target to reduce landfill disposal of organics by 50% from the 2014 level by 2020 and 75% from the 2014 level by 2025. The CEC, with help from CARB and CPUC, will develop recommendations and identify cost-effective strategies for the development and use of renewable gas, consistent with state policies such as the RPS, LCFS, and waste diversion goals. Production of renewable gas for these policies and goals would include the use of anaerobic digestion of the landfill diverted organics. CDFA will also need to investigate the markets for products generated by organic recycling facilities (e.g., compost, biomethane) including cost-effective electrical interconnections and common carrier pipeline injection of renewable gas.

http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB1383

2. RNG Resource Potential and Costs

The following sub-sections introduce the feedstocks for RNG, and review the potential RNG that could be produced in California and the United States. We have included supply-cost curves for RNG produced in California and the United States.

Feedstocks for Renewable Natural Gas

RNG can be produced from a variety of renewable feedstocks, as described in Table 2 below. It is important to note that many of these feedstocks are currently used for other purposes and therefore the price of the feedstock will largely depend on the cost of replacing the feedstock with another material. For example, animal manure is widely used as an alternative to chemical fertilizers. The cost of the animal manure will depend on factors such as the current market price of synthetic fertilizer and the ability to deliver cost-effectively the digestate and effluent left post anaerobic digestion. The table also includes a brief summary of the competitive markets for each feedstock.

EXHIBIT 2. RENEWABLE NATURAL GAS FEEDSTOCKS

Feedstock for RNG	Description	Feedstock Competition
Agricultural residue	The material left in the field, orchard, vineyard, or other agricultural setting after a crop has been harvested. Inclusive of unusable portion of crop, stalks, stems, leaves, branches, and seed pods.	▪ Animal feed; livestock bedding ▪ Liquid biofuels ▪ Carbon sequestration ▪ Soil enrichment (e.g., reduced soil erosion, soil nutrient recycling, and soil maintenance)
Animal manure	Manure produced by livestock, including dairy cows, beef cattle, swine, sheep, goats, poultry, and horses.	▪ Fertilizers and compost materials ▪ Electricity production
Energy crops	Inclusive of perennial grasses, trees, and some annual crops that can be grown specifically to supply large volumes of uniform, consistent quality feedstocks for energy production.	▪ Electricity production ▪ Liquid fuels production
Fats, oil, and greases (FOGs)	Long chain fatty compounds that are byproducts of cooking, such as fryer grease (yellow grease) and grease traps (brown grease)	▪ Animal feed ▪ Liquid biofuels production (e.g., biodiesel) ▪ Cosmetics and soaps
Forestry and forest product residue	Biomass generated from logging, forest and fire management activities, and milling. Inclusive of logging residues, forest thinnings, and mill residues. Also materials from public forestlands, but not specially designated forests (e.g., roadless areas, national parks, wilderness areas).	▪ Electricity production ▪ Fuel for boilers, kilns, dryers ▪ Pulp-and-paper, pellet, and briquette manufacturing ▪ Landscaping (e.g., bark chips) ▪ Fertilizer for forest land ▪ Particleboard manufacturing ▪ Animal bedding (e.g., shavings and sawdust)
Landfill gas (LFG)	The anaerobic digestion of biogenic waste in landfills produces a mix of gases, including methane (40-60%).	▪ Electricity production ▪ Industrial process heat
Municipal solid waste (MSW) (compost or lignocellulosic)	Refers to the organic fraction of waste that is typically landfilled, such as food waste, paper products, certain yard trimmings (e.g., branches), and construction and demolition debris.	▪ Recycling; fertilizer production through composting (e.g., food scraps, yard trimmings), ▪ Waste-to-energy

Many of these feedstocks are also being used to generate electricity to meet RPS targets in California and in other states. As noted previously, the California RPS requires that all retail sellers of electricity in California have at least 33% of retail sales derived from eligible renewable energy resources by December 31, 2020 and at least 50% of retail sales by 2030. Among eligible renewable energy technologies are certain biomass resources,[1] including agricultural products, landfill gas, and municipal solid waste.[2]

RNG is produced through a series of steps, depending on the type of organic waste being processed. At landfills and wastewater treatment facilities, the raw biogas must be collected and purified for pipeline injection or on-site transportation fuel use. Food, yard, construction, and wood waste must be collected and separated from recyclables and other parts of the urban waste stream, delivered to an anaerobic digestion or gasification facility,[3] then purified and compressed for on-site fueling or injection into the pipeline for transmission and delivery to a dedicated end-use customer. Dairy, agricultural, and forest waste must also be collected and converted to biogas through anaerobic digestion or gasification and then either purified or converted to biomethane for use on-site or injection into the pipeline.

California

Several studies have assessed the availability of renewable waste streams and feedstock resources that can be developed to produce RNG in California. These studies typically consider production from the feedstocks outlined in the previous subsection. Exhibit 3 summarizes the RNG production potential from various feedstocks from multiple studies, including the California Biomass Collaborative (CBC) and the University of California, Davis (CBC-Davis),[4] the Institute of Transportation Studies at UC Davis (ITS),[5] the American Gas Foundation (AGF),[6] and the Department of Energy's Billion Ton Study (DOE BT).[7] The table also includes ICF's estimates for RNG production based on our review of these studies and other resources.

[1] The eligibility includes agricultural crops, agricultural wastes and residues, waste pallets, crates, dunnage, manufacturing, construction wood wastes, landscape and right-of-way tree trimmings, mill residues that result from milling lumber, rangeland maintenance residues, biosolids, sludge derived from organic matter, wood and wood waste from timbering operations, and any other materials. See Public Resources Code Section 40106 "Renewables Portfolio Standard Eligibility" for a complete list: http://www.energy.ca.gov/2013publications/CEC-300-2013-005/CEC-300-2013-005-ED7-CMF-REV.pdf

[2] There are strict in-state requirements for tracking and verifying the quantities and sources of biomethane and deliveries from dedicated pipelines, common carrier pipelines, or certain on-site production facilities.

[3] Biomass-to-gas conversion takes place via anaerobic digestion or thermal gasification. Anaerobic digestion is the process whereby microorganisms break down organic material in an environment without oxygen, and the gaseous products of that process contain a large fraction of methane and carbon dioxide. Thermal gasification describes a broad range of processes whereby carbon-containing feedstocks are converted into a mixture of gases referred to as synthetic gas or syngas. The process occurs at high temperatures (650—1,350 °C) and varying pressures.

[4] An Assessment of Biomass Resources in California, 2013 DRAFT for the California Energy Commission under Contract 500-11-020, March 2015.

[5] The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute, Final Draft Report, Contract No 13-307.

[6] American Gas Foundation (AGF), The Potential for Renewable Natural Gas: Biogas Derived from Biomass Feedstocks and Upgraded to Pipeline Quality (September 2011).

[7] U.S. Department of Energy (DOE), Billion Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry.

EXHIBIT 3. RNG RESOURCE ASSESSMENT, CALIFORNIA, IN BILLION CUBIC FEET PER YEAR (BCF/Y)

Feedstock	RNG Production Potential in CA (BCF/y)						
	CBC – Davis	ITS	AGF[a]		DOE BT[b,c]		ICF Estimates
			low	high	low	high	
Agricultural Residue	29.9	n/a	4.1	10.2	29.6	32.5	**29.6 - 32.5**
Animal Manure	18.7	14	8.4	28.0	2.2	9.9	**12.3 - 18.7**
Energy Crops[d]	70.9	n/a	0.0	0.0	0.0	0.0	**n/a**
Fats, Oils and Greases	6.2	n/a	n/a	n/a	n/a	n/a	**n/a**
Forestry and Forest Product Residue[e]	78.0	n/a	4.7	11.8	8.9	n/a	**14.5 - 44.9**
Landfill Gas	50.2	50	27.4	54.8	n/a	n/a	**22-54.8**
MSW, food, leaves, grass	11.7	14.8	7.5	22.5	11.7	13.6	**22.5-50.1**
MSW, lignocellulosic	38.5				9.9	17.1	
WWT Gas	7.2	7.3	0.3	0.8	n/a	n/a	**4.1-7.2**
Total Potential	**311.3**	**90.6[f]**	**52.4-128**		**62.3-73.1**		***104.9-208.3***

a) The low and high values in the AGF study represent what the study refers to as non-aggressive and aggressive scenarios. The low/non-aggressive scenario assumes roughly 5-25% (depending on resource) of biomass is processed into RNG. The high/aggressive scenario assumes 15-75% (depending on resource) of biomass is processed into RNG.

b) The DOE BT study (including the most recent update) did not estimate yields of RNG. The focus of the study is on the feedstock rather than the finished fuel. ICF used conversion efficiencies from the UC Davis work to estimate the tBtu of finished fuel (in this case, RNG) based on the feedstock potential reported in the DOE BT study.

c) The low and high values from the DOE BT study represent the available feedstock assuming a price of $40/ton in 2015 and a price of $80/ton in 2030.

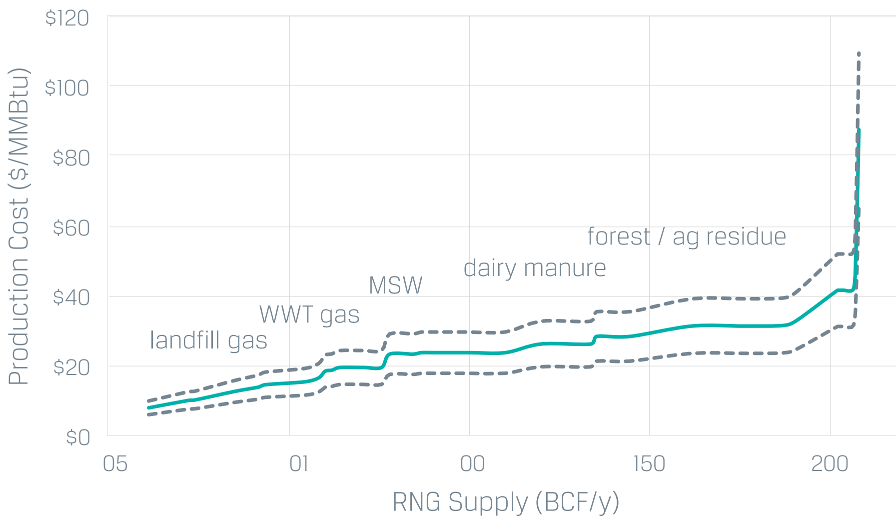
d) Energy crops were not identified in the BAC White Paper; nor were they included in the most updated UC Davis report available.

e) It is highly likely that this estimate is considerably lower than what might be available today. This estimate was developed prior to California's current Tree Mortality Crisis. Consider, for instance, that in November 2016 the US Forest Service confirmed that the number of dead trees in California since 2010 now exceeds 100 million.

f) Note that the potential of the various resources—animal manure, landfill gas, MSW, and WWT gas—do not sum to 90.6 BCF. The ITS report reads "we estimate that California's renewable natural gas resource base contains up to 90.6 BCF per year." There is not an explicit breakdown presented in the report that enables the reader to arrive at 90.6 BCF per year.

ICF developed a supply-cost curve based on a combination of a) the supply estimate included in Exhibit 3, and b) ICF's bottom-up estimate of cost to produce RNG. For each feedstock, ICF calculates the levelized cost of energy (LCOE) by incorporating the capital expenditures from equipment, operations and maintenance (O&M), and financing. ICF used a discount rate of 5% for our calculations and assumed a 20-year financing period. Exhibit 4 below shows the results of our analysis with dashed grey lines representing a 25% uncertainty (low/high).

EXHIBIT 4. RNG SUPPLY-COST CURVE, CALIFORNIA



The supply curve in Exhibit 4 bundles together the various feedstocks that ICF considered in our analysis. For illustrative purposes, we have identified the parts of the curve that are generally represented by different feedstocks: Landfill gas and WWT gas are the lowest cost RNG, followed by MSW and dairy manure. We estimate forest and agricultural residues as the highest cost RNG in part because of the uncertainties associated with the commercial scaling of thermal gasification of biomass. Please note that the RNG production costs are not stacked perfectly as shown in the exhibit; rather, these are meant to be illustrative to show the relative costs of RNG production from key feedstocks.

United States

Exhibit 5 shows a national-level RNG production potential resource assessment, broken down by feedstock type, for each of the studies considered. Unlike the California-focused estimates, ICF did not develop recommendations for the RNG production potential across the entire U.S., due in large part to the unique considerations across states and feedstocks.

EXHIBIT 5. RNG RESOURCE ASSESSMENT, UNITED STATES, IN BILLION CUBIC FEET PER YEAR (BCF/Y)

Feedstock	NPC[1]	AGF[2]		DOE BT[3,4]	
		low	high	low	high
Agricultural Residue	1,254	387	966	315	1,805
Animal Manure	135	143	475	69	324
Energy Crops	1,446	77	193	351	6,252
Forestry and Forest Product Residue	1,061	79	199	283	549
Landfill Gas	328	176	352		
MSW, food, leaves, grass	386	67	200	143	238
MSW, lignocellulosic				51	62
WWT Gas	58	4	13		
Total Potential	***4,667***	***932***	***2,397***	***1,212***	***9,230***

1. The NPC and AGF reports do not differentiate MSW feedstocks.

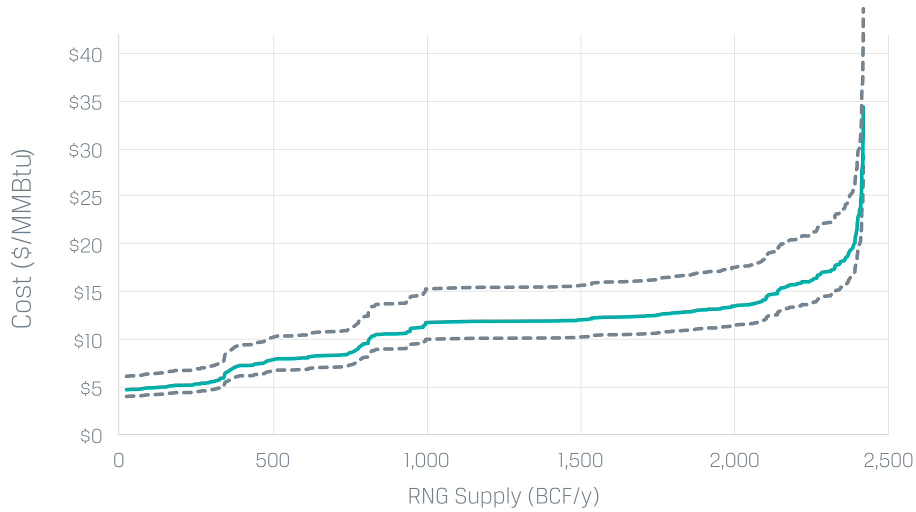
2. The low and high values in the AGF study represent what the study refers to as non-aggressive and aggressive scenarios. The low/non-aggressive scenario assumes roughly 5-25% (depending on resource) of biomass is processed into RNG. The high/aggressive scenario assumes 15-75% (depending on resource) of biomass is processed into RNG.

3. The DOE BT study did not estimate yields of biogas. The focus of the study is on the feedstock rather than the finished fuel. ICF used conversion efficiencies from the UC Davis work to estimate the tBtu of finished fuel (in this case, biogas) based on the feedstock potential reported in the DOE BT study.

4. The low and high values from the DOE BT study represent the available feedstock assuming a price of $40/ton in 2015 and a price of $80/ton in 2030.

ICF also developed a supply-cost curve for the broader renewable gas resource base in the United States, as shown in Exhibit 6 below. We used the same approach as listed previously, including a) the supply estimate shown in Exhibit 5 and b) ICF's bottom-up estimate of cost to produce RNG. For each feedstock, ICF calculates the LCOE by incorporating the capital expenditures from equipment, O&M, and financing. We used a discount rate of 5% for our calculations and assumed a 20-year financing period. Note that given the higher uncertainty associated with the breadth of projects addressed and the varying policies across states, ICF did not include the capital costs or O&M costs of pipeline interconnection. The dashed grey lines represent the uncertainty (15% low, 25% high) associated with our analysis.

EXHIBIT 6. RNG SUPPLY-COST CURVE, UNITED STATES



Please note that neither the national-level resource assessment nor the California resource assessment consider power to gas (P2G) as a resource. P2G—the process whereby electrical power is converted to gas—is expensive today and largely deployed at research and demonstration scale, with limited commercial scale deployments. Consider, for instance, that renewable electricity generation from sources like solar and wind have not always been as cost-effective as they are today. Cost reductions in those renewable energy technologies were spurred by a combination of factors, including innovation, economies of scale, and policies like the RPS. With the California Independent System Operator (CAISO) actively seeking solutions to avoid or reduce the amount of curtailment of renewable power generated in California, P2G will likely garner further consideration as the technology matures and costs are lowered. P2G is just one technology currently under development that could increase the RNG potential in California and the U.S. beyond the available estimates outlined in Exhibit 3 and Exhibit 5.

3. Designing a Renewable Gas Standard

First and foremost, one question needs to be answered regarding the development of a California Renewable Gas Standard: **Is there enough RNG to comply?** Most of the documentation that ICF has observed in the public domain focuses on a RGS standard equivalent to 5 percent of core natural gas usage by 2030. The forecasted demand for natural gas in 2030 reported in the 2016 California Gas Report, along with ICF's assessment of California-based resources, indicates that this target is achievable, regardless of the basis against which it is measured (e.g., volumetric or carbon-based). If the RGS is expanded to include five percent of all California gas usage, this target could likely be met using in-state resources. ICF notes, however, that the development of the RGS standard would benefit from provisions to accept out-of-state gas to ensure feasibility and cost containment. Including out-of-state resources could potentially enable a much larger volumetric RGS to be met as part of a longer-term vision to decarbonize the pipeline. This is especially true as the development of advanced low-carbon fuels, like P2G technologies, are considered over the mid to long-term future.

The underlying question regarding the design of an RGS: **How can an RGS drive consistent demand through a utility procurement mechanism that provides supply and price certainty without disrupting the success and market participation in existing programs driving renewable gas usage today?** The supply-cost curve in Exhibit 4 demonstrates that there is a market-based path that will enable the lowest cost resources to be deployed first. However, it is important to note that the RGS program does not exist in a vacuum. There is limited, but existing, participation in the renewable gas market, and there are other goals that must be addressed, including promoting in-state economic development, addressing environmental equity considerations, and reducing short lived climate pollutants. Any RGS design should be complementary to other programs currently driving renewable gas development and flexible enough to enable market innovation that will maximize benefits and minimize costs.

Despite the potential similarities to other programs, such as the RPS or the LCFS program, ICF notes that there are unique considerations about the natural gas market that must be accounted for in the development of a RGS. For instance, the natural gas market is not a bundled utility service—about 60 percent of total throughput on the system is non-core gas. Only the gas utilities and core aggregators are regulated explicitly by the CPUC. Conversely, anyone that wants to sell electricity to California customers is regulated by the CPUC or the CEC. This aspect of the natural gas market is important to preserve, as natural gas is used extensively in various applications (e.g., fuel, chemical feedstock) and across multiple sectors of the economy, enabling affordable space and water heating for California homes and businesses, and providing foundational support to California's robust manufacturing economy. Drastically modifying California's natural gas market could impact the state's ability to support these businesses.

Maintaining the open natural gas market will require creative approaches that provide utilities with sufficient flexibility to ensure compliance by working with third-party providers rather than just mandating universal procurement targets. For instance, utilities may be able to provide incentives to third-party providers--such as a transportation rate discount--to promote their continued use of renewable gas in California as a more cost-effective alternative to direct procurement. In this case, despite the potential for free ridership on the part of third-party providers, flexibility allows utilities to pursue the most cost-effective RGS compliance while continuing to enable robust third-party participation in the market.

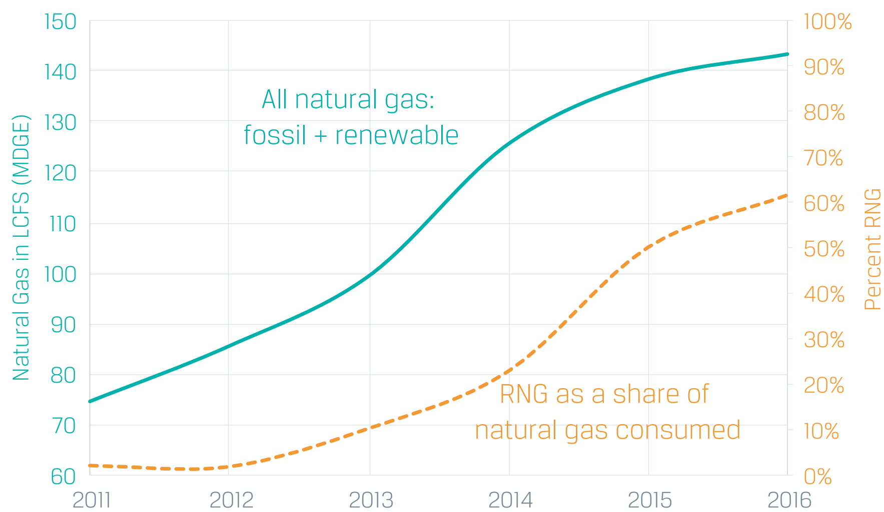
ICF considers three different approaches towards implementing an RGS:

- **Free market approach.** The free market approach suggests that a procurement target is established, and the market simply responds to the price signal according to the supply-cost curve (e.g., Exhibit 4 and Exhibit 6). ICF notes that while this approach will incentivize lowest-cost resources (likely landfill gas), a slightly more prescriptive design could enable more across-the-board RNG deployment and help achieve other priorities (e.g., in-state economic development) and deployment (e.g., more diverse feedstock supply).
- **Feed-in tariff.** A feed-in tariff, or standard offer contracts, would provide clear, reliable pricing for RNG producers. Although this approach provides a clear signal to help producers finance renewable gas projects, without distinguishing between feedstocks, a feed-in tariff has the potential to favor low-cost producers without recognizing the cost-effectiveness of GHG emission reductions. For instance, to incentivize higher cost pathways, the feed-in tariff would need to be set at a level that would yield considerable windfall profits to lower cost pathways (e.g., landfill gas). Some markets have included a degradation mechanism for feed-in tariffs to encourage technology cost reductions; however, it is unclear to what extent a simple degradation mechanism could be effective considering the cost disparities expected for different sources of renewable gas (see Exhibit 4), which may also have varying levels of technology maturity and cost reduction pathways.
- **Performance-based approach.** The RGS could take on a structure like the LCFS program, requiring a percent reduction in the carbon intensity of natural gas by some date. Similarly, the RGS could take on a structure that requires a percent volume target by some date (different from an absolute volumetric target, as is prescribed in the federal RFS program).

- Carbon intensity targets and percent volume targets should, in principle, provide clear signals to regulated parties and investors regarding the timeline required to achieve program targets.
- The downside of a carbon intensity target is that it may introduce undue complexity to the RGS. For instance, consider the boundary conditions of the lifecycle GHG assessment of dairy digester gas. Without regulations in place to capture and burn the methane that is released, the gas receives a lower carbon intensity for being credited with the avoided emissions from venting methane. Landfill gas, on the other hand, is regulated and required to be captured and burned, which means that it receives a lower carbon intensity when processed into RNG for being credited with the avoided emissions from flaring methane. The difference in the GHG benefit of avoided methane venting versus avoided methane flaring is huge: in the case of the former, you are avoiding methane emissions at a 100-year global warming potential of 25, whereas in the latter you are avoiding carbon dioxide emissions with a global warming potential of 1. California's SB 1383 may lead to regulations on manure management and capturing methane, changing the boundary conditions of the analysis.
- Another consideration related to a carbon intensity-based approach is the potential for the intent of the program to be expanded unexpectedly to include upstream emission reductions e.g., methane leaks in the natural gas pipeline. This could provide additional compliance opportunities for utilities that produce additional GHG benefits, but may detract from the intent of stimulating renewable gas development. Additionally, and similar to the example above, other regulations and programs that address these system improvements could complicate the benefit calculation, creating moving targets and challenging utilities' assessments of investment value for different compliance pathways.

Ultimately, ICF envisions the RGS taking on a hybrid of these approaches with the primary objective of accelerating market development of renewable gas through supply and price certainty. Consider the recent growth of renewable gas use in California's transportation fuels market: The LCFS program and the federal RFS program have worked in tandem to help accelerate its deployment into the transportation sector–capturing more than 60% of the California market in 2016. Exhibit 7 shows the volume of natural gas used as a transportation fuel, in million diesel gallon equivalents (MDGE), represented by the teal line, and the percent of that gas that is RNG represented by the orange dotted line.

EXHIBIT 7. RNG IN CALIFORNIA'S LCFS, 2011—2016



Despite the resounding success of RNG deployment in the transportation sector, some investors are still hesitant because of uncertainty linked to the LCFS program and the RFS2 program. Even as those programs presumably stabilize over the next several years, it is important that continued growth in the renewable gas market not be linked exclusively to growth in natural gas as a transportation fuel. While there is clearly a high value proposition for renewable gas used as a transportation fuel, and this value should be leveraged by the RGS to maximize benefits and minimize ratepayer costs, the RGS can also serve as a diversification strategy.

A thoughtfully constructed RGS will provide investors, developers, and utilities with the technical and policy certainty they seek to contribute cost-effectively to California's efforts to reduce GHG emissions. The RGS also has the potential to help maintain and build upon the success of the programs that have kick-started rapid growth in the renewable gas market.

About ICF

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