# Energy & Power – Biofuels: Renewable Natural Gas

*A game-changer in the race for net-zero*

Stifel Equity Research | March 8, 2021

**Stifel does and seeks to do business with companies covered in its research reports. As a result, investors should be aware that the firm may have a conflict of interest that could affect the objectivity of this report. Investors should consider this report as only a single factor in their investment decision.**

**All relevant risks, disclosures and certifications appear on pages 58-61 of this report.**

## Key contacts


**Derrick Whitfield**

Energy & Power – E&P and Biofuels
Managing Director, Stifel Equity Research
(214) 706-9451
whitfieldd@stifel.com

**John Annis, CPA**

Energy & Power – E&P and Biofuels
Associate Analyst, Stifel Equity Research
(214) 647-3528
annisj@stifel.com

**Billy Howell**

Energy & Power – E&P and Biofuels
Associate Analyst, Stifel Equity Research
(713) 237-4531
howellw@stifel.com

**Nate Pendleton, CFA**

Energy & Power – E&P and Biofuels
Associate Analyst, Stifel Equity Research
(214) 706-9457
pendletonn@stifel.com

# Contents

# Executive Summary

### *A game-changer in the race to net-zero*

We are bullish on the fundamentals of renewable natural gas (RNG) as it is positive for the environment (net negative carbon form of energy post-combustion), it is economic today (10-60% project IRRs), and offers immense growth potential (IEA projects an 18x increase in supply by 2040). Furthermore, for the world to get to net-zero by 2050, we need a lot of net negative carbon sources of energy, given that the most prevalent conventional (fossil fuels) and renewable (solar, wind) sources have positive carbon intensity profiles over their lifecycles (**Figure 1**). As a result, we believe the premium for RNG projects with negative carbon intensity profiles will only increase over time as investors internalize this reality. Irrespective of the final energy product, these projects are part of the solution.

### *What is RNG?*

Biogas is a renewable energy source comprised of a mixture of methane ($CH_4$), carbon dioxide ($CO_2$) and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment. Biomethane, or renewable natural gas (RNG), is a near-pure source of methane produced either by "upgrading" biogas or through the gasification of solid biomass followed by methanation. RNG is indistinguishable from conventional natural gas and can be used without any changes to transmission or end-user equipment.

### *If RNG is still a hydrocarbon, why does it matter?*

**RNG is a net positive for the environment.** In short, not all greenhouse gases (GHGs) are created equally. While methane only accounted for 10% of all U.S. GHG emissions in 2018, methane is one of the most potent GHGs with a global warming potential that is 28x to 36x greater than that of $CO_2$, according to IPCC. According to the EPA, in 2020, 30% of human-caused methane emissions in the U.S. stemmed from organic wastes at farms, landfills, and water recovery facilities. RNG enables the capture of these emissions that would have otherwise been released into the atmosphere and is used to displace fossil fuel consumption.

**RNG is economic today and improving.** In 2020, dairy and landfill gas projects earned average price realizations of $100/mmbtu and $30/mmbtu, respectively, well above their respective average cost of supply. Based on our assessment of over 20 projects across the primary RNG feedstocks (landfill, animal manure, wastewater), we estimate the industry generates project-level IRRs in the 10% to 65% range assuming strip prices and current federal and state program. We expect returns to improve as operators advance anaerobic digestion technology, improve operating efficiency, and better integrate digestate sales into their operations.

**RNG offers a differentiated source of growth.** RNG production has grown by a 17% CAGR over the last 15 years and is expected to grow at a 16% CAGR over the next 20 years based on the IEA's Stated Policy Scenario. As of year-end 2020, there were 157 RNG projects operational in the U.S. According to the AgSTAR database, only 58 active animal manure projects were operational out of the over 22,000 potential locations. We estimate approximately 4,800 farms are commercially viable based on ICF's economic thresholds for the low potential scenario (+1,000 cows, +5,000 pigs). Assuming only select dairy and swine farms, that represents a +80 fold increase in potential projects.

## Executive Summary (cont.)

### *Is policy supportive?*

**Policy has been the single most impactful catalyst.** The combination of policy (Senate Bill 1383, requiring reductions in short-lived climate pollutants) and regulatory incentives (both federal and state) have driven the recent inflection in RNG growth. In our view, producers are not in the business of producing RNG; they are in the business of monetizing RNG's environmental attributes through various federal and state programs.

**However, policies have been narrowly focused on the displacement of transportation fuels.** The theoretical market size for RNG in the U.S. is the same as total natural gas demand as RNG is chemically indistinguishable from geologic natural gas. However, current policy and regulatory incentives are transportation-focused policies, offering substantial incentives for the reduction of fossil-based transportation fuels. In 2019, natural gas consumed by the transportation sector was 940 Bcf, or approximately 16.4x greater than 2020 RNG production. While there is ample room to grow, we believe policy misses the mark as power generation is a far more significant opportunity than transportation, and the CI scores for transportation fuels and the electric grid are very similar.

**We expect the proliferation of LCFS programs and the growth of EV demand to be game-changers.** Beginning with policy, we expect the expansion of LCFS programs across the U.S., with Oregon and Washington being the next to implement programs formally. Regarding EV demand, Bloomberg Intelligence forecasts a ~22x increase in GW consumed by EV chargers from 2020 to 2040. We note one EV equals two cows assuming biogas' conversion to electricity via a Bloom Energy fuel cell.

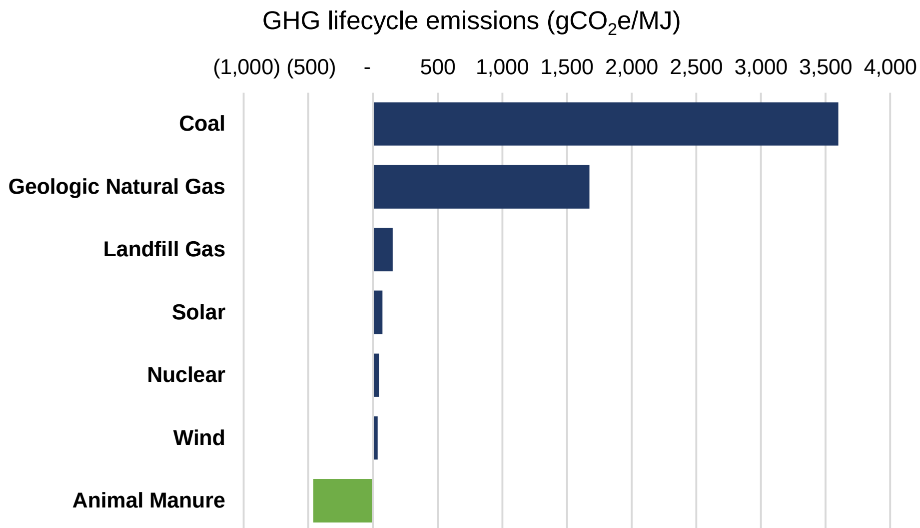
**Organic demand for lower-carbon options and mandatory renewable portfolio standards provide RNG a pathway to realize its potential.** Consumption of RNG outside of the transportation sector offers RNG the off-take required to realize its full production potential. Since 2017, there has been a proliferation of voluntary programs offered by utilities driven by customer demand for lower-carbon energy sources. On the regulatory-front, around 30 states have RPS that mandate utilities to source specific percentages of power from renewable sources. The mostly untapped power generation market, which consumed 12x more natural gas than the transportation sector in 2019, offers immense up-side for RNG. We expect RPS programs similar to Oregon's SB 98, a first-of-its-kind bill that sets 30-year targets for gas utilities to procure RNG and renewable hydrogen for customers, to drive demand growth in power generation markets.

### *How to play RNG?*

**We favor producers with vertical integration and projects with meaningfully negative carbon intensity profiles.** Through our extensive research process, including over 20 calls with industry participants (producers, service providers, and utilities) and all-encompassing sector research utilizing industry publications, industry events, and global academic research, we confirmed our initial thesis on the fundamentals of RNG and developed an appreciation for what we would view as a best-in-class business model. Our investment thesis, in short, is RNG is a game-changer in the race to net-zero. For the world to get to net-zero by 2050, we need a lot of net negative carbon sources of energy, given that the most prevalent conventional (fossil fuels) and renewable (solar, wind) sources have positive carbon intensity profiles over their lifecycles (**Figure 1**). As a result, we believe the premium for RNG projects with negative carbon intensity profiles will only increase over time as investors internalize this reality. Regarding our view on a best-in-class business model, it would be an operator that offers vertical integration (producer and dispenser) and a holistic local-market solution for the marketing of digestate solids (adding another source of income). As noted earlier, operators are not in the business of producing RNG, they are in the business of monetizing RNG's environmental attributes through various federal and state programs. In our view, vertical integration facilitates this end goal and offers the producer optimization optionality.

**We are initiating coverage of AMTX with a Buy rating, a $25.00 target price and Select List designation.** In short, we are constructive on the fundamentals of RNG and believe AMTX is the best vehicle to express a bullish view on low carbon intensity RNG as its projects are exclusively focused on dairy RNG (estimated CI of -416). In our view, management's experience with the production of renewable fuels is a differentiator as the company's success is driven by management's ability to develop projects that generate differentiated environmental attributes (LCFS, RFS, IRS 45Q) and the vertical integration of its operations to deliver them. In addition to RNG, we believe the company's Carbon Zero plants offers investors a free call on the upside of its other negative carbon intensity renewable jet/diesel business.

**Figure 1. Estimated lifecycle emissions for U.S. electrical power generation**




*Source: California Air Resources Board, U.S. EPA, U.S. National Renewable Energy Laboratory*

# Introduction

Over the past decade, economies around the world have laid out aspirational targets to achieve net-zero emissions. Electrification is central to these goals; however, hard-to-decarbonize sectors such as shipping, aviation, heavy-duty trucking, and industrial process with heat requirements unable to be met by renewable electricity will require other low-carbon sources of energy. Also, technologies such as solar and wind, while renewable, are not carbon neutral. To achieve net-zero ambitions, tomorrow's strategies to decarbonize need to incorporate energy sources with negative carbon intensities.

In this context, the case for biogas and biomethane is simple. Increasing amounts of organic waste produced by societies can be used to provide low-to-negative carbon energy to reduce greenhouse gas (GHG) emissions. Biomethane, also known as renewable natural gas (RNG), produced from animal manure is one of the few carbon-negative fuels available today and provides an amplified benefit given the potency of methane as a GHG. In the U.S., 30% of human-caused methane emissions during 2020 stemmed from organic wastes at farms, landfills, and water recovery facilities, according to the EPA.

Currently, biogas and biomethane account for only 0.3% of global primary energy demand. While only one-third of biogas production was upgraded to biomethane, we believe biomethane (RNG) is well-positioned for strong future growth as we expect increasing policy support at both the state and federal levels to achieve net-zero ambitions. Specifically, the IEA estimates that an 18x increase in global biomethane production, including an 8x increase in North America, by 2040 is needed to achieve net-zero targets.

This report aims to increase investor knowledge and interest in RNG. In this report, we review the RNG sector, feedstocks used to create RNG and their associated economics, and trends supporting RNG development. Lastly, we address the question of how investors can play this thematic. We complemented our research with additional insights and perspectives from interviews with leaders of 14 companies in the RNG value chain.

In short, we believe RNG is an Energy vertical that is a net positive for the environment, economical, offers immense growth potential and is woefully underappreciated.

# RNG Overview

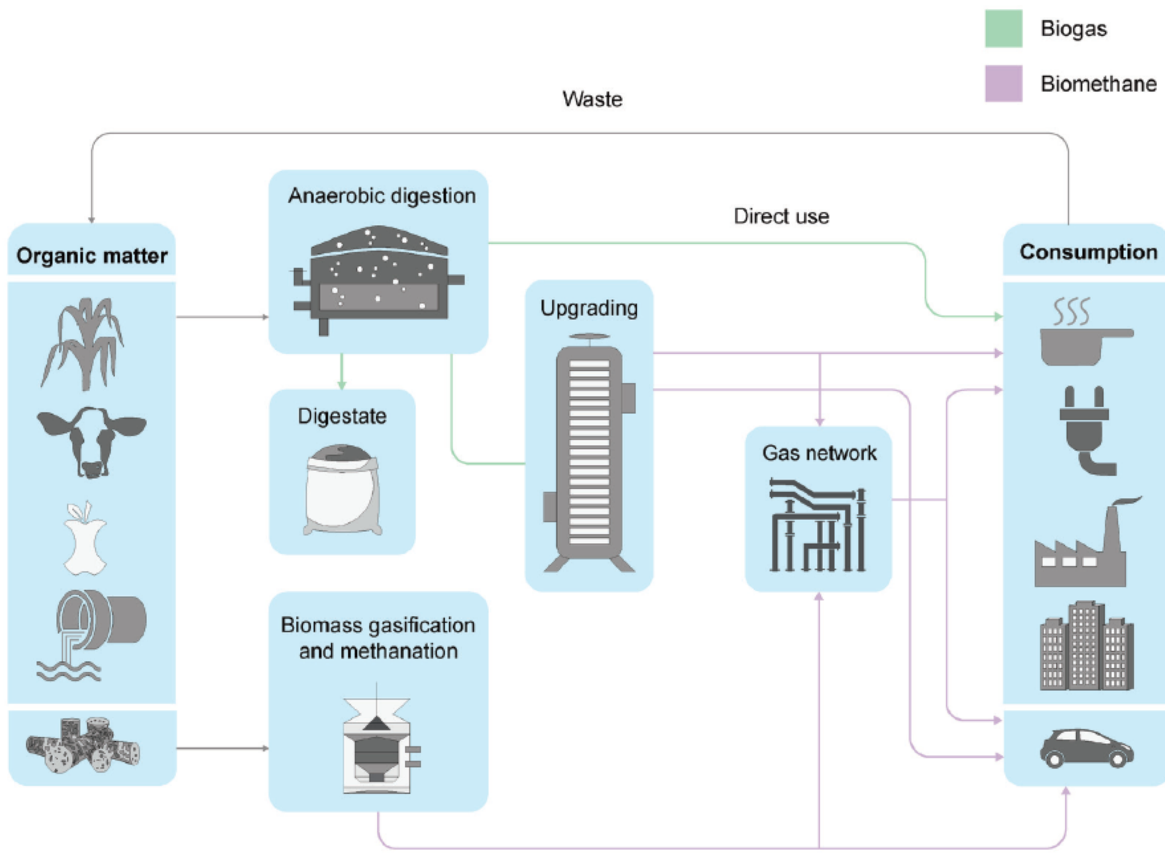
### *What is RNG?*

Biogas is a renewable energy source comprised of a mixture of methane ($CH_4$), carbon dioxide ($CO_2$) and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment. The precise composition of biogas depends on the type of feedstock and the production pathway. Feedstock is used to describe any raw input that is used to produce biogas.

Biomethane, or renewable natural gas (RNG), is a near-pure source of methane produced either by "upgrading" biogas or through the gasification of solid biomass followed by methanation. Put simply, both anaerobic digestion and thermal gasification break down organic materials into simpler molecules like carbon dioxide ($CO_2$) and methane ($CH_4$).

To be classified as RNG, raw biogas, which typically has a $CH_4$ content of 45-65% depending on the feedstock used, is upgraded by removing moisture, carbon dioxide ($CO_2$) and other contaminants present in biogas to create a near-pure methane gas (+90% $CH_4$) that is indistinguishable from conventional natural gas and can be used without any changes to transmission or end-user equipment. **Figure 2** provides an overview of the biogas and biomethane production pathways.

**Figure 2. Biogas and biomethane production pathways**




*Source: IEA*

### *RNG Feedstocks*

RNG feedstocks can be grouped into two broad categories: wet-waste feedstocks and dry feedstocks. Wet-waste feedstocks, including landfills, animal manure, water resource recovery facilities (WRRF) and food waste, are best suited for anaerobic digestion. Dry feedstocks, including agriculture residue, forestry and forest product residue, energy crops and municipal solid waste (MSW), are best suited for thermal gasification. **Figure 3** provides a summary of feedstock used for RNG production. We provide a look at feedstock supply in each of the individual feedstock sections below.

**Figure 3. Summary of Feedstocks Used for RNG Production**

| | Feedstock for RNG | Description |
|---|---|---|
| Anaerobic digestion | Landfill gas (LFG) | The anaerobic digestion of organic waste in landfills produces a mix of gases, including methane (40-60%). |
| | Animal manure | Manure produced by livestock, including dairy cows, beef cattle, swine, sheep, goats, poultry, and horses. |
| | Water Resource Recovery Facilities (WRRF) | Wastewater consists of waste liquids and solids from household, commercial, and industrial water use; in the processing of wastewater, a sludge is produced, which serves as the feedstock for RNG. |
| | Food waste | Commercial food waste, including from food processors, grocery stores, cafeterias, and restaurants, as well as residential food waste, typically collected as part of waste diversion programs. |
| Thermal Gasification | 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. |
| | 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). |
| | 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. |
| | Municipal solid waste (MSW) | Refers to the non-biogenic fraction of waste that would be landfilled after diversion of other waste products (e.g., food waste or other organics), including construction and demolition debris, plastics, etc. |

*Source: American Gas Foundation*

### *RNG Production Processes*

There are two primary methods of producing RNG: anaerobic digestion and thermal gasification. Current RNG producers in the U.S. almost exclusively use anaerobic digestion as thermal gasification technology is relatively immature and operates on a pilot-scale at this time. As shown in the chart on the previous page, the producer's feedstock choice determines the RNG production method used.

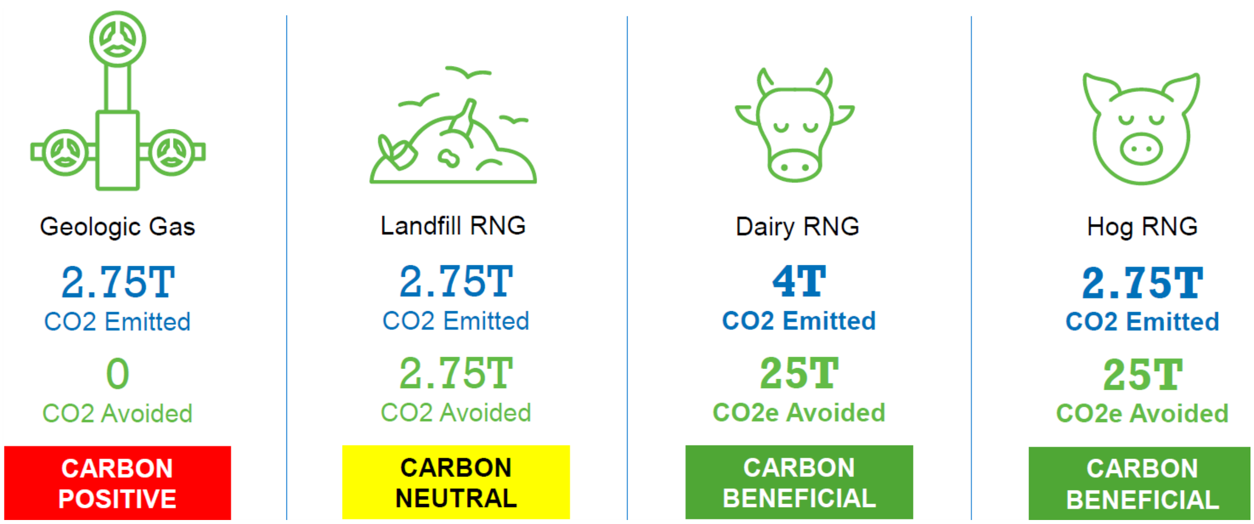
- **Anaerobic digestion:** This process, known as the "biological pathway', involves the collection and processing of methane-rich, low-lignocellulosic (plant biomass) feedstock in suitable conditions for bacteria to breakdown organic molecules into simpler molecules like carbon dioxide and methane (biogas). The biogas is then upgraded to pipeline quality methane (RNG). The feedstocks most commonly used are landfill waste, animal manure, or wastewater due to their low lignocellulosic content as bacteria have difficulty breaking down plant biomass. In the case of landfill waste, the anaerobic digester is the landfill itself.
- **Thermal gasification:** This process, known as the "thermochemical pathway," involves collecting and processing methane-rich, high-lignocellulosic feedstock using high heat to break down organic molecules into simpler molecules like carbon dioxide and methane (biogas). The biogas is then upgraded to pipeline quality methane (RNG), referred to as bio-synthetic natural gas (bio-SNG) to distinguish it from methane derived from anaerobic digestion. The feedstocks most commonly used are agricultural and forest residues due to their high lignocellulosic content.

### *RNG Environmental Benefits*

The use of RNG in energy systems provides three main benefits to the environment: waste management solutions, additional capture of methane from organic sources, and displacement of fossil fuels in sectors that lack cost-effective renewable alternatives. Regarding waste management, farmers can participate in the de-carbonization economy by supplying their waste byproducts, such as animal manure (one cow produces 80 pounds of manure per day) — which were previously liabilities — to RNG projects and create an additional revenue stream. Regarding emissions, RNG reduces GHGs and addresses climate change in two ways: i) it captures methane which would have otherwise been released into the atmosphere and ii) the methane captured in the form of biogas or biomethane is used as a renewable fuel and displaces the consumption of fossil fuels.

The EPA classifies the major GHGs as Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Hydrofluorocarbons (HFCs), and Sulfur Hexafluoride ($SF_6$). We note not all greenhouse gasses are created equal. While methane only accounted for 10% of all U.S. GHG emissions in 2018, methane is one of the most potent GHGs with its ability to trap heat in the atmosphere. The IPCC estimates methane has a global warming potential 28x to 36x greater than that of $CO_2$ over 100 years. When viewing global warming potential over 20 years, methane is 86x more potent than $CO_2$ because methane's average lifetime in the atmosphere is only 12.4 years. As a result, addressing methane emissions can have a near-term impact on addressing climate goals. In 2020, approximately 30% of human-caused methane emissions in the U.S. were from organic wastes at farms, landfills, and water recovery facilities, which can be harnessed by installing biogas processing facilities.

**Figure 4. RNG GHG Emission Reduction**




*Source: Dominion Energy*

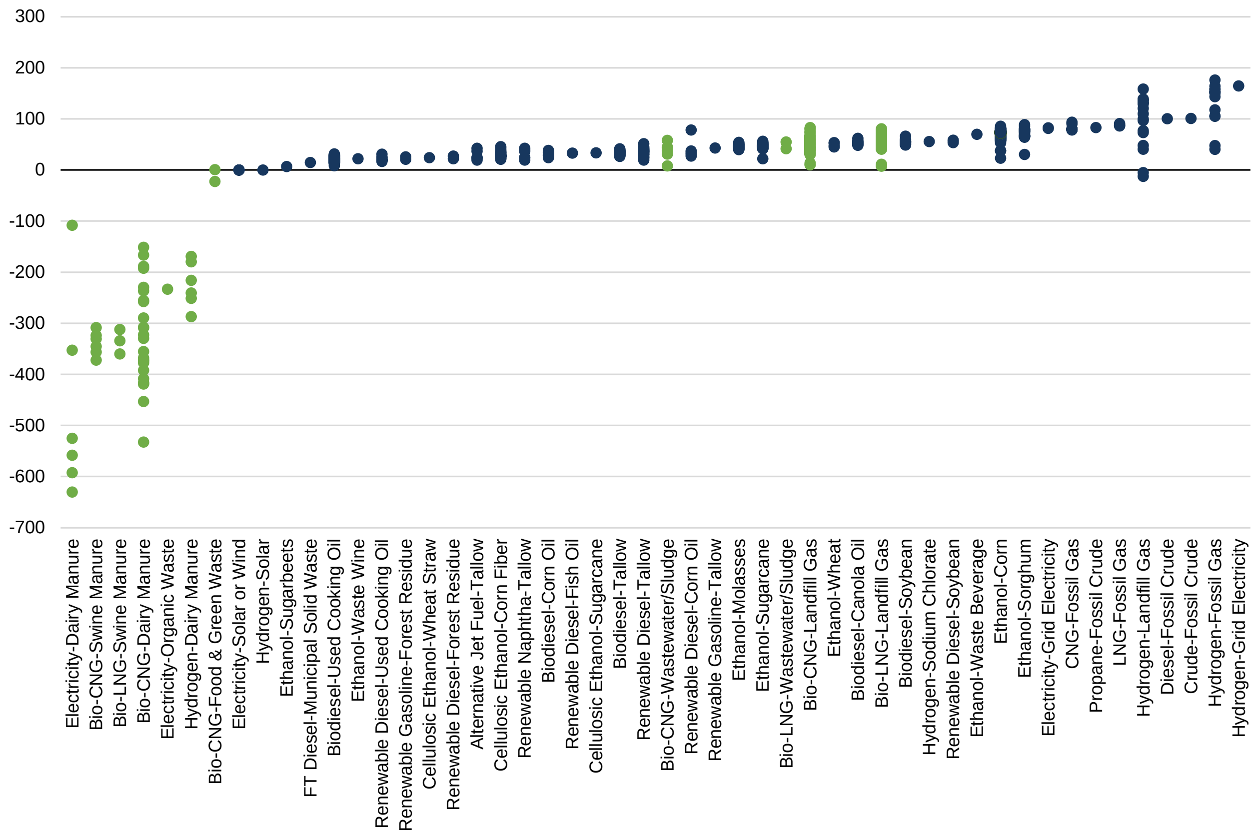
### *Monetizing Environmental Attributes of RNG*

In our view, RNG producers are not in the business of producing RNG; they are in the business of monetizing RNG's environmental benefits through various federal and state programs. At the federal level, the U.S. currently has the Renewable Fuel Standard (RFS), where renewable fuels generate Renewable Identification Numbers (RINs), which can be sold to refiners or importers who are required to meet their EPA-specified renewable volume obligation (RVO). At the state level, California and Oregon have pioneering emissions reduction programs, called Low Carbon Fuel Standard (LCFS), where RNG, when used as a transportation fuel, generates credits that can be sold to producers of conventional fuel to offset mandated carbon intensity (CI) deficits annually.

- **Federal-level:** Under the federal RFS program, the EPA sets RFS volume requirements annually for different biofuel types for an obligated party (refiners or importer of gasoline/diesel) to meet. Alternative fuel providers, such as RNG producers, receive a RIN for each gallon of renewable fuel used in transportation. Alternative fuel providers can then sell the RINs they generate to obligated parties so they can meet their renewable volume obligations. There are five categories, called "D-Codes," of RINs assigned to fuels based on their associated GHG reduction ability. RNG is qualified to receive the most valuable of the RINs, the D3 RIN, due to its ability to reduce the highest amount of GHGs.
- **State-level:** State LCFS programs create carbon markets by mandating the CI — the emissions from using a fuel — of transportation fuels to decrease. To comply with these mandates, obligated parties must reduce the CI of their fuel by blending either biofuels with conventional gasoline and diesel or purchase LCFS credits with lower CI scores generated by alternative fuel producers. The CI score of a given fuel is based upon the GHG emissions associated with the production, transportation and use of a given fuel, called a "pathway." As shown in **Figure 5**, RNG (called Bio-CNG/Bio-LNG in the chart below) has the lowest CI scores of any transportation fuel. Alternative fuel producers can sell the lower CI score LCFS credits to obligated parties so they can reduce their overall CI score. Currently, California and Oregon are the only states with LCFS programs in place that have mandates to reduce the carbon intensity of transport fuels by 20% from 2010 to 2030 in California and 20% from 2015 to 2030 in Oregon.

It is important to note that RNG production qualifies for both RINs and LCFS credits, which more than offset the additional cost of production versus geologic natural gas. RNG also qualifies for state-level programs that set mandatory or voluntary targets for a minimum amount of renewable energy in their electricity supply, called renewable portfolio standards (RPS); however, the incentives provided under RPS have historically traded at a discount to RFS and LCFS credits and why RNG is primarily consumed in the transportation sector. We provide a detailed overview of the federal and state policies that support RNG in later sections of this report.

**Figure 5. Carbon Intensity Values of Certified Pathways (green denotes biogas/biomethane related pathway)**




*Source: California Air Resources Board (CARB), Stifel Research*

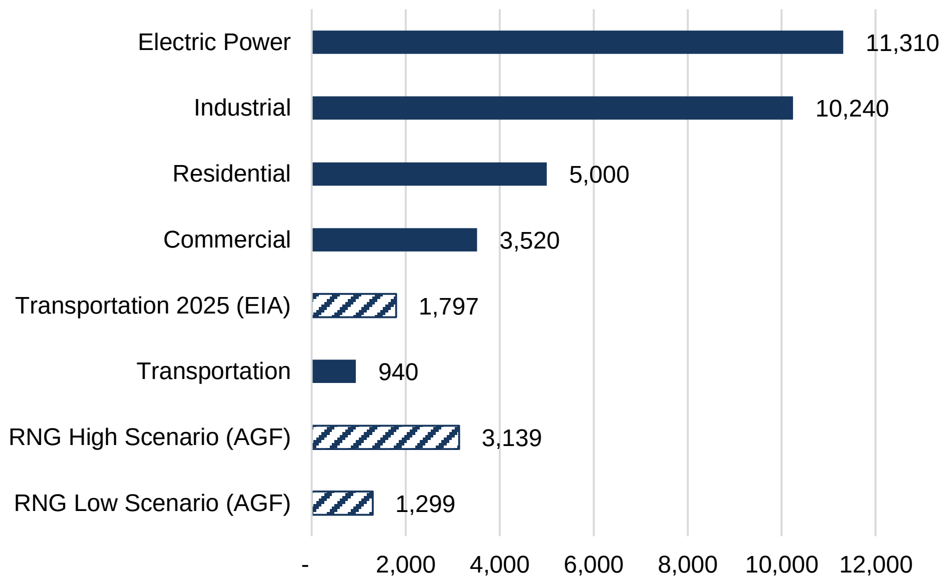
### ***RNG Demand***

The theoretical market size for RNG in the U.S. is the same as total natural gas demand as RNG is chemically indistinguishable from geologic natural gas. However, when environmental benefits are not valued using regulatory policies to drive demand, RNG cannot compete with natural gas on economics. Therefore, we view the current addressable market for RNG as limited to the transportation sector, where current policy and regulatory incentives such as the RFS and LCFS, which are both transportation-focused policies, offer the most significant economic value for RNG producers. This is why the transportation sector consumes almost all of RNG in the form of CNG and LNG. Assuming a more liberal application of LCFS, RNG use for electric power generation and heat for buildings and industry represent substantial upside demand potential as the CI scores for transportation fuels and the electric grid are very similar.

#### *Transportation market: CNG and LNG Vehicles*

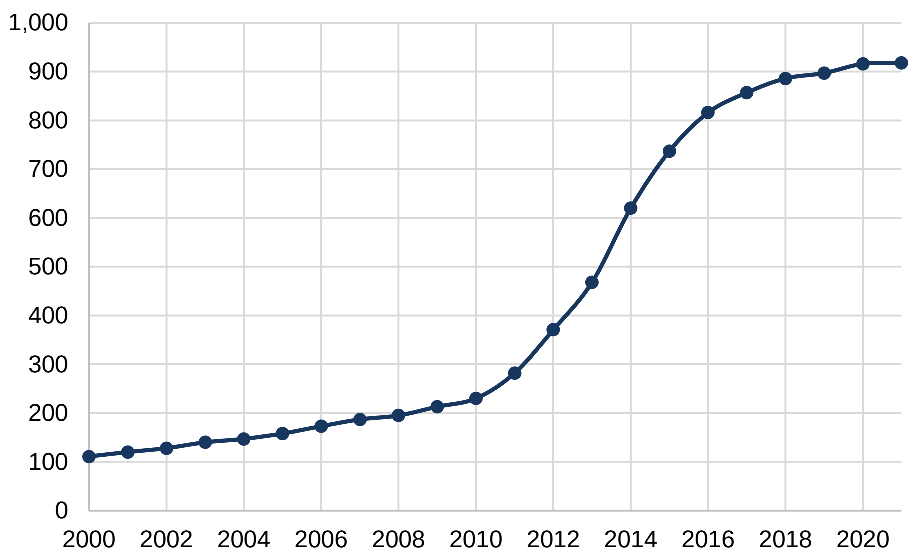
RNG can be used as a transportation fuel in the form of compressed natural gas (CNG) or liquefied natural gas (LNG). While CNG and LNG vehicles still emit emissions, the use of negative carbon sources, such as animal manure, results in a net decrease of GHG emissions. In 2019, natural gas consumed by the transportation sector was 940 bcf, or 3.0% of total natural gas consumption (**Figure 6**). Based on the AGF's estimate of potential RNG supply, RNG can displace all geologic natural gas supply within the transportation sector, implying upside in near-term demand. Longer term, the use of CNG for transportation fuel has grown at a five-year CAGR of 7.7% from 2014 to 2019, according to the EIA, and is forecasted to grow at an 11.4% CAGR from 2019 to 2025, offering continued outlets for growth in RNG production. We do note that the buildout of CNG/LNG refueling stations (**Figure 7**) has moderated following the expiration of a federal tax credit (EPACT 2005) in 2013 to help stimulate the shift of trucks and buses from diesel to natural gas fuel by covering up to 80% of the incremental costs of the new natural gas-powered vehicles. In addition, RNG production has saturated the key market in California for CNG/LNG vehicles (**Figure 8**). However, based on our discussions with utilities participating in RNG, we believe President Biden's EPA could look to expand renewable fuel obligations under the RFS, and, on a state-level, regulators are exploring rate-casing interconnection costs for RNG projects to drive further expansion of RNG.

**Figure 6. Natural Gas Consumption by End Use (2019)**



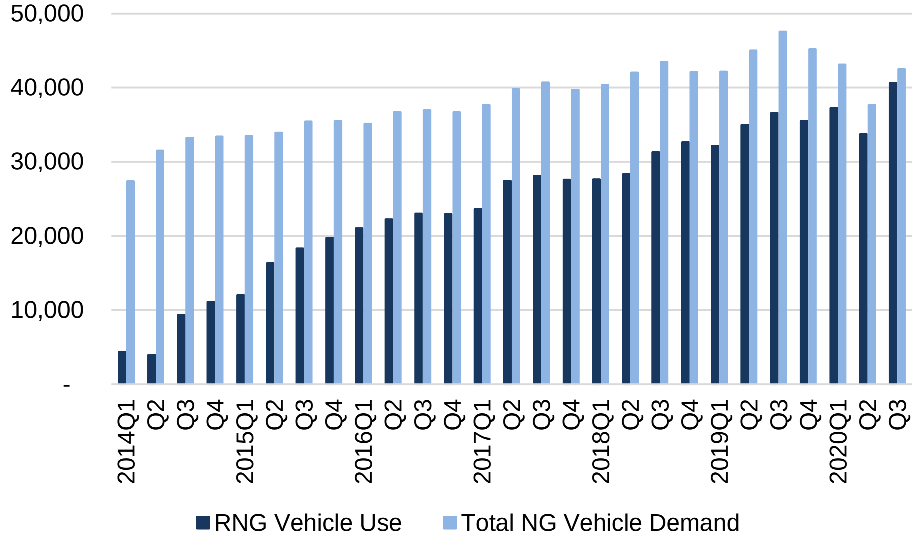

*Source: U.S. EIA, American Gas Foundation*

**Figure 7. CNG/LNG public refueling stations in the U.S. (cumulative)**




*Source: U.S. DOE's Alternative Fuels Data Center*

**Figure 8. California's NG vehicle market has been saturated by RNG production**




*Source: California Air Resources Board*

*Transportation market: EV Vehicles*

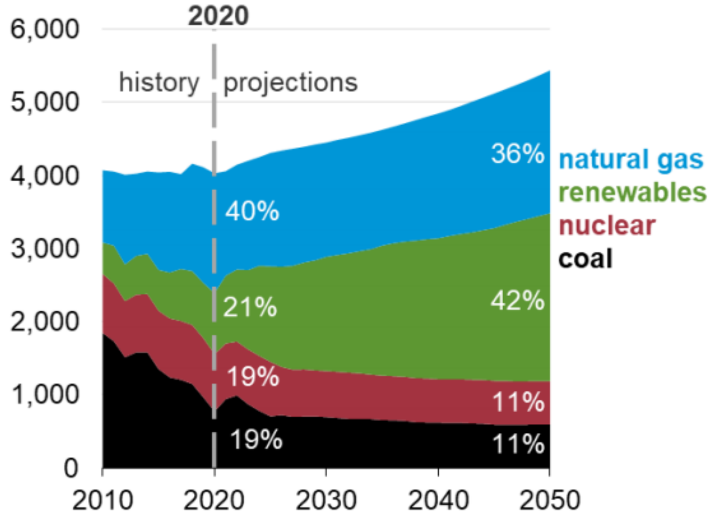
Currently, the only method that RNG producers can take advantage of RINs under the RFS program is to deliver RNG for fuel in CNG or LNG vehicles. In 2014, the EPA authorized an "eRIN" pathway to allow RNG producers to generate RINs when RNG is used to produce electricity for electric vehicle (EVs) charging. We believe the approval of an eRIN pathway could unlock a substantial market opportunity for RNG, especially in California, where, according to Bloom Energy, projected electricity demand for EVs is expected to exceed the state's total RNG capacity. To date, the EPA has not approved applications that would allow producers to begin generating eRINs. The Agency initially proposed that the "producer" should be the company that distributes the electricity (the utility) for use as a transportation fuel and should act as the RIN generator. Opponents to this interpretation argued for the company that first injects the pipeline quality biogas (RNG producers) into the grid should be eligible to act as the RIN generator. The EPA deferred a decision to define the "producer" for renewable electricity and has not revisited the topic since despite numerous applications that have been submitted for approval under the eRIN pathway.

There are pathways approved for RNG producers in California to generate LCFS credits when biogas or biomethane are used to produce electricity to charge EVs. When used to produce electricity, animal manure generates the lowest average CI score (-461) and the lowest absolute CI score (-631) under California's LCFS program. While the loss of revenue from monetizing federal RINs, technology solutions such as Bloom Energy's fuel cell technology are helping drive down costs. Specifically, Bloom's fuel cell technology can convert biogas into electricity directly, without the added cost of upgrading the biogas to RNG. Based on our discussions with industry leaders, we estimate a ~100 point reduction in the CI score possible due to transitioning from an internal combustion energy to a fuel cell for power generation.

*Upside demand: electric power generation and heating*

In our view, off-take for RNG used in the electric power generation and heating markets is needed to realize the full potential of RNG production capacity in the U.S. In the near term, we believe corporations' and residential customers' voluntary commitments to decarbonize will drive incremental growth of RNG for use in power generation and heating (see Voluntary Markets section below). Longer term, we believe an expansion of state renewable portfolio standard (RPS) programs that target GHG emission reductions outside of the transportation sector will increase as natural gas use in electricity generation is not projected to significantly decrease through 2050 (**Figure 9**) and will require negative carbon intensity fuels, such as RNG, to achieve emission reduction goals. Of particular importance, we note animal manure is the only lifecycle carbon-negative source of electricity commercially available (**Figure 1**). Regarding heating, natural gas boilers that provide heat to residential and commercial buildings have a lifespan of +15 years and offer RNG an option to displace natural gas to reduce emissions over the long term.

**Figure 9. U.S. electricity generation by fuel source (billion kilowatt-hours)**

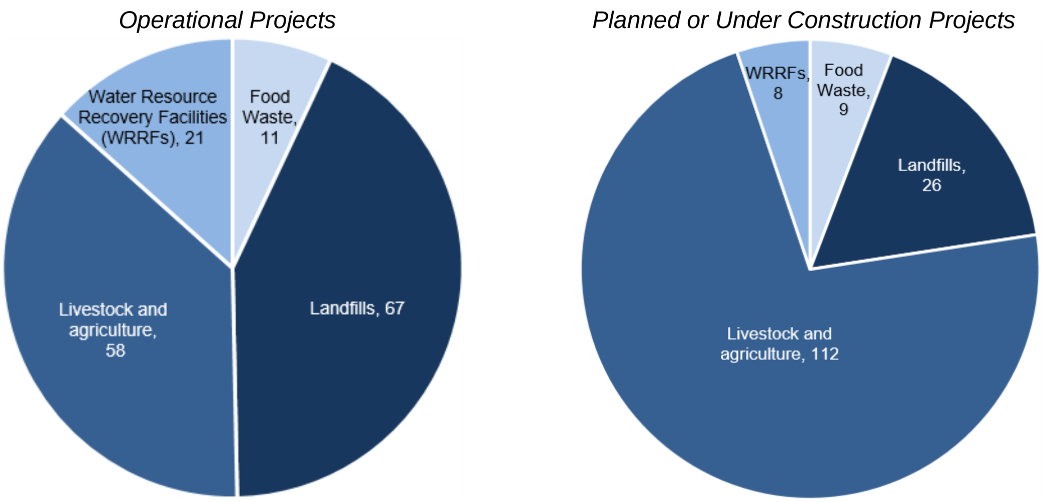



*Source: U.S. EIA, Annual Energy Outlook 2021 (Reference Case)*

### *RNG Supply*

Over the last five years, RNG production has grown 98% or a 17% CAGR, primarily driven by landfill gas (LFG) projects. Under its low potential scenario, the ICF estimates 425 of the more than 2,000 landfills included in the U.S. EPA's Landfill Methane Outreach Program ("LMOP") database are commercially viable, representing a material increase from the current 67 operational landfills. The potential supply capacity of the low scenario is ~10x the current capacity. Despite the growth potential of LFG, we expect future growth to be driven by animal manure due to the disproportionate environmental benefits realized economically through state-level incentive programs such as California's Low Carbon Fuel Standard. Under its low potential scenario, ICF International estimates that ~4,800 farms are commercially viable, representing a material increase from the current 58 operational farms. The potential supply capacity of the low scenario is ~16x the current capacity. As shown in **Figure 10**, animal manure accounted for approximately 37% of the commissioned and 72% of the planned or under construction projects. Industry participants have highlighted that economics can further improve, unlocking additional growth potential as the relatively mature technologies are applied in more novel ways, and best practices proliferate the market.

**Figure 10. RNG projects by feedstock**




*Source: U.S. DOE's Argonne National Laboratory*

### *RNG Economics*

The economics of RNG are compelling when considering state and federal incentive programs that value the environmental benefits of RNG. While state-level incentives depend on many variables, we estimate landfill gas (LFG) traded at an average price of $31.86 (1,245% premium to Henry Hub) over the last three years while the cost of supply as estimated by the American Gas Foundation (AGF) is $10-$20/mmbtu for most LFG opportunities. Over the last three years, we estimate dairy RNG traded at an average price of $103.32 (4,036% premium to Henry Hub). The AGF estimates a supply cost of $40/mmbtu for most dairy opportunities. After RNG is produced, the interchangeable nature of RNG with geologic natural gas means that no additional capital outlay is required for infrastructure. In **Figure 11**, we outline the basic economics and value drivers for RNG projects. We also caution investors to note that without state and federal incentive programs, RNG projects remain largely uneconomic compared to geologic natural gas due to the supply costs involved.

**Figure 11. Example economics and value drivers of key feedstocks**

| Example Project Economics | | | Value Drivers |
|---|---|---|---|
| **Dairy** | | | |
| Project Size (cows) | | 2,200 | Project size |
| RNG Production (mmbtupd) | | 84 | Digester type & upgrading technology |
| Price ($/mmbtu) | $ | 110.00 | Distance from natural gas infrastructure |
| Digestate Sales (Y/N) | | No | Sale of digestate solids |
| Capex ($mm) | $ | 7.0 | LCFS CI score |
| Opex ($mm/yr) | $ | 0.2 | |
| EBITDA ($mm/yr) | $ | 3.2 | |
| ***IRR (%)*** | | ***35%*** | |
| **Swine** | | | |
| Project Size (hogs) | | 454,000 | Project size |
| RNG Production (mmbtupd) | | 878 | Digester type & upgrading technology |
| Price ($/mmbtu) | $ | 112.00 | Distance from natural gas infrastructure |
| Digestate Sales (Y/N) | | No | Sale of digestate solids |
| Capex ($mm) | $ | 50.0 | LCFS CI score |
| Opex ($mm/yr) | $ | 2.1 | |
| EBITDA ($mm/yr) | $ | 32.0 | |
| ***IRR (%)*** | | ***46%*** | |
| **Landfill Gas** | | | |
| Landfill Capacity (mT) | | 10,000,000 | Landfill size and age |
| Peak RNG (mmbtupd) | | 2,071 | Current collection systems in place |
| Price ($/mmbtu) | $ | 31.00 | Methane generation capacity and pollutants |
| Capex ($mm) | $ | 27.0 | Upgrading technology |
| Opex ($mm/yr) | $ | 4.0 | Distance from natural gas infrastructure |
| EBITDA ($mm/yr) | $ | 53.0 | Revenue sharing agreements |
| ***IRR (%)*** | | ***56%*** | |
| **Water Resource Recovery Facilities** | | | |
| Facility Size (mmgpd) | | 13 | Facility flow rate |
| RNG Production (mmbtupd) | | 88 | Current waste treatment infrastructure |
| Price ($/mmbtu) | $ | 31.00 | Digester type & upgrading technology |
| Digestate Sales (Y/N) | | No | Distance from natural gas infrastructure |
| Capex ($mm) | $ | 6.1 | Sale of digestate solids |
| Opex ($mm/yr) | $ | 0.1 | Revenue sharing agreements |
| EBITDA ($mm/yr) | $ | 1.0 | |
| ***IRR (%)*** | | ***14%*** | |

*Source: Stifel estimates*

### ***Barriers to RNG development***

Despite the numerous tailwinds in place for RNG production growth, the potential we see for the sector is not without barriers. The broader challenges include the cost of upgrading biogas to RNG, the changing regulatory environment, the pipeline interconnection cost associated with connecting RNG producers to existing pipeline infrastructure, the differences in pipeline specifications, the variability of biogas feedstock and the perception of RNG quality. Although we believe there would still be a voluntary market for RNG, the demand for RNG would be significantly reduced without policy support.

- Due to the additional infrastructure required to upgrade biogas to RNG, it is unlikely RNG will ever directly compete with the economics of geologic natural gas. In 2020, the average natural gas price was $2.08/mmbtu, while RNG costs range from $7/mmbtu for the most economic landfill gas projects to $18/mmbtu for the most economical animal manure projects, according to the AGF. While various federal and state programs exist to support the industry, volatility in attribute markets (D3 RIN prices of $0.59 in September 2019 to $1.62 in December 2020) and policy risk may make some investors hesitant to finance an RNG project.
- The economics of RNG projects are highly dependent on regulatory incentives, which are subject to change. The ever-changing nature of the regulatory environment creates an impediment to entry. Future changes to the regulations at the federal, state, or local level could reduce RNG projects' economics. For example, waivers may be granted to refineries exempting them from biofuel blending requirements, which may negatively impact RIN prices. Specifically, the RFS statutory volumes are set to expire at the end of 2022, which means the Biden administration will have the discretion to set biofuel blending requirements post-2022. However, if Congress does not act to set statutory volumes post-2022, RVOs will be subject to uncertainty and the energy policies of the administration that occupies the White House.
- Additionally, the cost associated with connecting RNG infrastructure to existing natural gas pipelines is another barrier. High costs and long lead times are often required for RNG projects to connect to pipeline infrastructure. In California, the EPA estimates an average cost between $1.5 million and $3.0 million per site, and local distributors require almost a year to complete the preliminary studies before construction. As a result, smaller RNG producers who are further from distribution infrastructure with sufficient open capacity will be challenged to transport their gas economically. Recently, smaller farms have employed a "hub and spoke" model, whereby distributed individual farms pipe to a centralized gas pressurizing and cleaning/conditionally plant, to aggregate biogas to upgrade and pipe the gas through one common interconnection economically.
- Differences in U.S. pipeline specifications create another challenge for RNG, which has a slightly different heating value when compared to geologic natural gas. In the U.S., each independent gas system has its own specifications. Examples of the different requirements are shown in **Figure 12**. One of the most challenging requirements for RNG is an elevated heating value (Btu content) as RNG has a slightly lower Btu when compared to geologic natural gas (966 Btu/scf versus 1,011 Btu/scf) and can vary depending on upgrading technology.
- Due to the nature of biogas projects, the feedstock's quality can vary over time, requiring significant treatment to produce RNG-quality gas. While technically possible to upgrade almost any biogas stream to acceptable levels, if a source stream has depressed levels of methane or abnormally high levels of other gasses, installed upgrading infrastructure may be insufficient for the upgrading required. According to the EPA, landfill gas projects are particularly susceptible to quality fluctuations and the presence of dinitrogen ($N_2$) in gas streams. $N_2$ is an inert gas that reduces the heating value of RNG and is difficult to remove using standard upgrading technology.
- Although RNG is pipeline quality gas, it is often incorrectly perceived to be of lower quality than geologic gas. Due to RNG's feedstocks, one popular misconception even among industry participants is that RNG is of lower quality compared to geologic natural gas. The Gas Technology Institute conducted a study that showed RNG generally has lower concentrations of pollutants ($CO_2$, $O_2$, $H_2S$, etc.) and slightly higher levels of metals, siloxanes and halocarbons when compared to geologic natural gas.
- Lastly, and perhaps one of the most important gating factors to RNG development, is apprehension from farmers to work with RNG developers. Aemetis Inc. CEO Eric McAfee summarized it, perhaps, best of what the ask of a farmer is when an RNG developer wants to build an anaerobic digestion facility: *"I, the RNG developer, will be walking on your property for the next 25 years. I want to have a football-size piece of your property, and, at some*

*point in the future, I am going to pay you. But first, I need to get the AD facility and pipelines permitted, then built, then get the biogas to a pipeline, then into a renewable natural gas dispenser, find an off-taker, and, years down the road, when someone pays me, I will give you a cut."* When framed in that light, it is clear why relationships with individual farmers are crucial when building commercial-scale RNG projects.

**Figure 12. Example pipeline specifications**

| Pipeline Company | Heating Value (Btu/scf) | | Water Content | Various Inerts | | | Hydrogen Sulfide ($H_2S$) |
|---|---|---|---|---|---|---|---|
| | Min | Max | (Lbs/ MMscf) | $CO_2$ | $O_2$ | Total Inerts | (Grain/100scf) |
| SoCalGas | 970 | 1150 | 7 | 3% | 0.20% | 4 | 0.25 |
| Dominion Transmission | 967 | 1100 | 7 | 3% | 0.20% | 5 | 0.25 |
| Equitrans LP | 970 | - | 7 | 3% | 0.20% | 4 | 0.3 |
| Florida Gas Transmission Co. | 1000 | 1110 | 7 | 1% | 0.25% | 3 | 0.25 |
| Colorado Intrastate Gas Co. | 968 | 1235 | 7 | 3% | 0.001% | 0 | 0.25 |
| Questar Pipeline Co. | 950 | 1150 | 5 | 2% | 0.10% | 3 | 0.25 |
| Gas Transmission Northwest Co. | 995 | - | 4 | 2% | 0.40% | 0 | 0.25 |

Source: SoCalGas

# RNG Feedstocks

In the U.S., there are currently three primary sources of biogas used to produce RNG through anaerobic digestion: municipal solid waste (MSM) landfills, animal manure from livestock farms, and municipal water resource recovery facilities (WRRFs). We provide an overview of each feedstock's production processes; however, we limit review of economics to RNG produced from landfill and animal manure as they account for the majority of the growth wedge and have the ability to deliver the most significant emission reductions (**Figure 13**). In our view, RNG producers are in the business of monetizing RNG's environmental attributes, not RNG itself, and we believe animal manure, with the lowest CI scores, offers the best economics and long-term value proposition.

**Figure 13. CI Ranges of Fossil and Renewable Vehicle Fuels**

| Fuel | Feedstock | Average CI (g CO2e/MJ) | Range (g CO2e/MJ) | Number of Pathways | %Δ Relative to Diesel |
|---|---|---|---|---|---|
| Diesel | Fossil Crude | 100 | 100 | 1 | - |
| Fossil CNG | Fossil Gas | 83 | 78 to 94 | 8 | -17% |
| Fossil LNG | Fossil Gas | 88 | 86 to 91 | 3 | -12% |
| Renewable Diesel | Corn Oil | 42 | 27 to 79 | 5 | -58% |
| | Fish Oil | 33 | 33 | 1 | -67% |
| | Forest Residue | 25 | 22 to 27 | 2 | -75% |
| | Soybean | 56 | 54 to 58 | 3 | -44% |
| | Tallow | 35 | 20 to 52 | 19 | -65% |
| | Used Cooking Oil | 22 | 17 to 31 | 8 | -78% |
| Renewable Gasoline | Forest Residue | 24 | 21 to 26 | 2 | -76% |
| | Tallow | 43 | 43 | 1 | -57% |
| Electricity | Dairy Manure | -461 | -631 to -108 | 6 | -561% |
| | Grid Electricity | 82 | 81 to 83 | 2 | -18% |
| | Organic Waste | -233 | -233 | 1 | -333% |
| | Solar or Wind | 0 | 0 | 6 | -100% |
| Hydrogen | Dairy Manure | -224 | -287 to -169 | 6 | -324% |
| | Fossil Gas | 147 | 105 to 176 | 15 | 47% |
| | Grid Electricity | 164 | 164 | 1 | 64% |
| | Landfill Gas | 95 | -13 to 158 | 17 | -5% |
| | Sodium Chlorate | 56 | 56 | 1 | -44% |
| | Solar | 0 | 0 | 1 | -100% |
| Bio-CNG | Diary Manure | -325 | -533 to -151 | 25 | -425% |
| | Food & Green Waste | -11 | -23 to 0 | 2 | -111% |
| | Landfill Gas | 49 | 10 to 83 | 111 | -51% |
| | Swine Manure | -340 | -372 to -309 | 6 | -440% |
| | Wastewater/Sludge | 37 | 8 to 58 | 6 | -63% |
| Bio-LNG | Landfill Gas | 55 | 7 to 80 | 43 | -45% |
| | Swine Manure | -336 | -360 to -312 | 3 | -436% |
| | Wastewater/Sludge | 48 | 42 to 55 | 2 | -52% |

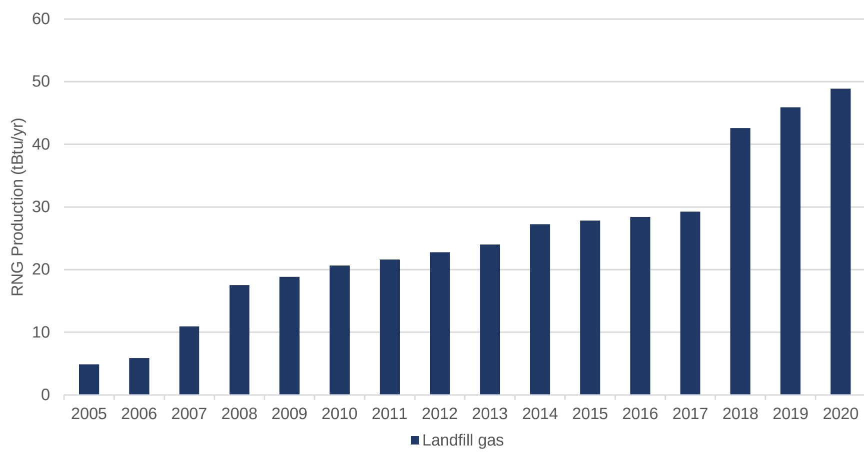
*Source: California Air Resources Board, Stifel estimates*

### *RNG from Landfills*

Biogas from landfills or "Landfill Gas" (LFG) contains 50-55% $CH_4$, 45-50% $CO_2$, and less than 1% non-methane organic compounds. The biogas is the natural byproduct of the decomposition of organic material in anaerobic conditions and has a typical heating value of 500 BTU/SCF. Due to air quality standards, many landfills already have LFG collection and flaring systems in place to remove harmful emissions. The EPA estimates 1 million tons of municipal solid waste (MSW) produces ~43 mcfpd of LFG for 20-30 years.

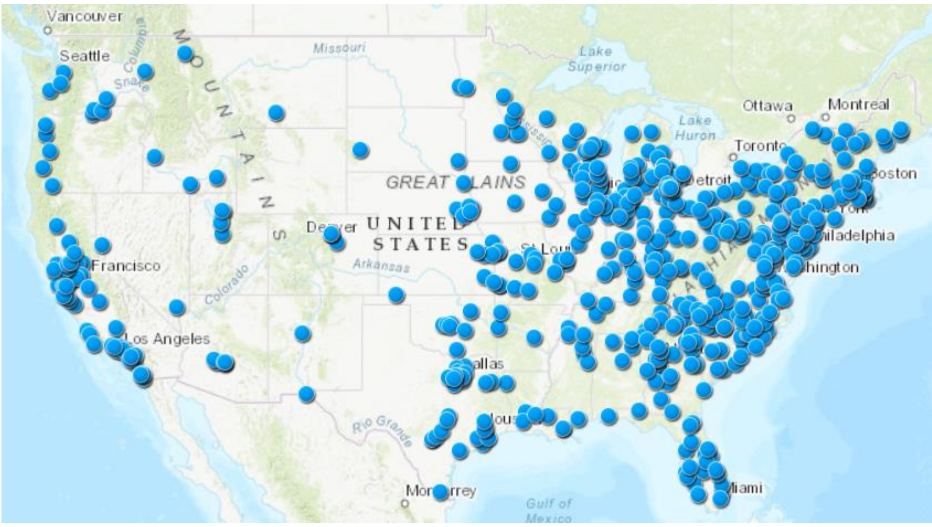
There are currently 67 active RNG LFG projects in the US. ICF estimates 425 of the more than 2,000 landfills included in the U.S. EPA LMOP database are commercially viable. Significant regulatory and compliance requirements for operating landfills serve as a barrier to new landfill development in the U.S., and the number of operational landfills has decreased since 1986. As a result, existing landfills continue to grow larger, and over time, the trend will increase the number of landfills that have the scale to be commercially viable for RNG production. Additionally, Montauk estimates there are 399 operating renewable electricity projects that have the potential to be converted to produce RNG.

**Figure 14. Annual landfill gas RNG production**



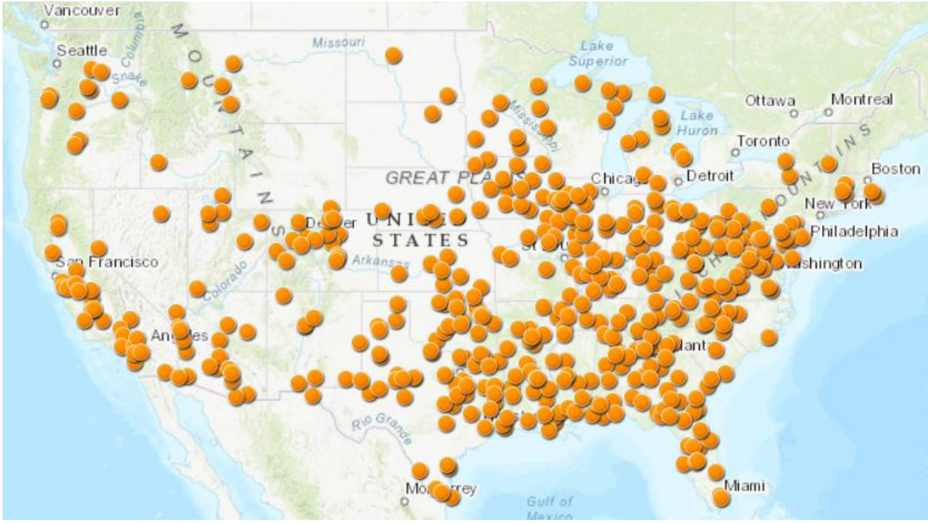

*Source: Bloomberg*

**Figure 15. Operational or planned landfill gas projects for RNG and electricity**




*Source: U.S. EPA*

**Figure 16. Candidate landfill gas projects according to the EPA**




*Source: U.S. EPA*

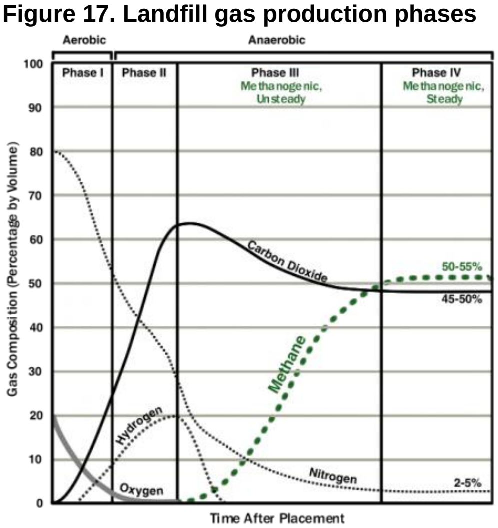
*Landfill gas production process*

In the U.S., landfills are the primary form of solid waste disposal. These landfills are constructed and operated under tight safeguards to limit the risk of water or air pollution. In a landfill, waste is deposited in separate compaction areas or "cells" until a cell is full. The cell is then compacted, covered in a polyethylene cap, and buried under a layer of soil.

Once the waste is in place, the bacteria begin to decompose the waste in four phases (**Figure 17**). Initially, aerobic bacteria break down long molecular chains to create carbon dioxide until all oxygen is consumed. In the second phase, anaerobic bacteria generate acids and alcohols, generating carbon dioxide and hydrogen. In the third phase, bacteria consume the organic acids to form acetate, which is consumed along with carbon dioxide by methane-producing bacteria. After about a year, the cell then enters the final phase where methane and carbon dioxide are produced at a relatively stable rate for the next 20 years.

To collect the landfill gas, either vertical or horizontal wells are drilled into the cell and a blower or vacuum induction system is used to extract the gas. The raw LFG is treated to remove moisture, particulates and other impurities depending on the desired product (direct use, on-site electrical power generation, or RNG).

**Figure 17. Landfill gas production phases**

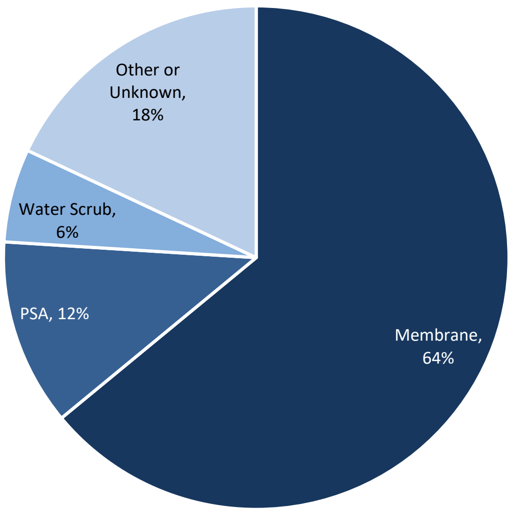



*Source: U.S. EPA*

*Biogas upgrading*

To reach RNG quality, the biogas must be upgraded to remove carbon dioxide and other impurities based on the end-user or pipeline injection requirements. In most cases, the gas stream is first pretreated to remove water and hydrogen sulfide. Hydrogen sulfide can be removed through various technologies, including chemical scrubbing and activated carbon filtration. The gas stream is then upgraded through one (or more) methods. According to the EPA, the most common technologies include membranes, pressure swing absorption (PSA), solvent scrubbing, and water scrubbing. Below are the most common technologies and a brief description of the process.

**Figure 18. Upgrading technologies currently in use**




*Source: U.S. EPA*

- **Membranes:** A membrane is a type of filter that uses pore sizes to distinguish between different molecules in the gas stream. The gas is routed at high pressure through a series of membranes that consist of long, thin (0.5mm to 1.0mm in diameter) fibers with a hollow center. Methane has a nonpolar charge and is larger in size than carbon dioxide, so it remains in the center as the other gasses are allowed to permeate through the porous membrane. To achieve RNG-quality, the gas is often routed through a series of membranes multiple times to reach methane concentrations between 96% and 99% methane. Some operators claim costs as low as $1.00/mmbtu of treated gas and low maintenance due to limited moving parts.
- **Pressure swing absorption:** PSA is a process where the gas stream is forced through an absorptive substance at high pressure, which captures molecules based on weight and size. Once the absorptive substance is saturated, the tank is depressurized and the captured molecules are released separately from the remainder of the gas stream. The process is repeated until the quality of the resulting gas reaches desired levels. According to the EPA, the resulting gas stream is generally 95% to 98% methane after multiple cycles. It is important to note PSA systems are unique in their ability to separate nitrogen and oxygen from the gas stream, a common pollutant in LFG.
- **Solvent scrubbing:** Solvent scrubbing uses a chemical solvent to strip carbon dioxide and other impurities from the gas stream. The solvent is introduced to the biogas stream, absorbing carbon dioxide and other impurities while allowing the methane to continue. The solvent is then either heated (in an amine system) or depressurized (in a Selexol process) to release the captured impurities. The process generally results in a methane concentration of between 97% and 99%.
- **Water scrubbing:** Biogas is pressurized through a column of water where the carbon dioxide and other soluble gasses dissolve in the water while methane passes through. When the water is depressurized, the dissolved gasses are released. Water scrubbing can result in a methane concentration of over 99%.

### *Landfill gas RNG project economics*

Landfill gas RNG projects are primarily influenced by the size of the landfill, how long the waste has been in place and the rate at which new waste is being added to the landfill, if active. According to the EPA, the average landfill will be substantially depleted after 30 years of methane production. Additionally, the waste's biogas productivity is determined by many factors, including the methane generation capacity of the waste itself and the underlying methane generation rate, which is influenced by factors such as moisture content. Biogas streams from landfills often contain pollutants, including nitrogen, which can be expensive to remove compared to other biogas sources. Depending on the biogas stream's quality and required specifications for offtake, RNG upgrading costs can be elevated. From a design perspective, landfill gas collection depends on the methane capture rate (or the ability of wells to extract the methane within a target region) and the collection efficiency (or the ability to target all source areas with collection wells). Lastly, landfills of economic size for RNG production often have established gas capture infrastructure, which can demand a higher royalty or share of the revenue going to the landfill owner.

**Figure 19. Landfill gas economics**

| Example Project Economics | | |
|---|---|---|
| **Landfill Gas** | | |
| Landfill Capacity (mT) | | 10,000,000 |
| Peak RNG (mmbtupd) | | 2,071 |
| Price ($/mmbtu) | $ | 31.00 |
| Capex ($mm) | $ | 27.0 |
| Opex ($mm/yr) | $ | 4.0 |
| EBITDA ($mm/yr) | $ | 53.0 |
| ***IRR (%)*** | | ***56%*** |

*Source: Stifel estimates*

**Figure 20. Landfill gas CI score sensitivity using Stifel's base case**

| | | | CI Score | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IRR | | 70 | 60 | 50 | 40 | 30 | 20 |
| D3 RIN Price ($) | $ | 0.50 | 7.6% | 13.8% | 19.3% | 24.6% | 29.9% | 35.3% |
| D3 RIN Price ($) | $ | 1.00 | 23.4% | 28.8% | 34.1% | 39.6% | 45.1% | 50.7% |
| D3 RIN Price ($) | $ | 1.50 | 38.4% | 43.9% | 49.5% | 55.2% | 61.0% | 66.8% |
| D3 RIN Price ($) | $ | 2.00 | 53.9% | 59.7% | 65.5% | 71.5% | 77.5% | 83.6% |
| D3 RIN Price ($) | $ | 2.50 | 70.2% | 76.2% | 82.3% | 88.4% | 94.7% | 101.0% |
| D3 RIN Price ($) | $ | 3.00 | 87.1% | 93.3% | 99.6% | 106.0% | 112.4% | 118.9% |

*Source: Stifel estimates*

**Figure 21. Landfill gas environmental attribute price sensitivity using Stifel's base case**

| | IRR | LCFS Credit Price ($) | | | | | |
|---|---|---|---|---|---|---|---|
| | | $ 120 | $ 140 | $ 160 | $ 180 | $ 200 | $ 220 |
| D3 RIN Price ($) | $ 0.50 | 14.9% | 17.3% | 19.7% | 22.1% | 24.6% | 27.1% |
| | $ 1.00 | 29.4% | 31.9% | 34.4% | 37.0% | 39.6% | 42.2% |
| | $ 1.50 | 44.3% | 47.0% | 49.7% | 52.4% | 55.2% | 58.0% |
| | $ 2.00 | 60.0% | 62.8% | 65.7% | 68.6% | 71.5% | 74.4% |
| | $ 2.50 | 76.4% | 79.4% | 82.4% | 85.4% | 88.4% | 91.5% |
| | $ 3.00 | 93.5% | 96.6% | 99.7% | 102.8% | 106.0% | 109.2% |

*Source: Stifel estimates*
*Note: Stifel's base case assumes a CI score of 40*

### *RNG from Animal Waste*

Animal manure from dairy, beef, swine, and poultry farms can be processed in anaerobic digesters to produce a raw biogas stream that is 50%-80% methane, 30% to 50% carbon dioxide, and up to 5% other gases. The biogas stream can be upgraded to produce RNG-quality gas by removing other gasses and impurities.

In 2018, manure management operations accounted for 10% of all U.S. methane emissions. In fact, cows are among the most notorious producers of GHG emissions on the planet, producing an estimated ~100 lbs of manure per day. Stored livestock waste also generates a strong odor due to volatile organic acids and hydrogen sulfide. Through anaerobic digestion, volatile organic compounds are reduced to methane and carbon dioxide, and the hydrogen sulfide is captured, resulting in an odorless product. From a health perspective, industry sources estimate that heated anaerobic digesters can destroy more than 90% of disease-causing bacteria that might otherwise enter water systems.

In the U.S., there are only 58 active dairy farm projects out of the over 22,000 potential locations, according to the AgSTAR database. We estimate ~4,800 farms are commercially viable based on ICF's economic thresholds for the low potential scenario (+1,000 cows, +5,000 pigs). By harnessing this harmful waste's energy content, farmers can generate a valuable product rather than incurring a cost for waste disposal.

#### *RNG from animal waste: production process*

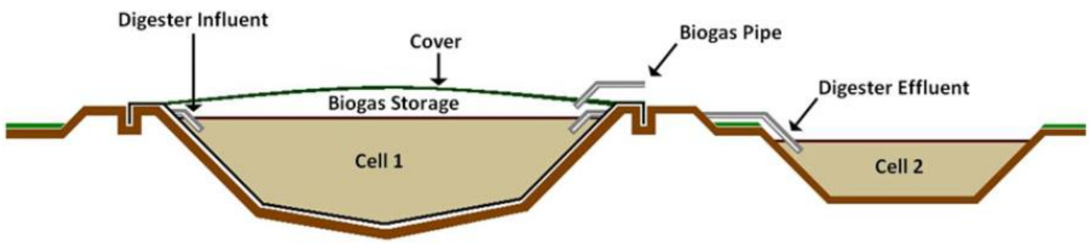
Anaerobic digestion operations vary depending on feedstock and operation-specific factors. **Figure 25** provides an example of the various pathways available for anaerobic digestion. Below are the generalized steps in the process:

1. **Collection & pretreatment:** Manure is collected at the farms, and any co-digestion feedstocks are acquired and stored. The waste must then be separated to ensure no debris can cause damage depending on the digester type. The waste is then pretreated as required based on the digester type and feedstock. Pretreatment generally includes solid waste size reduction to aid digester operation, removal of contaminants, the addition of any chemical additives, and temporary storage to make the waste more homogeneous and prevent large chemical variations in each batch of waste.

2. **Digestion:** The waste is placed in aerobic digestion to be broken down by bacteria to produce biogas. Digester types vary depending on several factors, including waste type, solid content, and rate of feedstock replacement. Digesters are generally classified as "wet" if the feedstock is less than 15% solids or "dry" if the feedstock contains at least 15% solids. Below are the most common animal manure technologies and a brief description of their operating conditions and parameters.

   **Covered Lagoon:** Covered lagoons are ponds of manure lined and covered to enable anaerobic digestion and prevent leaks. The digesters operate at ambient temperatures, creating some variability in digestion as colder temperatures reduce biogas production rates. It is important to note that anaerobic digestion is immaterial below 59°F. Covered lagoons generally have poor bacteria-to-substrate contact, which limits biogas yields. Based on the temperature and feedstock, hydraulic retention times can range from 30 days to 180 days. Covered lagoon digesters are generally low-cost compared to other alternatives, and many farms currently use uncovered aerobic lagoons to manage animal waste. **Figure 22** shows a standard covered lagoon design that uses one primary cell where the waste is maintained at a relatively constant volume and a second cell where the effluent is collected after digestion.

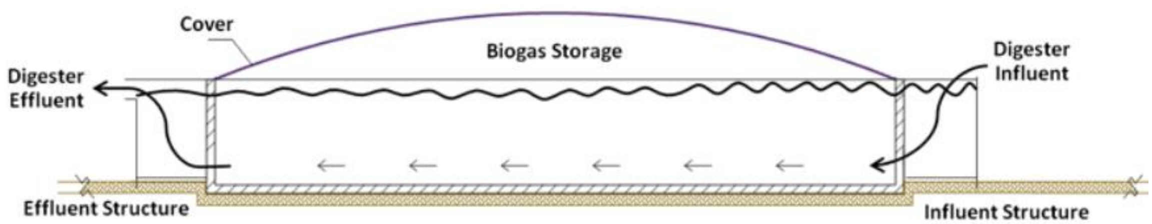
**Figure 22. Covered lagoon anaerobic digester**




*Source: U.S. EPA*

**Plug Flow:** Plug flow digesters generally have feedstocks enter on one end and digestate exit on the other end in a continuous manner. The feedstock generally is not mixed within the digester and moves gradually though the digester over 14 to 30 days. Plug flow digesters tend to have higher solids content (7% to 13%) and require mesophilic temperatures (86°F-100°F). Mesophilic digesters tend to be easier to maintain, have a longer hydraulic retention time, and cannot eliminate pathogens as well as thermophilic (122°F -140°F) digesters. Plug flow digesters may accumulate debris over time which must be cleaned and produces biogas at a moderate rate when compared to other alternatives.

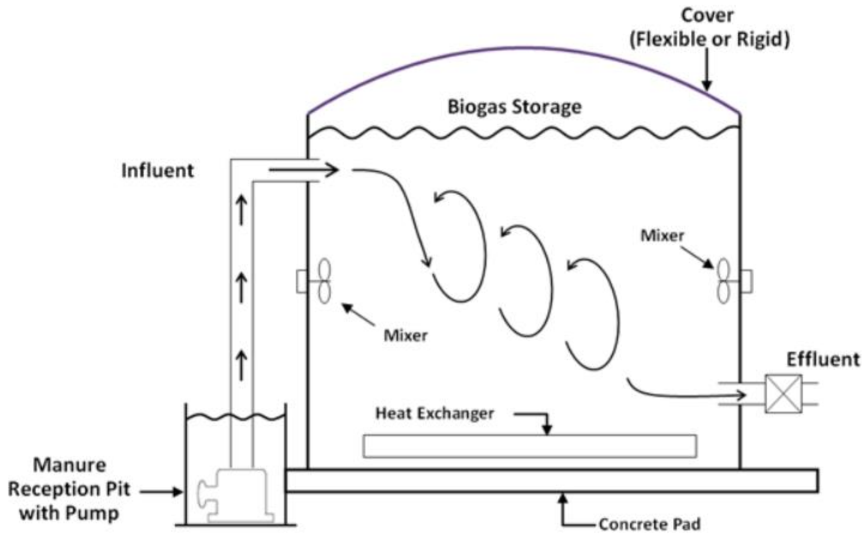
**Figure 23. Plug flow anaerobic digester**




*Source: U.S. EPA*

**Complete Mix and Continuously Stirred Tank Reactors (CSTR):** A CSTR digester is an enclosed, heated tank that includes a mixing system. The mixer can be mechanical, hydraulic, or gas-based. Mixing the waste increases bacteria-to-substrate contact and minimizes solids settling to the bottom of the system. The feedstock used with this digester is typically between 3% and 10% solids and the system can operate at mesophilic or thermophilic temperatures depending on desired yields and hydraulic retention times (HRT). The HRT is generally between 14 and 30 days. It is important to note that most systems continuously add and remove the waste, causing some partially digested material to be removed from the digester prematurely due to mixing.

**Figure 24. Continuously stirred tank reactor**




*Source: U.S. EPA*

**Induced Blanket Reactor (IBR):** IBRs use a blanket of sludge that retains anaerobic bacteria that react with the feedstock as it is gradually forced through the bacteria. The digester typically uses thermophilic temperatures and operates with less than 10% solids. IBRs are classified as high-rate with hydraulic retention times of 3 to 10 days and a high biogas yield.

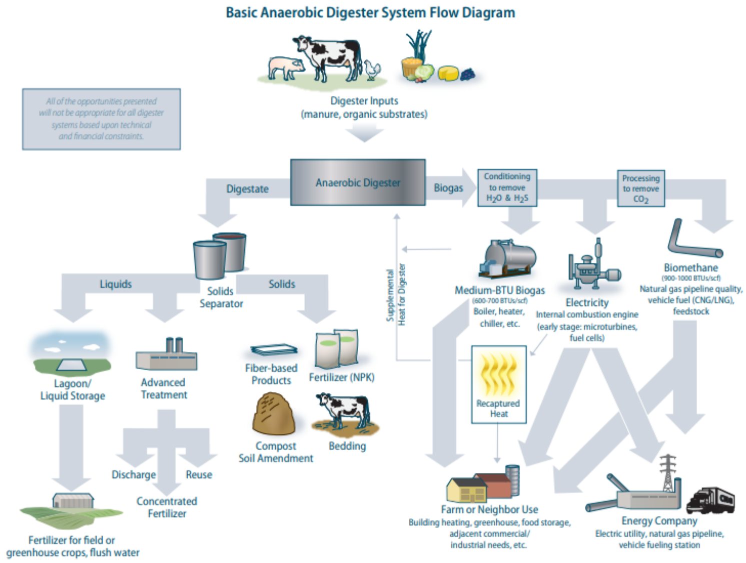
**Dry Digester:** Dry digesters require at least 15% solid content and are often used with poultry litter. The feedstock is placed in a sealed chamber where moisture is monitored and is added as necessary to facilitate digestion. Dry digestion has a retention time of 20 to 40 days and does not require any mixing or stirring over that period. Once biogas production declines to a predetermined level, the digestate is removed and replaced with another batch.

3. **Biogas production:** There are four distinct chemical and biological steps in the production of biogas within any anaerobic digester: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. The waste is first transformed by hydrolytic bacteria that break down complex organic matter into smaller units. Once sufficient molecules exist, acidogenic bacteria begin to transform the hydrolysis byproducts into short-chain volatile fatty acids during the acidogenesis phase. In acetogenesis, short-chain volatile organic acids created in the prior phase are consumed to create acetate, carbon dioxide, and hydrogen. Lastly, methanogenesis is when methanogenic bacteria utilize the acetate, carbon dioxide, and hydrogen to create methane. The methanogenic bacteria are the most sensitive to pH levels and must be carefully managed in a digester.

4. **Biogas upgrading:** To reach RNG quality, the biogas must be upgraded to remove carbon dioxide and other impurities based on the end-user or pipeline injection requirements. In most cases, the gas stream is first pretreated to remove water and hydrogen sulfide. Hydrogen sulfide can be removed through various technologies, including chemical scrubbing and activated carbon filtration. The gas stream is then upgraded through one (or more) methods. According to the EPA, the most common technologies include membranes, pressure swing absorption (PSA), solvent scrubbing, and water scrubbing (for more detail on each technology, please refer to our LFG production process).

5. **Digestate handling:** After the biogas is produced in the digester, the remaining digestate is removed from the digester. The digestate is now virtually odor-free and contains valuable nutrients that can be used as a direct fertilizer, upgraded to create a commercial fertilizer product, or dried for use as animal bedding. Digesters that operate using thermophilic bacteria can produce Class A biosolids that can be applied to land without any EPA restrictions. Alternatively, mesophilic digesters cannot eliminate sufficient pathogens to qualify as Class A biosolids without additional treatment.

**Figure 25. Anaerobic production processes and products**




*Source: U.S. EPA*

### *Dairy RNG project economics*

Dairy RNG projects are primarily influenced by the size of the contributing farm, the cost to upgrade the resulting biogas and the project's carbon intensity score. Smaller farms (less than 1,000 cows) often lack the scale to economically upgrade biogas produced from anaerobic digestion. The "hub and spoke" model of collecting biogas from multiple contributing farms and upgrading at a central facility helps to address the economies of scale. The digester costs can vary significantly based on the digester type; however, more expensive digesters often have higher biogas yields or lower hydraulic retention times that can benefit the project in the long run. Another key factor is the distance from an interconnection with capacity for the RNG volumes. In rural settings, the distance from an interconnect can often prove to be the deciding factor in pursuing RNG production compared to onsite electrical power. Several companies have expressed interest in upgrading or monetizing the digestate solids as fertilizer after biogas production which could add another source of income, depending on the local market. At this time, the solids are generally used at farms for animal bedding or provided to local farmers as a soil additive. Lastly, the project's carbon intensity score is critical to the economics for dairy RNG projects taking advantage of the lucrative LCFS credit market in California. We estimate that revenue from LCFS credits at a dairy with a CI score of -330 would be ~80% of the project's total. For reference, the most negative score to date was -762 at a dairy farm converting biogas to electricity in Arizona.

**Figure 26. Dairy RNG project economics**

| Example Project Economics | | |
|---|---|---|
| **Dairy** | | |
| Project Size (cows) | | 2,200 |
| RNG Production (mmbtupd) | | 84 |
| Price ($/mmbtu) | $ | 110.00 |
| Digestate Sales (Y/N) | | No |
| Capex ($mm) | $ | 7.0 |
| Opex ($mm/yr) | $ | 0.2 |
| EBITDA ($mm/yr) | $ | 3.2 |
| ***IRR (%)*** | | ***35%*** |

*Source: Stifel estimates*

**Figure 27. Dairy RNG CI score sensitivity using Stifel's base case**

| | | CI Score | | | | | |
|---|---|---|---|---|---|---|---|
| | **IRR** | **(100)** | **(200)** | **(300)** | **(400)** | **(500)** | **(600)** |
| **D3 RIN Price ($)** | **$ 0.50** | 16.2% | 23.1% | 29.5% | 35.4% | 41.1% | 46.4% |
| | **$ 1.00** | 18.2% | 24.9% | 31.2% | 37.0% | 42.6% | 47.9% |
| | **$ 1.50** | 20.1% | 26.7% | 32.8% | 38.6% | 44.1% | 49.3% |
| | **$ 2.00** | 22.0% | 28.5% | 34.5% | 40.2% | 45.6% | 50.7% |
| | **$ 2.50** | 23.9% | 30.2% | 36.1% | 41.7% | 47.0% | 52.1% |
| | **$ 3.00** | 25.7% | 31.8% | 37.7% | 43.2% | 48.4% | 53.5% |

*Source: Stifel estimates*

**Figure 28. Dairy RNG environmental attribute price sensitivity using Stifel's base case**

| | | LCFS Credit Price ($) | | | | | |
|---|---|---|---|---|---|---|---|
| | **IRR** | **$ 120** | **$ 140** | **$ 160** | **$ 180** | **$ 200** | **$ 220** |
| **D3 RIN Price ($)** | **$ 0.50** | 20.8% | 23.6% | 26.3% | 28.9% | 31.4% | 33.9% |
| | **$ 1.00** | 22.7% | 25.4% | 28.0% | 30.6% | 33.1% | 35.5% |
| | **$ 1.50** | 24.5% | 27.1% | 29.7% | 32.3% | 34.7% | 37.1% |
| | **$ 2.00** | 26.3% | 28.9% | 31.4% | 33.9% | 36.3% | 38.7% |
| | **$ 2.50** | 28.0% | 30.6% | 33.1% | 35.5% | 37.9% | 40.2% |
| | **$ 3.00** | 29.7% | 32.3% | 34.7% | 37.1% | 39.5% | 41.8% |

*Source: Stifel estimates*
*Note: Stifel's base case assumes a CI score of -332*

### *Chicken litter RNG project economics*

Poultry RNG projects are primarily influenced by the amount of waste being processed at the plant, the cost to upgrade the resulting biogas and the project's carbon intensity score. Few poultry farms have the scale to upgrade biogas produced from anaerobic digestion economically. Chicken litter generally has a high solids content so it can be more economically transported compared to other animal waste feedstocks, expanding the areas that can contribute to a centralized plant and enabling larger-scale operations. Regarding digestion, chicken litter tends to require slightly more attention and costs than other feedstocks due to the tendency to produce excess ammonia, inhibiting biogas production. Chicken litter economics can be significantly influenced by fertilizer sales due to the nutrient content and potential for soil remediation by using the digestate as a fertilizer input. Lastly, the project's carbon intensity score is critical to the economics for poultry RNG projects taking advantage of the lucrative LCFS credit market in California.

### *Swine RNG project economics*

Swine RNG projects are primarily influenced by the number of hogs contributing to the plant, the cost to upgrade the resulting biogas and the project's carbon intensity score. Smaller farms (less than 5,000 finishing spaces) often lack the scale to economically upgrade biogas produced from anaerobic digestion and are similar to dairy manure in the growing number of centralized upgrading operations. The digester costs can vary significantly based on the digester type; however, more expensive digesters often have higher biogas yields or lower hydraulic retention times that can benefit the project in the long run. Another key factor is the distance from an interconnection with capacity for the RNG volumes. In rural settings, the distance from an interconnect can often prove to be the deciding factor in pursuing RNG production compared to onsite electrical power. We currently do not model any material benefit from the sales of digestate solids and note potential upside if the product can be sold into the fertilizer market. Lastly, the project's carbon intensity score is critical to the economics for swine RNG projects taking advantage of the lucrative LCFS credit market in California.

**Figure 29. Swine RNG project economics**

| Example Project Economics | | |
|---|---|---|
| | Swine | |
| Project Size (hogs) | | 454,000 |
| RNG Production (mmbtupd) | | 878 |
| Price ($/mmbtu) | $ | 112.00 |
| Digestate Sales (Y/N) | | No |
| Capex ($mm) | $ | 50.0 |
| Opex ($mm/yr) | $ | 2.1 |
| EBITDA ($mm/yr) | $ | 32.0 |
| ***IRR (%)*** | | ***46%*** |

*Source: Stifel estimates*

**Figure 30. Swine RNG CI score sensitivity using Stifel's base case**

| | | CI Score | | | | | |
|---|---|---|---|---|---|---|---|
| | IRR | (100) | (200) | (300) | (400) | (500) | (600) |
| D3 RIN Price ($) | $ 0.50 | 21.8% | 30.5% | 38.3% | 45.5% | 52.3% | 58.7% |
| | $ 1.00 | 24.3% | 32.7% | 40.3% | 47.4% | 54.1% | 60.4% |
| | $ 1.50 | 26.7% | 34.9% | 42.3% | 49.3% | 55.9% | 62.1% |
| | $ 2.00 | 29.1% | 37.0% | 44.3% | 51.2% | 57.7% | 63.8% |
| | $ 2.50 | 31.4% | 39.1% | 46.3% | 53.0% | 59.4% | 65.5% |
| | $ 3.00 | 33.6% | 41.1% | 48.2% | 54.8% | 61.1% | 67.1% |

*Source: Stifel estimates*

**Figure 31. Swine RNG environmental attribute price sensitivity using Stifel's base case**

| | IRR | LCFS Credit Price ($) $ 120 | $ 140 | $ 160 | $ 180 | $ 200 | $ 220 |
|---|---|---|---|---|---|---|---|
| D3 RIN Price ($) | $ 0.50 | 27.9% | 31.3% | 34.7% | 37.9% | 41.1% | 44.1% |
| | $ 1.00 | 30.2% | 33.6% | 36.8% | 40.0% | 43.1% | 46.1% |
| | $ 1.50 | 32.4% | 35.7% | 38.9% | 42.0% | 45.0% | 48.0% |
| | $ 2.00 | 34.6% | 37.8% | 41.0% | 44.0% | 47.0% | 49.9% |
| | $ 2.50 | 36.7% | 39.9% | 43.0% | 46.0% | 48.9% | 51.7% |
| | $ 3.00 | 38.8% | 41.9% | 44.9% | 47.9% | 50.8% | 53.6% |

*Source: Stifel estimates*
*Note: Stifel's base case assumes a CI score of -338*

### *RNG from Water Resource Recovery Facilities*

Wastewater treatment facilities or water resource recovery facilities (WRRFs) are designed to clean wastewater generated for residences, commercial or industrial facilities for reuse. WRRFs can use anaerobic digestion to treat the sewage sludge byproduct of the treatment process to create a valuable biogas stream. The EPA estimates that every 1 million gallons per day (MGD) of wastewater can generate ~6.5 mmbtu of RNG.

According to the EPA, WRRFs generate 14% of U.S. emissions from waste, 2.3% of U.S. methane emissions and 1.5% of U.S. nitrous oxide emissions. Historically, aerobic digestion of the sludge has been used due to its more effective treatment of large quantities than anaerobic digestion. Anaerobic digestion is a less energy-intensive method to treat waste that can further reduce emissions while generating additional revenue streams in the form of biogas and biosolids.

According to the ICF, there are ~14,500 WRRFs in the U.S., and 45% of the wastewater is being produced at only 142 facilities. There are only 21 active WRRF biogas projects producing RNG with another eight projects under construction according to the Argonne National Laboratory despite 1,250 that currently have installed anaerobic digestion capacity. While anaerobic digestion is standard among WRRFs, most use the resultant biogas for on-site electrical generation. We expect state-level incentives to drive conversions of already existing facilities from electrical power generation to RNG. Additionally, the combination of new incentives and improving techniques can enable RNG from smaller WRRFs.

#### *RNG from water resource recovery facilities: production process*

Wastewater resource recovery facilities that produce RNG follow the same general processes as other anaerobic digestion operations. Below are the generalized steps in the process:

1. **Collection & screening:** Wastewater flows from residences and businesses along with pollutants that are swept up in the flow of water and waste as it makes its way through a sewage system to the WRRF. Once at the plant, the influent typically goes through an initial screening process where a separator removes harmful materials that can clog or damage system components.

2. **Wastewater treatment:** The wastewater is treated in three stages. The primary treatment stage typically uses a settling tank where heavier, nutrient-rich sludge settles to the bottom while oils and fats float to the top. The "primary sludge" that settles out of the wastewater stream is then collected for digestion. The primary sludge has a high organic matter content and is easily digestible. The remaining wastewater progresses to the second stage. Here, biological reactors are used to treat the waste for reuse. After the biological treatment of the wastewater, the stream enters a second settler which produces a "secondary sludge" that can be used for anaerobic digestion. The secondary sludge has a lower biogas yield than the primary sludge due to the prior treatment and separation.

3. **Sludge preparation:** The primary and secondary sludge is combined and can be sieved and disintegrated to attain a target dry solids content depending on the anaerobic digester being used. The resulting sludge is combined with any substrates with the main feedstock and prepared for anaerobic digestion.

4. **Anaerobic digestion:** The sludge is loaded into an aerobic digester where bacteria break it down in order to produce biogas. Digester types vary depending on several factors, including waste chemical composition, solid content, and rate of feedstock replacement. For more detail on the types of digesters and chemical processes, please refer to our animal manure production process.

5. **Biogas upgrading:** To reach RNG quality, the biogas must be upgraded to remove carbon dioxide and other impurities based on the end-user or pipeline injection requirements. In most cases, the gas stream is first pretreated to remove water and hydrogen sulfide. Biogas from sewage sludge typically has elevated levels of siloxanes, leading to deposits in equipment and deteriorating system performance. Both hydrogen sulfide and siloxanes can be removed through various technologies, including chemical scrubbing and activated carbon filtration. The gas stream is then upgraded through one or more methods. According to the EPA, the most common technologies include membranes, pressure swing absorption (PSA), solvent scrubbing, and water scrubbing (for more detail on each technology, please refer to our LFG production process).

6. **Digestate handling:** After the biogas is produced in the digester, the remaining digestate becomes more liquid as some of the solid matter was transformed into biogas. To create a useful product, the digestate is thickened or dried to reduce the water content for use as a direct soil additive or upgraded for fertilizer use. Digesters that operate using thermophilic bacteria can produce Class A biosolids that can be applied to land without any EPA restrictions. Alternatively, mesophilic digesters cannot eliminate sufficient pathogens to qualify as Class A biosolids without additional treatment.

### *Water resource recovery facilities economics*

WRRF RNG projects are primarily influenced by the wastewater flow rate, wastewater content, and current water treatment systems. The wastewater flow rate and methane generating capacity of the wastewater are the key factors in biogas production. Facilities often do not have sufficient scale for RNG production to be economical compared to onsite electrical power generation. Additionally, the water treatment systems currently installed can include anaerobic digesters, which can significantly influence capital costs. Biogas streams from WRRF often contain pollutants, including nitrogen, which can be expensive to remove compared to other biogas sources. Depending on the biogas stream's quality and required specifications for offtake, RNG upgrading costs can be elevated. While we currently do not view the sale of WRRF digestate solids as a material revenue stream, the IEA noted the potential monetization of WRRF digestate solids due to the energy and nutrient content. Lastly, the economics are significantly influenced by any revenue sharing or royalty payments required to the operator of the WRRF, if that is a separate entity.

**Figure 32. WRRF RNG project economics**

| Example Project Economics | | |
|---|---|---|
| **WRRF** | | |
| Facility Size (mmgpd) | | 13 |
| RNG Production (mmbtupd) | | 88 |
| Price ($/mmbtu) | $ | 31.00 |
| Digestate Sales (Y/N) | | No |
| Capex ($mm) | $ | 6.1 |
| Opex ($mm/yr) | $ | 0.1 |
| EBITDA ($mm/yr) | $ | 1.0 |
| ***IRR (%)*** | | ***14%*** |

*Source: Stifel estimates*

**Figure 33. WRRF RNG CI score sensitivity using Stifel's base case**

| | | CI Score | | | | | |
|---|---|---|---|---|---|---|---|
| | **IRR** | **60** | **50** | **40** | **30** | **20** | **10** |
| D3 RIN Price ($) | **$ 0.50** | 5.6% | 6.9% | 8.1% | 9.2% | 10.3% | 11.3% |
| | **$ 1.00** | 9.0% | 10.1% | 11.1% | 12.1% | 13.0% | 14.0% |
| | **$ 1.50** | 11.9% | 12.8% | 13.8% | 14.7% | 15.6% | 16.5% |
| | **$ 2.00** | 14.5% | 15.4% | 16.3% | 17.2% | 18.0% | 18.9% |
| | **$ 2.50** | 17.0% | 17.9% | 18.7% | 19.5% | 20.4% | 21.2% |
| | **$ 3.00** | 19.4% | 20.2% | 21.0% | 21.8% | 22.6% | 23.4% |

*Source: Stifel estimates*

**Figure 34. WRRF RNG environmental attribute price sensitivity using Stifel's base case**

| | | LCFS Credit Price ($) | | | | | |
|---|---|---|---|---|---|---|---|
| | **IRR** | **$ 120** | **$ 140** | **$ 160** | **$ 180** | **$ 200** | **$ 220** |
| D3 RIN Price ($) | **$ 0.50** | 5.8% | 6.3% | 6.8% | 7.3% | 7.7% | 8.2% |
| | **$ 1.00** | 9.1% | 9.5% | 10.0% | 10.4% | 10.8% | 11.2% |
| | **$ 1.50** | 12.0% | 12.4% | 12.7% | 13.1% | 13.5% | 13.9% |
| | **$ 2.00** | 14.6% | 14.9% | 15.3% | 15.7% | 16.0% | 16.4% |
| | **$ 2.50** | 17.0% | 17.4% | 17.7% | 18.1% | 18.4% | 18.8% |
| | **$ 3.00** | 19.4% | 19.7% | 20.1% | 20.4% | 20.8% | 21.1% |

*Source: Stifel estimates*
*Note: Stifel's base case assumes a CI score of 43*

### *RNG from Thermal Gasification*

Thermal gasification is a process that uses high temperatures (700-800°C) in a low oxygen environment to convert solid or liquid-based biomass, primarily forestry products and residual waste, into a mixture of gases consisting of mostly carbon monoxide (CO), hydrogen ($H_20$) and methane ($CH_4$). Collectively this mixture of gases is referred to as synthetic gas (syngas). The syngas then undergoes further processing to produce a near-pure stream of methane, commonly referred to as bio-synthetic or bio-substitute natural gas (bio-SNG), to distinguish it from methane derived from anaerobic digestion.

RNG production from thermal gasification is considered a secondary alternative to anaerobic digestion as biomass gasification technology is at an early commercialization stage. While current gasification plants are built at a pilot scale, the ability to process both dry and wet feedstock means future plants could operate on a larger scale than anaerobic digestion projects due to the greater availability and sustainability of feedstock. Also, technological developments in coming years could overcome issues, such as residual tar, that currently preclude the use of commercialized methanation units.

*Thermal gasification: production process*

The process to produce RNG via thermal gasification can be broken down into four steps:

1. **Pretreatment:** Feedstock is dried and ground into smaller pieces. Pretreatment is not done in all cases and dependent on the feedstock used.

2. **Gasification:** Through the process of pyrolysis, the feedstock is fed into a gasifier, and weaker bonds in the feedstock break down in high temperatures, releasing volatile gases such as tar vapors, methane, and hydrogen. Charcoal is also produced, which undergoes further reactions to gasify. Oxygen and water vapor are introduced to react with the volatile products to form carbon dioxide ($CO_2$) and carbon monoxide (CO). The volatile gases become highly reactive and strip the oxygen from the carbon dioxide and any remaining water to produce hydrogen monoxide and hydrogen. The remaining mixture is syngas, comprised mostly of $CO_2$, CO and $H_2$. During the gasification process, a residual tar is also produced that can foul downstream equipment and effectively exclude commercialized methanation units.

3. **Gas processing:** Like the biogas generated through anaerobic digestion, the syngas must be cooled, and solvents used to filter and purify the syngas by removing pollutants like sulfur, chlorides, and carbon dioxide.

4. **Methanation:** Carbon dioxide is added to the upgraded syngas to produce reactions over catalysts (predominately nickel-based) to increase the speed of chemical reactions. The resulting mixture is approximately 98% methane. The rate at which the end product is produced is on the order of minutes versus days for RNG from anaerobic digestion.

*Thermal gasification: feedstock*

As listed below, thermal gasification can use a variety of sources. Currently, coal and petroleum-based feedstock are typically used over biomass/waste due to lower costs. However, technical feasibility studies have shown the largest physical feedstock potential for RNG production, whether from anaerobic digestion or thermal gasification, comes from thermal gasification of agricultural and forest residue. The feedstocks typically used in thermal gasification are:

- **Agriculture residue:** Represents unusable material leftover in fields, orchards, vineyards, or other crops after harvest.
- **Forestry and forest product residue:** Biomass from logging (bark, stems, leaves, branches), forest and fire management activities (biomass removed to reduce fire danger), and milling (slabs, edgings, trimmings, sawdust).
- **Energy crops:** Crops, such as grasses and trees, which are grown for the specific purpose of producing feedstock for energy production.

- **Municipal solid waste (MSW):** Trash from household, commercial, and industrial consumers that is otherwise landfilled

An added benefit of thermal gasification is the process does not require the feedstock to be kept moist since there is no need to keep the bacteria alive, as is the case in anaerobic digestion. Since maintaining the feedstock's moisture content is not essential, the feedstock can be sourced and transported over greater distances. Therefore, compared to an anaerobic digestion facility, a gasification plant's cost is not as heavily dependent on proximity to local feedstock sources.

*Thermal gasification: byproducts*

The primary byproduct of the thermal gasification process is biochar, a charcoal-like product that is produced from the pyrolysis of biomass. According to a University of Colorado Boulder study, approximately 25-35% of biomass feedstock is converted into biochar during pyrolysis. After exiting the gasifier, biochar can be used in numerous ways: in agriculture (i.e., feed additive, slurry treatment, silage agent, co-fertilizer), land management (soil conditioner, carbon sequestration, soil remediation, fire-hazard reduction), and as a renewable fuel (thermal energy for processes such as cement production). The sale of biochar from thermal gasification plants could provide a secondary revenue stream to improve commercial-scale projects' economics and serve as a negative emission technology that could take advantage of future climate policies (carbon tax).

*Thermal gasification: economics*

RNG is not currently produced commercially, resulting in limited knowledge and data about the economics compared to anaerobic digestion. The first large-scale project, the GoBiGas project (20 MWh) in Sweden, was placed into service in 2013 but subsequently canceled in 2018 due to cheaper RNG sources from anaerobic digestion. The project's cancellation highlights the need for additional technological advancements to lower costs and enable the commercialization of RNG from thermal gasification. Based on our review of thermal gasification cost of supply estimates found in literature, the current cost range is $24.00-$63.00/mmbtu, which is materially higher than cost estimates of $9.00-$42.00/mmbtu for anaerobic digestion. Several companies, such as REN Energy and Red Rock Biofuels, have commercial thermal gasification projects expected to be in-service within the next few years.

## RNG Policy and Regulatory Support

### U.S. Renewable Fuel Standard

The Renewable Fuel Standard (RFS) is a federal U.S. policy created in 2005 that mandates the blending of biofuels with transportation fuels. The EPA designed the RFS to reduce GHG emissions and expand the renewable fuels sector. The Clean Air Act requires the EPA to set the RFS volume requirements annually for different biofuel types for an obligated party (refiner or importer of gasoline/diesel) to meet. An obligated party's requirement, known as Renewable Volume Obligation (RVO), is calculated by multiplying annual percentages set by the EPA by the volume of gasoline or diesel they produce. The EPA tracks compliance with RFS through a tradable credit system known as Renewable Identification Numbers, or RINs. Obligated parties must return a certain amount of RINs, based on their RVO, to the EPA to prove compliance with the annual standard at the end of the compliance year. **Figure 35** provides the annual volume standards that the EPA has finalized for 2010 to 2020.

**Figure 35. RFS Annual Volumes**

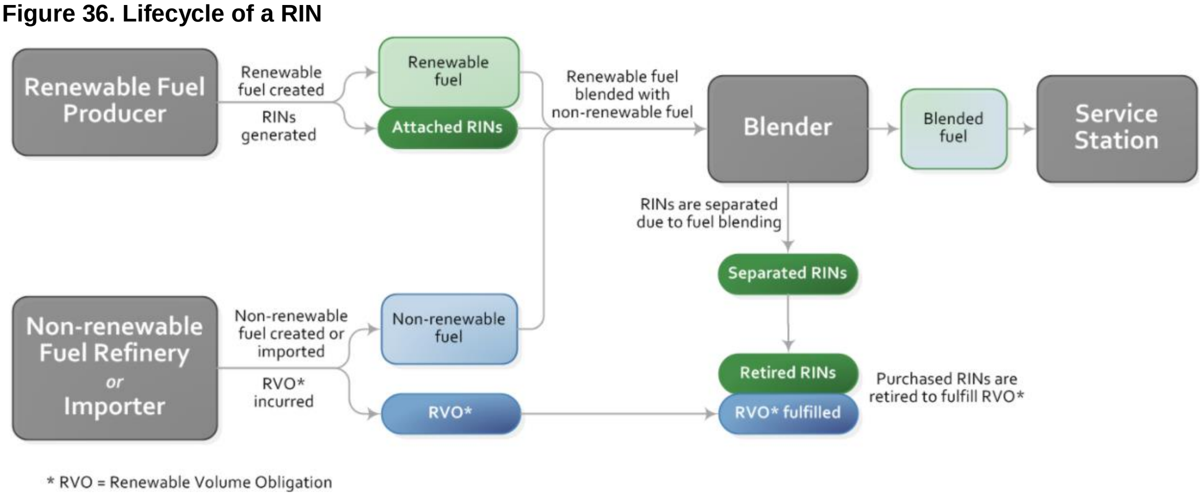
| Biofuel Category | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cellulosic biofuel** | 6.5 | 0 | 0 | 0.8 | 33 | 123 | 230 | 311 | 288 | 418 | 590 |
| **Biomass-based diesel** | 1.15 | 0.8 | 1 | 1.28 | 1.63 | 1.73 | 1.9 | 2 | 2.1 | 2.1 | 2.43 |
| **Advanced biofuel** | 0.95 | 1.35 | 2 | 2.75 | 2.67 | 2.88 | 3.61 | 4.28 | 4.29 | 4.92 | 5.09 |
| **Total renewable fuel** | 12.95 | 13.95 | 15.2 | 16.55 | 16.28 | 16.93 | 18.11 | 19.28 | 19.29 | 19.92 | 20.09 |

*Source: U.S. EPA*

*Renewable Fuel Standard – RIN lifecycle*

RINs represent individual batches of renewable fuel that are blended into gasoline and diesel pools. When renewable fuels are generated, an "Assigned RIN" is created and directly associates with a batch of fuel that travels with the batch of fuel from party to party. Purchasers obtain both the renewable fuel and RIN together. Once the fuel is blended into gasoline or diesel, the RIN is separated from the individual batch, and "Separated RINs" are tradable to settle Renewable Volume Obligations (RVO) with the EPA. RINs last for two years before expiring; however, no more than 20% of the RINs used by an obligated party to meet its RVO can be previous-year RINs

**Figure 36. Lifecycle of a RIN**




*Source: U.S. EPA*

*Renewable Fuel Standard – Types of RINs*

For fuel to qualify as a renewable fuel under the RFS, it must reduce GHG emissions compared to a 2005 petroleum or diesel baseline. The EPA has approved fuel pathways under the RFS program under five categories of renewable fuel. Each fuel type is assigned a "D-Code" that identifies the renewable fuel type based on the feedstock used, fuel type produced, energy inputs and GHG reduction thresholds. We summarize the five categories of renewable fuel in **Figure 37**.

**Figure 37. Renewable Fuel Categories**

| Biofuel Category | D-Code | GHG Lifetime Reduction Requirement | Example Feedstocks |
|---|---|---|---|
| **Renewable Fuels** | D6 | 20% | Ethanol derived from corn starch, or any other qualifying renewable fuel |
| **Advanced Biofuels** | D5 | 50% | Any renewable biomass expect corn starch ethanol |
| **Biomass Advanced Biofuels** | D4 | 50% | Biodiesel and renewable diesel |
| **Cellulosic Biofuels** | D3 | 60% | Renewable fuels produced from cellulose, hemicellulose or lignin |
| **Cellulosic Diesel** | D7 | 60% | Crop/tree residue |

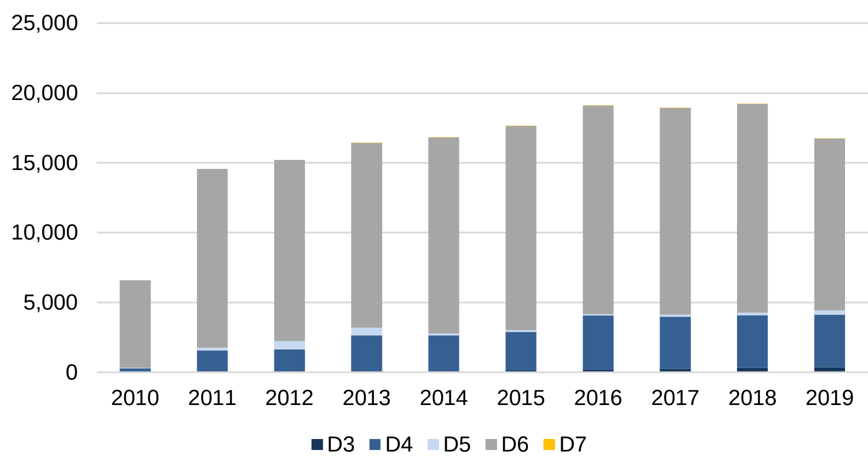
*Source: EPA (GHG lifetime reduction requirements are in relation to 2005 petroleum/diesel baselines)*

One RIN is equal to one gallon of fuel ethanol. Other types of renewable fuels carry higher values based on their energy equivalence relative to ethanol. For example, one mmbtu of RNG has the same energy content as 11.727 gallons of ethanol and therefore receives 11.727 RINs under the RFS program.

The four RIN requirements are "nested," meaning fuel with a higher GHG reduction threshold can be used to meet the standards for a lower GHG reduction threshold (i.e., D3 count against compliance for D4, D5 and D6; D4 against D5 and D6; and D5 against D6). As shown in **Figure 38**, RINs for the biofuel categories with higher GHG savings have historically been more valuable due to having the most flexibility for compliance to retire several mandate categories.

For cellulosic fuels, sufficient amounts to satisfy the Clean Air Act's volume levels have not yet been produced (**Figure 39**). The law allows the EPA to reduce the required volume of cellulosic biofuel by offering obligated parties cellulosic waiver credits (CWCs). The CWCs can be purchased at prices set by the EPA using established methodology under the statute. Unlike RINs, CWCs cannot be traded or banked for future use and must meet the cellulosic biofuel standard for the year they are offered.

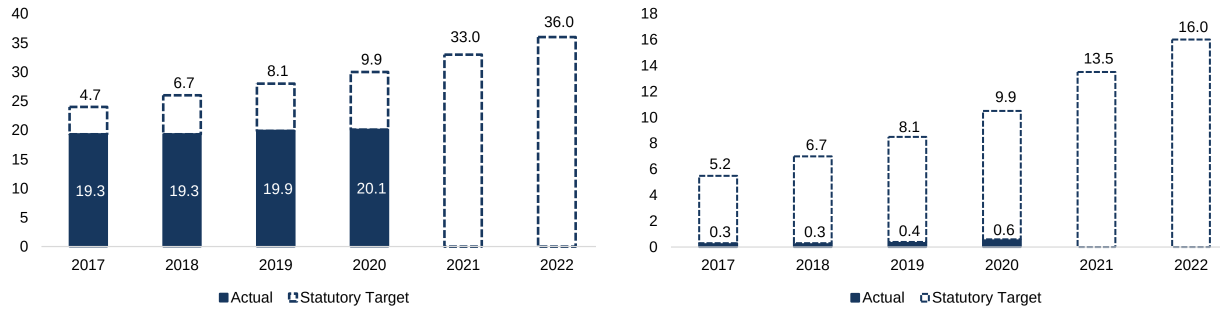
**Figure 38. Total RINs retired for annual compliance by RIN year (in millions)**




*Source: U.S. EPA (2020 data is incomplete)*

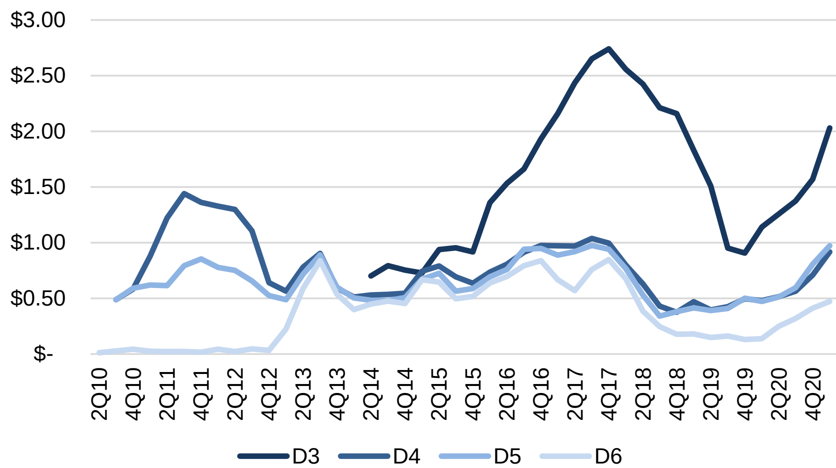
**Figure 39. RFS Statutory target and actual production (in billions of gallons)**

*Total Renewable Fuel* *Cellulosic Biofuel (D3 RIN)*




*Source: U.S. EPA*

**Figure 40. Quarterly D3, D4, D5 and D6 RIN Prices**




*Source: U.S. EPA*

*Renewable Fuel Standard – Recent developments*

The RFS was developed with a method for small refiners with no more than 75,000 barrels per day of crude inputs to obtain temporary small refiner exemptions (SREs) from the EPA if they could demonstrate both an existing exemption and a disproportionate economic hardship created by RIN purchases. Under the Trump administration's EPA, these SREs were granted in greater numbers than in previous years, including a blanket waiver in 2019 (for the compliance year 2018) for 31 refiners, which caused a decline in RIN prices as shown above (**Figure 40**). Various biofuel groups litigated these waivers, and in January 2020, the 10th Circuit Court of Appeals ruled the EPA exceeded its authority by granting exemptions to three refineries that had not received an exemption for all prior years of the RFS program. On February 22, 2021, the EPA announced its agreement with the 10th Circuit's interpretation that only refiners with existing exemptions are eligible for SREs. As of December 2020, Biofuel groups requested 1.43 billion gallons of ethanol be added back to the 2021 volume requirements due to improperly approved exemptions in 2019 (blanket waiver). The EPA has not released updated blending requirements for 2021 as of the date of this report, but the Biden administration has come out against waivers.

The statutory volumes under the RFS are set to expire at the end of 2022, giving the EPA unilateral authority to set biofuel blending requirements post-2022 unless new statutory volumes are established through the legislative process. Some members of Congress have voiced support for the replacement of the RFS with a national LCFS program (similar to California's) that provides incentives for a wider-range of low-carbon fuels (e.g., hydrogen, electricity, biofuels, etc.). While there appears to be bipartisan support for the continuation of the RFS in some form, we believe a failure to create new statutory volumes after 2022 will introduce uncertainty into RIN markets.

Specifically, RVOs would be subject to the administration that occupies the White House, making it more challenging to underwrite RNG projects that take multiple years to construct.

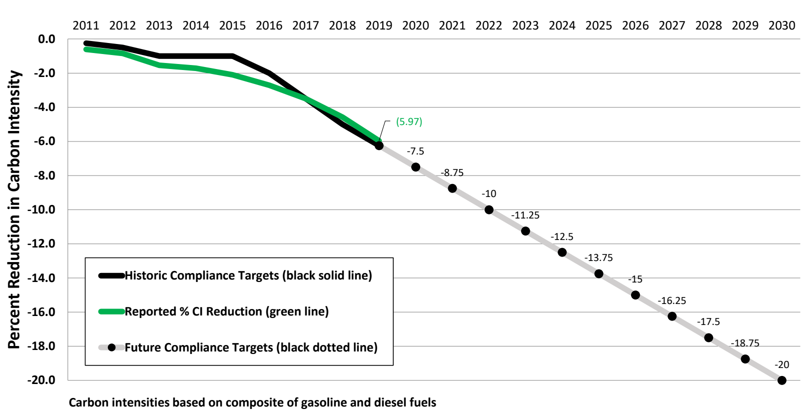
### *California Low Carbon Fuel Standard*

The Low Carbon Fuel Standard is a carbon pricing scheme passed in 2006 and administered by the California Air Resources Board (CARB) to decrease the carbon intensity of California's transportation sector, which is responsible for 50% of GHG emissions, 80% of ozone-forming gas emissions, and 95% of diesel particulate matter in California. The LCFS requires producers, importers, or wholesalers of petroleum-based fuels to reduce their products' carbon intensity over time. The program targets a 10% total reduction in 2020 and a 20% reduction in 2030 from 1990 levels, with annual CI benchmarks established for each year to 2030. The compliance curve was "back-loaded" to allow for the development of low-CI fuels and advanced vehicles.

Each fuel source has a CI assigned to it that considers GHG emissions over the complete lifecycle (i.e., production, transportation, and consumption) of a fuel. The CI is expressed in grams of carbon dioxide equivalent per megajoule of energy ($gCO_2e/MJ$). Each LCFS credit represents one metric ton of carbon dioxide reduced. The credits awarded to each pathway are based on the difference between the pathway's CI score and CARB annual CI benchmark, divided by the fuel's Energy Economic Ratio. Fuels with a CI score above the annual benchmark generate deficits while those below generate credits proportional to how low the fuel's CI is. A deficit generator's annual compliance obligation is met when it has retired a number of credits--which can be purchased--equal to its deficits. Credits do not expire and can be held by producers that overproduced renewable fuels for use in future years when annual compliance targets become more aggressive. The LCFS includes a Credit Clearance Market (CCM) that provides a maximum credit price of $217.97/credit in 2020 (adjusted for inflation annually) for regulated parties to purchase credits as a last resort. The CCM has not been needed since 2016, with LCFS credits trading near the annual maximum for the previous two years.

RNG from livestock waste has been awarded a temporary CI score of -150 $gCO_2e/MJ$. However, livestock waste RNG projects have received approved modeled CI scores -532.74 $gCO_2e/MJ$. A negative score indicates that a pathway is a net emission detractor while a positive score indicates that a pathway is a net emission generator. Additionally, there are two other ways to generate credits in the LCFS, project-based crediting and capacity-based crediting. Through project-based crediting, projects that reduce emissions at regulated entities, such carbon capture and sequestration (CCS), may qualify for LCFS credits. CARB evaluates the lifecycle emissions reduction of the project and issues the credits when the reported reductions are verified. Finally, under capacity-based crediting, created in a 2018 LCFS amendment, credits are awarded for deploying zero-emission vehicle infrastructure capacity. Hydrogen stations or EV fast-charging sites receive credits based on the station's capacity minus the actual fuel dispensed.

**Figure 41. Performance of the LCFS from 2011 to 2019**




*Source: California Air Resources Board*

### *Other State-Level Programs*

California was the first mover in providing incentives for RNG producers; however, more states have since added low-carbon standards to incentivize the reduction of GHGs from the transportation sector.

*Oregon*

Alongside California, Oregon has emerged as a leader and maintains a program very similar to California's LCFS. Oregon's Clean Fuels Program, which started in 2016, aims to reduce pollution from transportation fuels by 25% compared to 2015 levels by 2030. The program, which is currently being formalized and expected to take effect in 2022, calculates carbon intensity for each fuel type and requires producers or sellers to purchase offsets based on how far above/below each is to an annual benchmark. Furthermore, in March 2020, Oregon's governor signed an executive order directing state agencies to reduce and regulate GHG emissions to achieve 45% below 1990 levels by 2035 and 80% below 1990 levels by 2050. As part of the high-level implementation plan produced by the Oregon Department of Energy, the state highlighted previous efforts to increase RNG generation to displace fossil fuels and reduce emissions

In June 2019, Oregon passed SB 98 that sets voluntary RNG goals for the state's natural gas utilities, creating a path for RNG to become an increasing part of Oregon's energy supply by authorizing expenditures on new RNG projects and infrastructure. Large natural gas utilities, who worked with legislatures to get the bill passed, that participate in RNG programs may make qualified investments and procure RNG from third parties to meet a specified portfolio of targets for the percentage of RNG purchased by the utility for distribution to retail natural gas customers in Oregon that is RNG. The portfolio allows 5% RNG for calendar years 2020 through 2024, increasing to 10% in 2025-2029, 15% in 2030-2034, 20% in 2035-2039, 25% in 2040-2044, and 30% in 2045-2050.

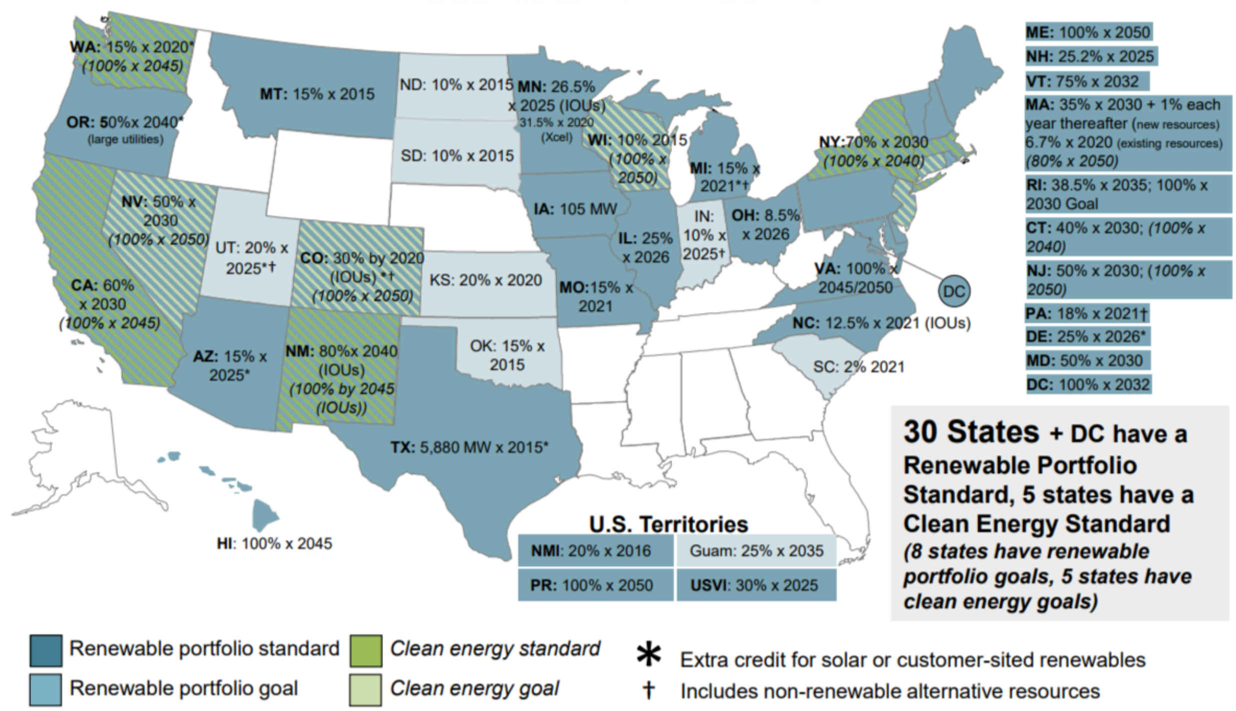
*Other States*

Also on the West Coast, Washington State passed legislation to develop a carbon pricing scheme that has been partially upheld by the state supreme court only to apply to direct emitters. The exact details of the scheme are still being decided. Of note, the Regional Greenhouse Gas Initiative ("RGGI") was established in 2005 and operates as a regional cap-and-trade program for power plants. Power plants over 25 MW are required to comply with the cap and purchase offsets. Avoided agricultural methane through RNG production and landfill methane capture are qualifying offsets that provide carbon allowances based on avoided emissions. Members of the RGGI include Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Virginia, and Vermont.

### *RNG for Power Generation*

U.S. renewable electricity markets are classified as mandatory markets, those required to buy renewable due to legislative or regulatory decisions, or voluntary markets, driven by consumer preference for renewable electricity. Renewable portfolio standards (RPS) are state-level programs that set mandatory or voluntary targets for a minimum amount of renewable energy in their electricity supply to support the growth of renewable energy markets (**Figure 42**). According to Bloomberg's analysis of mandatory state RPS programs, current state laws demand 18% renewable U.S. power by 2030.

**Figure 42. Renewable & Clean Energy Standards (September 2020)**

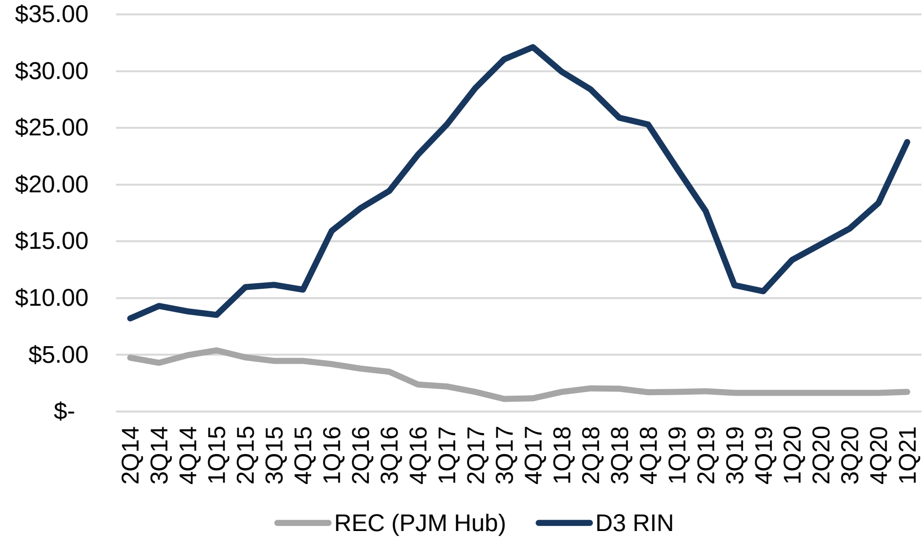



*Source: NC State University*

Utilities purchase renewable energy certificates (RECs), a market-based instrument issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable source, from renewable energy producers to prove compliance under mandates. Utilities may also generate their own RECs by generating and delivering renewable electricity themselves. RECs are also available in voluntary markets as utilities want to publicly disclose their use of renewables; however, the voluntary market is separate from and incremental to the mandatory market to avoid double claims on the same megawatt-hour. RECs are the accepted legal instrument through which renewable energy generation and usage claims are substantiated in U.S. markets, and are supported by various state governments, utility commissions, trade organizations and U.S. case law. It should be noted that RPS programs and prices vary from state to state; however, in general, RECs that supply mandatory markets tend to hover just below the cost of non-compliance with a given RPS state program.

While RNG is classified as a renewable energy electricity source, RPS programs were primarily designed to support the development of the solar and wind industries. Due to increasing renewable electricity supply from solar and wind, RECs under RPS programs have historically traded at a significant discount to D3 RIN prices under the RFS (**Figure 43**). The premium received for RINs explains why most of the RNG is consumed by the transportation sector. Assuming no change in the pricing dynamics between RECs and RINs and the continued proliferation of solar and wind capacity, we do not foresee RNG playing a significant role in the generation of renewable electricity.

**Figure 43. Historical REC vs. RNG D3 RIN Prices ($/mmbtu)**




*Source: U.S. EPA, Bloomberg*

***RNG Voluntary Programs***

There has been an increase in the number of natural gas utilities offering voluntary opt-in programs for customers to procure RNG at a premium. As RNG is more expensive than geologic natural gas, legislative or regulatory approval is required for utilities to invest in RNG gas supply. Vermont Gas was the first to offer such a program beginning in 2018. In 2019, Oregon signed SB 98 into law that sets voluntary RNG targets for the state's regulated utilities. As of September 2020, 15 natural gas utilities had active or under-development voluntary RNG programs for residential, commercial, and industrial customers. The American Gas Association's RNG Activity Tracker provides an up-to-date listing of utility RNG programs, regulatory actions, and state government proposals.

In December 2020, SoCalGas and SDG&A received approval in California for a three-year, voluntary RNG tariff pilot program for residential, small commercial, and industrial customers. This voluntary program offers insight into how future voluntary RNG tariffs are likely to be structured, which we break down in the sections below. Fees from these programs are one method gas utilities use to increase RNG percentages in their gas supply to gain scale and lower costs.

*RNG voluntary programs: subscription structure example*

Residential customers are required to commit to one year of participation with an election of a fixed dollar amount (e.g., $10, $25, or $50 per month) to purchase RNG. Non-residential customers are required to commit to two years of participation with an election to either a fixed dollar amount (e.g., $10, $25, $50 per month) or a fixed purchase percentage (e.g., 25%, 50%, 75% or 100%) that the customer selects to be renewable.

*RNG voluntary programs: bill calculation example*

A residential customer, or non-residential customer that selects a Monthly Purchase Option, would have their RNG Monthly Purchase Amount divided by the current RNG rate to calculate their RNG therm usage. The RNG therm usage would be multiplied by the current RNG rate, with the remaining therm usage multiplied by the traditional natural gas rate. The RNG rate the customer is charged is net of the benefit of RIN and LCFS credits.

A non-residential customer that selects the RNG Purchase Percentage option would have their total therm usage multiplied by the customer's RNG Purchase Percentage. Monthly charges would then be calculated by multiplying the RNG usage therms by the current RNG rate, with the remaining therm usage by the traditional natural gas rate.

*RNG voluntary programs: RNG rates example*

SoCalGas and SDG&A provided an illustrative example of rate in documentation filed with the Public Utility Commission of California. Specifically, the example includes an RNG Commodity Charge of $1.51/therm or four times higher than the non-RNG Commodity Charge of $0.36/therm. Customers would also be charged a Program Charge for the marketing and administrative costs associated with the program. The Program Charge was estimated to be $0.23/therm for SoCalGas customers and $1.42/therm for SDG&E customers.

***Canadian RNG Policies and Regulations***

*Canada Clean Fuel Standard*

The Clean Fuel Standard (CFS) is a federal proposed policy that would require fossil fuel primary suppliers, including producers and importers to reduce the carbon intensity of the liquid fossil fuels they produce and import into Canada from 2016 carbon intensity (CI) levels by 2.4 grams of carbon dioxide equivalent per megajoule ($gCO_2e/MJ$) in 2022, increasing to 12 $gCO_2e/MJ$ in 2030. The CFS takes a performance-based approach to reduce greenhouse gas emissions. The program is designed to incentivize innovation and adoption of clean technologies while giving fuel suppliers to meet requirements in a cost-effective way that works for their businesses. It also creates an incentive for industries to innovate and adopt cleaner technologies to lower their compliance costs. Under the program, compliance credits can be created in three ways, including by undertaking projects that reduce the lifecycle carbon intensity of fossil fuels, such as carbon capture and storage (CCS) or renewable electricity; supplying low carbon fuels, such as ethanol and biodiesel; or supporting the switch from fossil fuels to lower carbon fuels or energy, such as electricity or hydrogen in vehicles. According to Advanced Biofuels Canada, the proposal's biofuel sustainability criteria align with the U.S. Renewable Fuel Standard requirements.

*British Columbia Low Carbon Fuel Standard*

Similar to the California LCFS, British Columbia enacted a province-level carbon pricing scheme in 2008. The B.C. Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act and the B.C. Renewable and Low Carbon Fuel Requirements Regulation are together referred to as the B.C. Low Carbon Fuel Standard (BCLCFS). Under the Regulation, fuel suppliers must progressively decrease their fuel's average carbon intensity to achieve a 10% reduction in 2020, and the Government has proposed requiring a 20% reduction in 2030. The carbon intensity of fuel represents the greenhouse gas emissions associated with its production and use as determined by a lifecycle assessment, presented in terms of grams of carbon dioxide equivalent per megajoule ($gCO_2e/MJ$) of the produced fuel. A lifecycle assessment considers the emissions associated with each stage of a fuel product's life and all materials and energy used from feedstock production or acquisition through fuel use. The number of low carbon fuel credits that can be obtained from the fuel is directly proportional to the difference in carbon intensity (CI) between the fuel class limit (81.09 $gCO_2e/MJ$ for gasoline and 87.18 $gCO_2e/MJ$ for diesel in 2019) and the low carbon fuel. Low carbon fuel credits are used to cancel debits from obligated parties and are traded within the credit market.

*CleanBC*

In March 2017, the province of B.C. released its study "Resource Supply Potential for Renewable Natural Gas in British Columbia." This study, a collaboration of government and the two gas utilities, determined that the achievable short-term RNG production potential was estimated to be 4.4 petajoules per year (PJ/yr), of which more than 30% would come from landfills upgrading biogas to RNG. Later that spring, the province amended the Greenhouse Gas Reduction Regulation to include a renewable portfolio allowance of up to five percent RNG on the natural gas system. In December 2018, the government released its CleanBC plan to reduce climate pollution while creating more jobs and economic opportunities for people, businesses and communities. The plan was developed as a pathway to achieve the Province's legislated climate targets of reducing greenhouse gas emissions by 40% by the year 2030. Under CleanBC, renewable fuels, such as RNG, would contribute to meeting its targets in many sectors of the economy, including 1) increasing the low carbon fuel standard to 20% by 2030 and increasing the production of renewable transportation fuels; 2) supporting the production of 650 million liters of renewable fuels per year for the transportation sector, and 3) making residential and industrial natural gas consumption cleaner by putting in place a minimum requirement of 15% to come from renewable gas. Of note, beyond the province's initiatives, Canada's natural gas utilities have set a target of 5% RNG in the pipeline distribution system by 2025 and 10% by 2030. By 2030, increased RNG content to meet these targets is projected to result in 14 megatons of GHG reductions per year.

## RNG Operators

***Aemetis, Inc. (Buy, AMTX, $12.16): Renewable diesel and RNG dairy producer***

Aemetis was founded in 2006 and owns and operates a 60 million gallon per year capacity ethanol and animal feed production facility in Keyes, California, and a 50 million gallon per year capacity renewable chemical and advanced fuel production facility on the East Coast of India producing high quality, distilled biodiesel and refined glycerin for customers in Europe and Asia. During 2017, management began formulating its development plans to capitalize on the business opportunity resulting from Senate Bill 1383. Following CalGren's (CA ethanol peer) effective RNG launch with 15 dairies near their Fresno ethanol plant and Aemetis' successful marketing campaign with local dairies near its Keyes ethanol plant, the company signed exclusive participation agreements with a dozen dairies in 2018 with two of the dairies completing 20-year biogas supply agreements.

Since management's initial launch into RNG, the Aemetis Biogas team has completed the first phase of its dairy digester cluster project, including the commissioning of a four-mile Aemetis-owned pipeline and two dairy digesters. The biogas team is actively working on the second phase of the growth plan to build 15 additional dairy digesters under 25-year contracts, a centralized gas clean-up unit, and about 26 more miles of pipeline in the Aemetis dairy digester cluster, which is expected to be fully completed within approximately 18 months. In 2021, Aemetis will inject dairy renewable natural gas into the common carrier pipeline and utilize an on-site renewable compressed natural gas fueling station. Beyond the second phase, management is targeting another approximate 37 dairies by 2025 and sees a path to a total of 100 dairies.

We estimate the company's average dairy RNG project generates an approximate 47% IRR at strip prices assuming LCFS credit generation based on a 2,200 wet cow equivalent farm, a central upgrading facility, and Aemetis' operating and capital cost structure. We assume the average project produces 84 mmbtupd of RNG with an average CI score of -416. At this time, Aemetis does not market the solids post anaerobic digestion.

**Figure 44. Aemetis RNG operations**


*Source: Company presentations*

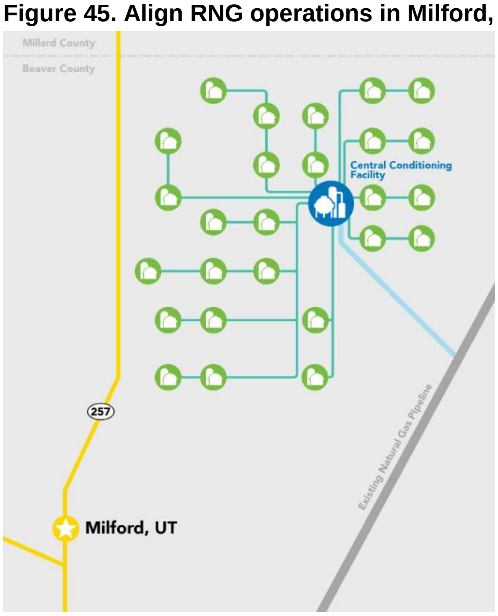
### *Align Renewable Natural Gas (NC): Dominion Energy and Smithfield Foods JV*

In 2018, Dominion Energy and Smithfield Foods, Inc. joined forces to form a joint venture called Align Renewable Natural Gas for the shared goal of capturing methane emissions from hog farms and converting them into clean renewable energy to power homes and businesses. In 2019, the joint venture partners doubled their 10-year investment commitment from $250 million to $500 million to allow Align to expand its initial projects in North Carolina, Virginia, and Utah and to pursue new projects across the country in Arizona and California. With the additional investment, Align expects to become the largest RNG producer in the U.S. and produce enough RNG to power more than 70,000 homes and businesses by 2029.

On December 9, 2020, Align announced it had completed its first RNG project in Milford, Utah. The project consists of a network of 26 family farms that raise hogs under contract with Smithfield and is the first large-scale effort in the state to capture methane from hog farming operations. At full capacity, the project is expected produce approximately 650 mmbtupd of RNG or enough biomethane to heat more than 3,000 homes and businesses and reduce annual emissions from participating farms by more than 100,000 metric tons. Looking forward, Align expects to complete 12 to 16 RNG projects over the next decade with Sampson and Duplin Counties, North Carolina (a network of 19 farms, 2H21) and Waverly, Virginia (a network of 20 farms, 2H22) being the next projects slated for completion. A typical RNG project consists of a cluster of 15 to 20 farms, where methane is captured from covered manure lagoons or digesters and then transported by a low-pressure biogas transmission line to a central conditioning facility. Once the gas is processed, it is then delivered to end-users through existing underground pipelines.

We estimate the company's average swine RNG project can generate an approximate 48% IRR at strip prices assuming LCFS credit generation based on a 454,000-hog project and average industry operating and capital cost assumptions. We assume the project is capable of producing 878 mmbtupd of RNG with an average CI score of -338. At this time, we do not model any value for solids post anaerobic digestion; however, the company noted potential for creating pelletized fertilizer using the digestate.

**Figure 45. Align RNG operations in Milford, Utah**




*Source: Company website*

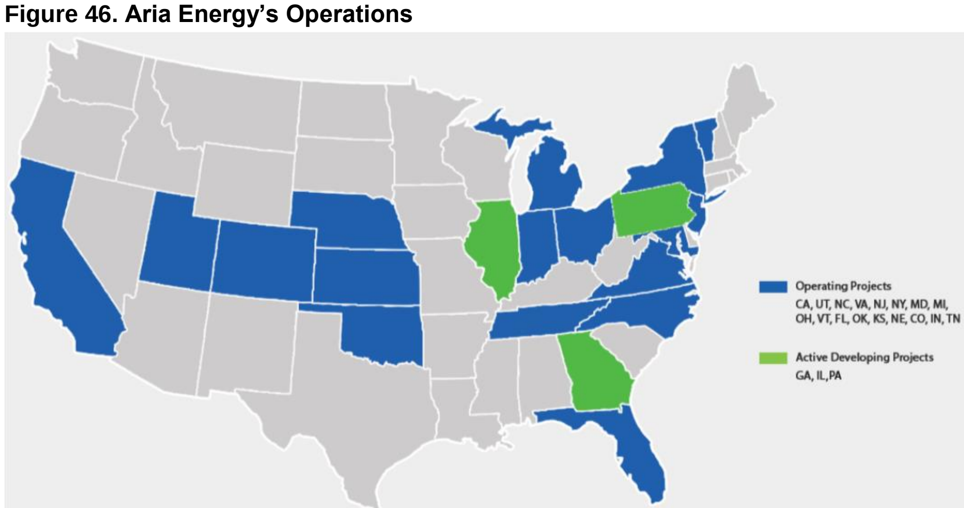
### *Aria Energy (NC): One of the largest companies in the North American LFG sector*

Aria Energy provides engineering, design, construction, operations and maintenance services for LFG to energy facilities. The company is one of the largest in the North American LFG sector, owning and/or operating a portfolio of 41 LFG recovery and processing projects across 17 states, or 207 MW of electricity capacity and 24,880 mmbtupd of renewable natural gas. The company's 41-project portfolio consists of 26 owned projects that generate electricity, 10 owned projects that produced produce RNG and 5 projects owned by third parties where Aria provides O&M services. The company sees attractive growth potential in the LFG sector as LFG projects are baseload power generation resources that can operate 24 hours a day, providing a reliable and continuous source of renewable power. Because of this, 1 MW of installed capacity at an LFG project generates 2-4 times as many MWh of electricity, renewable energy credits (RECs) and production tax credits (PTCs) as 1 MW at a wind or solar facility.

In December 2020, Aria Energy announced an expansion of its owned and operated landfill-gas-to-energy ("LFGTE") project at the Republic Services' County Line Landfill in Argos, Indiana. Once the expansion is complete, the LFGTE project is expected to power 4,800 area homes annually and prevents carbon emissions equivalent to more than 43 million gallons of gasoline per year. The project highlights the increasing number of waste disposal companies that are setting sustainability goals and targeting an increasing LFG for reuse. This follows the previously announced partnership with Republic Services and BP on a new LFG RNG project in Memphis Tennessee, with an expected production capacity of 4,000 mmbtupd.

We estimate an average landfill RNG project generates an approximate 59% IRR at strip prices assuming LCFS credit generation based on a peak RNG production rate of 2,100 mmbtupd and **average** industry operating and capital costs. We assumed an average CI score of 40 and an NRI of 80%.

**Figure 46. Aria Energy's Operations**




*Source: Company website*

***Amp Americas (NC): Operators of the first dairy biogas-to-transportation fuel project in U.S.***

Amp Americas was formed in 2010 as a renewable energy company and has been a pioneer in renewable transportation fuel since 2011. The company partnered with Fair Oaks Farms in Indiana to build the first on-farm dairy gas-to-vehicle fuel upgrade project in in 2011, and concurrently, worked with Fair Oaks and Ruan to convert a fleet of 42 semi-tractors to run on renewable compressed natural gas, making it one of the largest fleets of Class 8 natural gas trucks in the country at the time. In addition to being the first dairy biogas-to-transportation fuel project in the country, the company's project at Fair Oaks Farms was the first dairy RNG project certified by the EPA under the Renewable Fuel Standard and with CARB under its Low Carbon Fuel Standard program.

The company currently operates under three business units, comprised of Amp Americas Development (develops, owns, and operates dairy digester and biogas upgrade projects), Amp Americas Services (operates, maintains, and manages performance of biogas upgrade projects developed by Amp and others), and Amp Americas RNG Marketing (provides environmental attribute and gas marketing services for biogas operations). Amp has brought online 4 dairy RNG projects on 12 dairies processing waste from more than 66,000 cows. Amp has delivered more than 650,000 mT of $CO_2e$ reductions since inception, and its developed projects will reduce 400,000 mT each year going forward. Looking forward, the company is targeting dozens of additional dairy RNG projects with 15 projects in various stages of development accounting for approximately $300 million of potential investment.

We estimate the company's average dairy RNG project design can generate an approximate 52% IRR at strip prices assuming LCFS credit generation based on an 11,500 wet cow equivalent project and average industry operating and capital cost assumptions. We assume a project of this size produces 437 mmbtupd of RNG with an average CI score of -330. At this time, Amp Americas does not market the solids post anaerobic digestion.

**Figure 47. Amp Americas operations in Jasper, Indiana**


*Source: Company website*

**_Brightmark (NC): Global waste solutions focused on RNG and plastics renewal_**

Founded in 2016, Brightmark's mission is to build a world without waste. Brightmark's first biogas project was the 1.5 megawatt Sumter project in Sumter, SC, which uses biogas generated by Pilgrim Pride's poultry processing facility to produce hot water and enough electricity to power 500 to 700 households. Following the Sumter project, the company pursued three large-scale dairy RNG projects, which are all operational at this time. On October 7, 2020, Brightmark LLC and Chevron U.S.A. announced the formation of a joint venture, Brightmark RNG Holdings LLC, to own projects across the U.S. to produce and market RNG.

By 2024, the company aspires to offset 22 million metric tons of $CO_2$ with RNG projects and divert 8.4 million metric tons of plastic from landfills. Through Brightmark RNG Holdings, management and Chevron have partnered for an additional nine dairy RNG projects across six states. Of note, the Castor project in Western Michigan is the largest project Brightmark has announced to date. The project is expected to produce 328,500 mmbtu per year once it's operational in early 2022.

We estimate the company's average dairy RNG project can generate an approximate 46% IRR at strip prices assuming LCFS credit generation based on feedstock from 23,700 wet cow equivalents and average industry operating and capital costs. We assume the project will produce approximately 900 mmbtupd of RNG with an average CI score of -332. At this time, we do not model sales of the solids post anaerobic digestion.

**Figure 48. Brightmark's Castor RNG project in Western Michigan**


*Source: Company website*

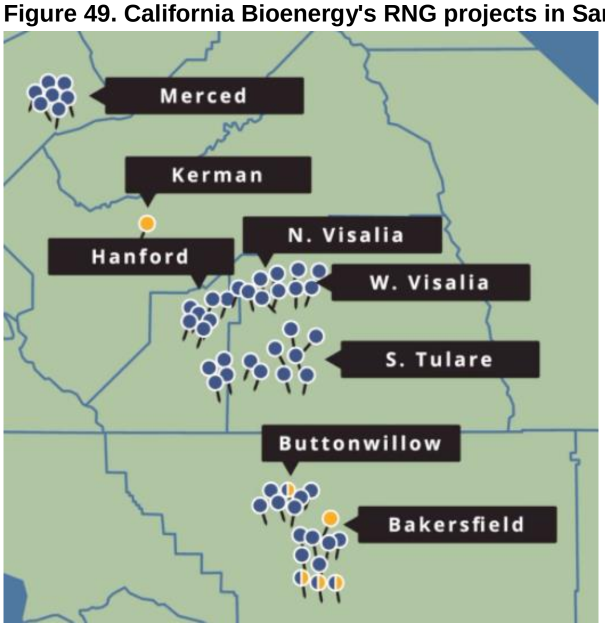
## *California Bioenergy (NC): A leading dairy RNG producer with Chevron and Bloom Energy partnerships*

Founded in 2006, California Bioenergy (CalBio) has worked closely with the dairy industry and state agencies to develop programs to help the state achieve its methane reduction goals while delivering a new revenue source to California dairies. CalBio's first biogas project was the 600-kilowatt facility located outside of Bakersfield at the Bidart-Stockdale Dairy. The project was also one of the first in the state to utilize a double-lined covered lagoon digester and is currently being upgraded to accommodate a Bloom fuel cell generator. In 2019, CalBio and Chevron announced a joint investment in a holding company, CalBioGas LLC, to produce and market dairy RNG as a vehicle fuel in the state. Through this holding company, CalBio secured funding from Chevron to build infrastructure for dairy RNG projects in California's San Joaquin Valley, adding to the investment from dozens of dairy farmers. Late in 2019, CalBio announced a collaboration with Bloom Energy to deploy a commercial solution for the conversion of dairy waste into renewable electricity without combustion.

At present, CalBio has over 60 dairy digester projects operational or in development. When completed, the company's network of dairy biogas projects will be the largest system of its kind in the world. CalBio estimates that its current projects and the projects it will be bringing online in 2021 will reduce $CO_2$ equivalent emissions by over 1 million metric tons per year.

We estimate the company's average dairy RNG project generates an approximate 33% IRR at strip prices assuming LCFS credit generation based on a 2,200 wet cow equivalent sized farm and average industry operating and capital costs. We assume the average farm produces 84 mmbtupd of RNG with an average CI score of -332. At this time, we do not model sales of the solids post anaerobic digestion. Of additional importance, by incorporating Bloom Energy's fuel cell design, we estimate a dairy manure to electricity project can generate an approximate IRR of 36% at strip prices and assuming LCFS credit generation at a conservative CI score -500 with significant upside for avoided emissions and cost reductions.

**Figure 49. California Bioenergy's RNG projects in San Joaquin Valley**




*Source: Company presentation*

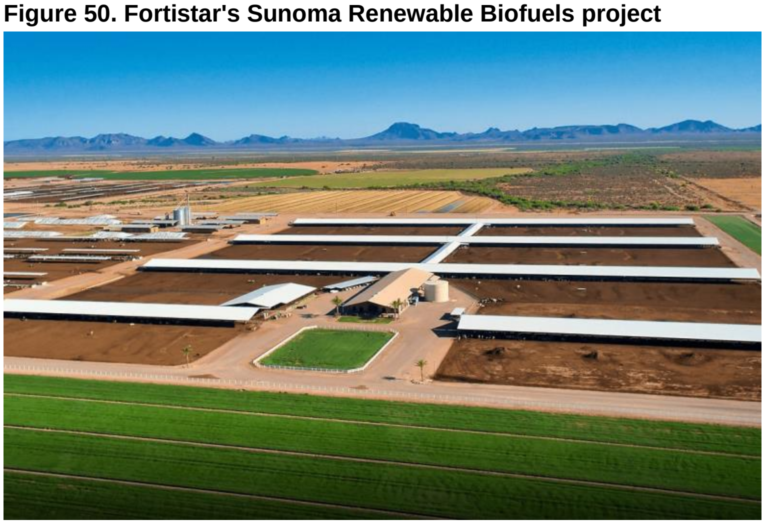
***Fortistar Renewable Power: Industry leader in the de-carbonization of the transportation sector via RNG***

Founded in 1993, Fortistar is a privately-owned investment firm that provides capital to build, grow and manage companies that address complex sustainability challenges. Whether in energy, transportation or industrials, Fortistar's seven portfolio companies maintain a shared focus on sustainability and superior performance. For the purpose of this report, we are focused on Fortistar's Renewable Power Portfolio, a leading producer of renewable electricity and renewable natural gas by capturing harmful emissions from landfills and dairies). In our view, the combination of Renewable Power Portfolio and TruStar Energy (a Fortistar portfolio company and leading designer and developer of CNG fueling stations, providing its clients a fully integrated offering of construction, service, and fuel sales services) places Fortistar in a position to be a leader in the de-carbonization of the transportation sector as the company has developed nearly 400 fueling stations and brings true vertical integration to the table.

Fortistar is an industry pioneer in the landfill gas vertical. The company began developing landfill gas projects in 1998 and operates a portfolio of 20 landfill projects at present. Last August, Fortistar announced the beginning of construction with its first dairy project (Sunoma Renewable Biofuels) in Gila Bend, Arizona at the Paloma Dairy. The Sunoma project is expected to be online in November 2021 and produce 1.6 million gasoline gallon equivalent of RNG. Looking forward, the company plans to bring on 12 new RNG projects over the next year, totaling nearly $500 million in capital and 120 million gallon equivalents of RNG over the next three years. Fortistar has announced five of the projects to date, including Greentree Landfill in Kersey, Pennsylvania (1st), Imperial Landfill in Imperial, Pennsylvania (2nd), Sunoma Renewable Biofuels in Gila Bend, Arizona (3rd), Noble Road Landfill in Shiloh, Ohio (4th) and New River Landfill in Railford, Florida (5th). We expect the remaining to be a mix of landfill and dairy projects.

We estimate the company's average dairy RNG project can generate an approximate 44% IRR at strip prices based on a 10,000 wet cow equivalent farm and industry average operating and capital costs. We assume the average project produces 380 mmbtupd of RNG with an average CI score of -332. At this time, we do not model sales of the solids post anaerobic digestion.

**Figure 50. Fortistar's Sunoma Renewable Biofuels project**



*Source: Paloma Dairy and Sunset Farms*

### *Montauk Renewables (NC, $13.33): Experienced landfill RNG producer*

Founded in 1980, Montauk Renewables is a renewable energy company specializing in the recovery and processing of biogas from landfills and other non-fossil fuel sources. Having participated in the industry for over 30 years, Montauk is one of the largest United States producers of RNG. Montauk's legacy company, Montauk Holdings Limited, was spun off from Hosken Consolidated Investments Limited on December 15, 2014, as a publically-owned company listed on the JSE Limited. On January 21, 2021, the company priced its initial public offering of 3,047,015 shares at a price of $8.50 per share. On January 22, 2021, the shares were listed on the Nasdaq and began to trade under the ticker symbol MNTK. Montauk owns the distinction of being the only public company listed in the United States that offers investors pure-play exposure to the RNG sector.

Through self-development, partnerships, and acquisitions, the company has established an operating portfolio of 12 RNG and three renewable electricity projects that span across six states. Looking forward, management expects to grow Montauk through the acquisition of prospective landfill projects, the conversion of existing operated electricity projects to RNG, and the expansion of focus to new feedstock sources and technology. Of note, management recently commercialized its first dairy RNG project (Pico Energy RNG) at Bettencourt Dairy in Wendell, Idaho and is actively evaluating wastewater resource recovery facilities, organic waste, and sludge opportunities.

We estimate an average landfill RNG project generates an approximate 59% IRR at strip prices assuming LCFS credit generation based on a peak RNG production rate of 2,100 mmbtupd and average industry operating and capital costs. We assumed an average CI score of 40 and an NRI of 80%.

**Figure 51. Montauk's RE and RNG projects**

Renewable Electricity Generation

| Site | COD (1) | Capacity (MW) | Source |
|---|---|---|---|
| Bowerman Irvine, CA | 2016 | 23.6 | Landfill |
| Security Houston, TX | 2003 | 3.4 | Landfill |
| AEL Sand Spring, OK | 2013 | 3.2 | Landfill |
| Total Capacity (MW) | | 30.2 | |

Renewable Natural Gas

| Site | COD(1) | Capacity (MMBtu/day) (2) | Source |
|---|---|---|---|
| Rumpke Cincinnati, OH | 1986 | 7,271 | Landfill |
| Atascocita Humble, TX | 2002*/ 2018 | 5,570 | Landfill |
| McCarty Houston, TX | 1986 | 4,415 | Landfill |
| Apex Amsterdam, OH | 2018 | 2,673 | Landfill |
| Monroeville Monroeville, PA | 2004 | 2,372 | Landfill |
| Valley Harrison City, PA | 2004 | 2,372 | Landfill |
| Galveston Galveston, TX | 2019 | 1,857 | Landfill |
| Raeger Johnston, PA | 2006 | 1,857 | Landfill |
| Shade Cairnbrook, PA | 2007 | 1,857 | Landfill (3) |
| Coastal Plains Alvin, TX | 2020 | 1,775 | Landfill |
| Southern Davidsville, PA | 2007 | 928 | Landfill |
| Pico (4) Jerome, ID | 2020 | 903 | Livestock (Dairy) |
| Total Capacity (MMBtu/day) | | 33,850 | |

● = Renewable Natural Gas Project
▲ = Renewable Electricity Project

*Source: Company filings*

### ***Morrow Renewables: A leading American manufacturer, supplier, and midstream operator for LFG***

Founded in 1986, Morrow Renewables, formerly operating as SouthTex Renewables, is a privately-owned company that provides integrated waste-to-energy solutions to the private and municipal waste sector. Since its inception, Morrow has received two patents in biogas treating, led the industry in plant run-times and methane efficiencies, and established a reputation as one of the top biogas treating firms in America. The company has established a reputation as one of the top firms in America for the design, construction, start-up, and operation of high-btu RNG plants and is also a founding member of the Renewable Natural Gas Coalition, a non-profit trade association comprised of over 125 companies and organizations.

Morrow Renewables produces and sells approximately 6,500 mmbtu of renewable biogas each day from existing facilities. The company has built 15 high-btu renewable facilities and currently operates seven sites. Morrow's Blue Ridge Landfill High btu project in Pearland, Texas is one of the largest treating facilities in the U.S. The facility currently treats over 8,000 scfpm of inlet gas, which is among the country's top-producing facilities. Morrow, along with Republic, continues to drill and expand the wellfield and expects production to grow each year significantly. The landfill accepts over 4,000 tons per day of Municipal Solid Waste, and the final gathering system design will be able to accommodate 30,000 mmbtu at peak production in approximately 45 years.

We estimate an average landfill RNG project generates an approximate 59% IRR at strip prices assuming LCFS credit generation based on a peak RNG production rate of 2,100 mmbtupd and average industry operating and capital costs. We assumed an average CI score of 40 and an NRI of 80%.

**Figure 52. Morrow's Landfill projects**

*Source: Company filings*

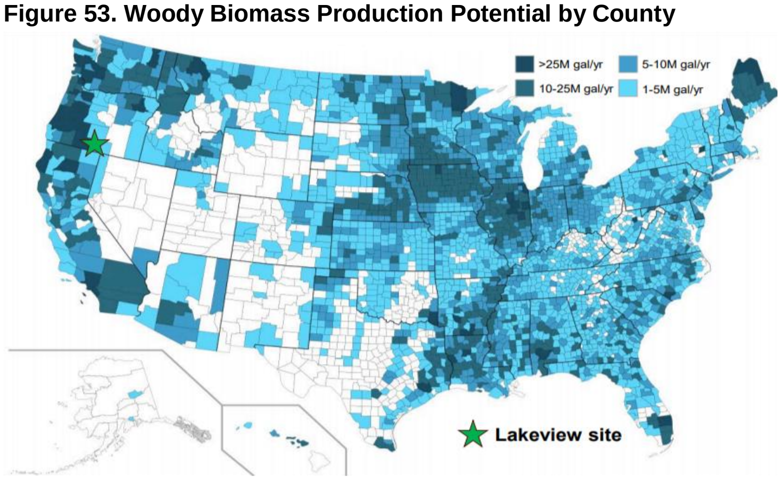
### ***Red Rock Biofuels (NC): Turning woody biomass into sustainable jet fuel and cellulosic renewable diesel***

Founded in 2011 and based in Fort Collins, Colorado, Red Rock Biofuels (RRB), a subsidiary of IR1 Group LLC (IR1), develops processing plants to convert woody biomass into renewable, drop-in diesel and jet fuels. In general the company plans to complete three refineries, each refinery is designed to utilize 175,000 dry tons of woody biomass feedstock to produce 16 million gallons per year of finished products. RRB's technology platform converts woody biomass to jet, diesel, and naphtha fuels. The process begins with the gasification of woody biomass to produce synthesis gas. This synthesis gas is cleaned and sent to a Fischer-Tropsch unit where it is converted to liquid hydrocarbons. Hydroprocessing refines the liquid hydrocarbons to produce jet, diesel, and naptha fuels. The company plans to complete its first biofuel facility in Lakeview, Oregon in the spring of 2021.

The Lakeview project aims to convert 166,000 tons of dry waste woody biomass into 16.1 million gallons of renewable jet fuel, or Sustainable Aviation Fuel (SAF), and cellulosic renewable diesel fuels. In general, lifecycle carbon emissions from SAF and cellulosic renewable diesel are expected to be up to 80% lower than conventional jet fuel. In addition, clearing unused forest by-products helps the area with fire mitigation. The plant is expected to produce 40% jet fuel, 40% diesel and 20% naphtha, or 6 million gallons, 6 million and 3 million, respectively. The project is expected to be completed in the spring of 2021 and will be the world's first commercial-scale cellulosic biorefinery to convert waste woody biomass into SAF and cellulosic renewable diesel fuels. The woody biomass feedstock will be sourced from forest by-products (mostly slash piles and pre-commercial thinnings) from a 125-mile feedstock draw radius around the Lakeview facility. The $320 million facility will utilize the Fisher-Tropsch method to create fuel. The process, at a high-level, is to heat woody biomass to 1,800 degrees in an oxygen free, high pressure environment to convert the materials to a gas. The liquid hydrocarbons are then refined into ASTM International (ASTM) pathway-approved SAF and cellulosic renewable diesel fuels.

IR1 seeks to build a global portfolio of biorefineries to convert woody biomass into renewable jet and diesel fuels. RRB is targeting deployment of its next commercial plant in California, and has plans for Plant #2 and #3 after the Lakeview project is completed and operating successfully.

**Figure 53. Woody Biomass Production Potential by County**



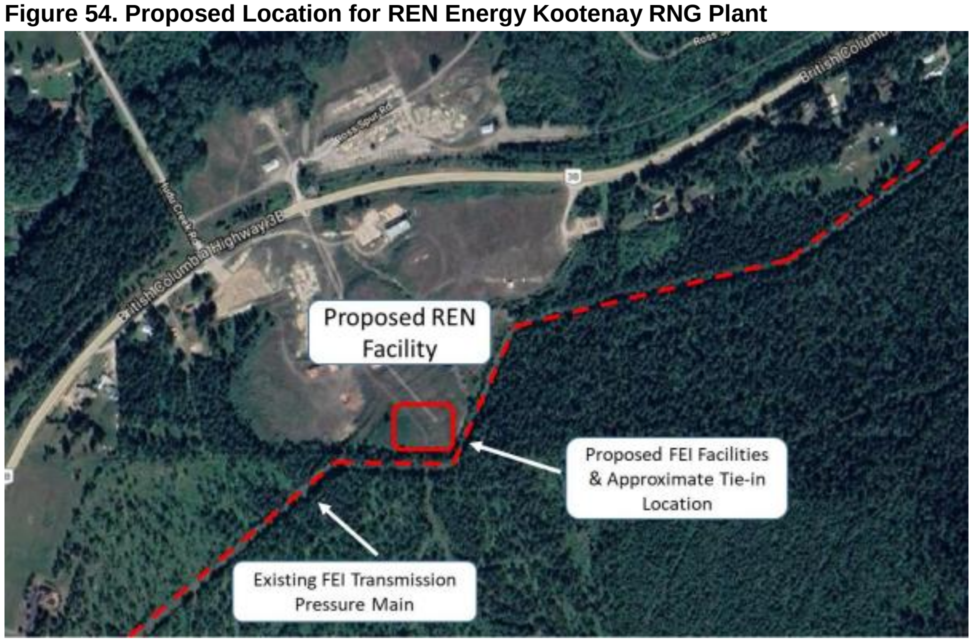

*Source: RRB Presentation*

### *REN Energy International (NC): Developing the world's largest biomass project*

Founded in 2018 by six entrepreneurs, REN Energy's global vision is to reduce waste to zero by providing clean energy solutions that incorporate proven technologies to produce renewable fuels from waste. The company's first project will produce RNG from wood waste. The Kootenay Biomass to RNG Plant, located in Fruitvale British, Columbia, will generate a carbon-neutral, and potentially 'carbon negative', RNG product as there is no increase in net forest harvest and the removal of the target feedstock (unused biomass from logging operations) will allow forests to re-grow faster. Additionally, new jobs will be created, and the environment will benefit from lower greenhouse gas emissions. The production process will utilize a novel combination of three essential and proven technologies (gasification, gas cleaning, and methanation) in a manner that will generate a uniquely high methane output. There are no similar commercial technologies or processes in the world at the scale of REN's first project. The REN Solution™ is inherently clean and safe because the production system is fully enclosed and the process uses 100% of the solids, liquids and gases produced. The Kootenay Biomass to RNG Plant is expected to be operational by mid-2022 and produce 1.2 million gigajoules per year. REN Energy has a long-term supply agreement in place with FortisBC for its first plant

Looking beyond the first plant, REN plans to build multiple RNG plants with the second plant producing at a targeted capacity of up to 2.4 million gigajoules. Of importance, we note FortisBC launched a RNG program in 2011, aiming for RNG to reach 20% of gas volumes by 2030 or 30 gigajoules. Additionally, the province of BC amended the Greenhouse Gas Reduction Regulation to include a renewable portfolio allowance of up to 5% RNG on the natural gas system in 2017. As RNG currently accounts for less than 1% of total gas volumes for FortisBC, there is robust utility and regulatory support for RNG.

**Figure 54. Proposed Location for REN Energy Kootenay RNG Plant**




*Source: FortisBC Disclosures*

***SustainRNG (NC): Focused on bringing anaerobic digestion technology to farms across the U.S.***

Founded by Clean Source Capital in 2019, SustainRNG was formed and capitalized as the business entity to commercialize its advanced methane generation (AMG) technology. The company's business model is to develop, design, engineer, finance, construct, and operate renewable natural gas generation projects in partnership with dairy farmers. On July 30, 2020, SustainRNG and Duke Energy announced a partnership to harness RNG on dairy farms, starting in the Southeast. By capturing and processing biogas from farms into RNG, the partnership will be able to provide a local renewable energy source to end-users through the existing natural gas pipeline network. Of note, Duke Energy has invested in a minority share of SustainRNG and retains the option to invest in future operating projects.

The advanced technology employed in SustainRNG's projects utilizes specialized anaerobic digestion units, which stratify the flow of particles by size, facilitating the breakdown of the organic materials in manure. SustainRNG is initially targeting the use of the technology to deploy digesters on dairy farms of 3,000 to 6,000 heads that use water wash-down manure management, which management believes is currently an underserved niche in the dairy digester market. The company expects to complete its first project in 2022.

***Vanguard Renewables (NC): Focused on bringing anaerobic digestion technology to farms across the U.S.***

Founded in 2014, Vanguard Renewables was formed on three principles including, produce energy from organic waste, sustain farms for future generations by reducing emissions and providing a diversified income stream, and reduce greenhouse gas emissions from food waste by diverting food waste from landfills. In 2017, Vanguard Renewables and Dairy Famers of America (DFA) announced a strategic partnership to help bring anaerobic digestion technology to more farms across the country. In 2019, Vanguard Renewables and Dominion Energy announced a $200 million nationwide strategic partnership to convert methane from dairy farms into clean RNG. In concert with this announcement, Vanguard Renewables formed Vanguard Renewables Ag, a subsidiary of the parent company, to develop and operate Farm Powered manure-only anaerobic digestion facilities on domestic dairy farms. Under the strategic partnership, Dominion Energy will own the projects and market the RNG, and Vanguard Renewables' subsidiary Clean Energy Investment USA (Vanguard Renewables Ag) will design, develop and operate the projects.

At present, Vanguard Renewables owns and operates six anaerobic digesters, including one RNG project, in the Northeast that recycle more than 500 tons of organic waste per day into renewable energy. Vanguard Renewables Ag (Dominion and Vanguard partnership) has multiple projects under development in Georgia, Nevada, Colorado, New Mexico, and Utah, with additional projects planned nationwide. The strategic partnership's first project is scheduled to come online in 2021. A typical Vanguard Renewables Ag dairy waste to energy project consists of a cluster of two to four farms and 10,000 to 30,000 dairy cows.

We estimate an average dairy RNG project could generate an approximate 33% IRR at strip prices assuming LCFS credit generation based on a 2,200 wet cow equivalent sized farm and average industry operating and capital costs. We assume the average farm produces 84 mmbtupd of RNG with an average CI score of -332. At this time, we do not model sales of the solids post anaerobic digestion.

# Important Disclosures and Certifications

**I, Derrick Whitfield, certify that the views expressed in this research report accurately reflect my personal views about the subject securities or issuers; and I, Derrick Whitfield, certify that no part of my compensation was, is, or will be directly or indirectly related to the specific recommendations or views contained in this research report.**

**Our European Policy for Managing Research Conflicts of Interest is available at [www.stifel.com/institutional/ImportandDisclosures](http://www.stifel.com/institutional/ImportandDisclosures).**

Aemetis Inc. (AMTX) as of March 05, 2021 (in USD)


*Represents the value(s) that changed.
Buy=B; Hold=H; Sell=S; Discontinued=D; Suspended=SU; Discontinued=D; Initiation=I

For a price chart with our ratings and any applicable target price changes for AMTX go to
http://sf.bluematrix.com/bluematrix/Disclosure?ticker=AMTX

Stifel or an affiliate expects to receive or intends to seek compensation for investment banking services from Aemetis Inc. in the next 3 months.

Stifel or an affiliate is a market maker or liquidity provider in the securities of Aemetis Inc.

The equity research analyst(s) responsible for the preparation of this report receive(s) compensation based on various factors, including Stifel's overall revenue, which includes investment banking revenue.

**Investment Rating System**

Our investment rating system is defined as follows:

**Buy** - We expect a total return of greater than 10% over the next 12 months with total return equal to the percentage price change plus dividend yield.

**Speculative Buy**[1] **-** We expect a total return of greater than 30% over the next 12 months, with total return equal to the percentage price change plus dividend yield, accompanied by substantially higher than normal risk including the possibility of a binary outcome.

**Hold** - We expect a total return between -5% and 10% over the next 12 months with total return equal to the percentage price change plus dividend yield.

**Sell** - We expect a total return below -5% over the next 12 months with total return equal to the percentage price change plus dividend yield.

Occasionally, we use the ancillary rating of **Suspended (SU)** to indicate a long-term suspension in rating and/or target price, and/or coverage due to applicable regulations or Stifel policies. Alternatively, **Suspended** may indicate the analyst is unable to determine a "reasonable basis" for rating/target price or estimates due to lack of publicly available information or the inability to quantify the publicly available information provided by the company and it is unknown when the outlook will be clarified. **Suspended** may also be used when an analyst has left the firm.

[1] This rating is only utilised by Stifel Canada.

Of the securities we rate, 55% are rated Buy, 1% are rated Speculative Buy, 29% are rated Hold, 2% are rated Sell and 13% are rated Suspended.

Within the last 12 months, Stifel or an affiliate has provided investment banking services for 16%, 15%, 26% and 12% of the companies whose shares are rated Buy, Hold, Sell, and Suspended respectively.

Within the last 12 months, Stifel or an affiliate has provided material services for 36%, 40%, 17%, 20% and 14% of the companies whose shares are rated Buy, Speculative Buy, Hold, Sell, and Suspended respectively.

**Additional Disclosures**

Please visit the Research Page at www.stifel.com for the current research disclosures and respective target price methodology applicable to the companies mentioned in this publication that are within the Stifel coverage universe. For a discussion of risks and changes to target price including basis of valuation or methodology please see our stand-alone company reports and notes for all stocks.

The information contained herein has been prepared from sources believed to be reliable but is not guaranteed by us and is not a complete summary or statement of all available data, nor is it considered an offer to buy or sell any securities referred to herein. Opinions expressed are as of the date of this publication and are subject to change without notice. These opinions do not constitute a personal recommendation and do not take into account the particular investment objectives, financial situation or needs of individual investors. Employees of Stifel, or its affiliates may, at times, release written or oral commentary, technical analysis or trading strategies that differ from the opinions expressed within. Stifel or any of its affiliates may have positions in the securities mentioned and may make purchases or sales of such securities from time to time in the open market or otherwise and may sell to or buy from customers such securities on a principal basis; such transactions may be contrary to recommendations in this report. Past performance should not and cannot be viewed as an indicator of future performance. Unless otherwise noted, the financial instruments mentioned in this report are priced as of market close on the previous trading day and presumed performance is calculated always over the next 12 months.

As a multi-disciplined financial services firm, Stifel regularly seeks investment banking assignments and compensation from issuers for services including, but not limited to, acting as an underwriter in an offering or financial advisor in a merger or acquisition, or serving as a placement agent in private transactions.

**Affiliate Disclosures**
References to “**Stifel**” (collectively ”Stifel”) refer to SFC and other associated affiliated subsidiaries including (i) Stifel, Nicolaus & Company, Incorporated (“**SNC**”); (ii) Keefe, Bruyette & Woods, Incorporated (“**KBWI**’’), which are both U.S. broker-dealers registered with the United States Securities and Exchange Commission (“**SEC**”) and members of the Financial Industry National Regulatory Authority (“**FINRA**”), respectively; (iii) Stifel Nicolaus Canada, Incorporated. (“**Stifel Canada**”), which is authorised and regulated by Investment Industry Regulatory Organization of Canada (“**IIROC**”), and also trades under the names “**Stifel GMP**” and/or “**Stifel FirstEnergy**”; (iv) Stifel Nicolaus Europe Limited (“**SNEL**”), which is authorised and regulated by the Financial Conduct Authority (“**FCA**”) (FRN 190412) and is a member of the London Stock Exchange and also trades under the name Keefe, Bruyette & Woods Europe (“**KBW Europe**”); and (v) Stifel Europe Bank AG (“**SEBA**”), which is regulated by the German Federal Financial Supervisory Authority (Bundesanstalt für Finanzdienstleistungsaufsicht; “BaFin”) and is a member of Deutsche Boerse and SIX Swiss Exchange and (vi) Stifel Schweiz AG (“**STSA**”), which is representative of SEBA in Switzerland and regulated by the Eidgenössische Finanzmarktaufsicht (“**FINMA**”). SNEL, SEBA and STSA are collectively referred to as **Stifel Europe**.

**Registration of non-US Analysts:** Any non-US research analyst employed by Stifel contributing to this report is not registered/qualified as a research analyst with FINRA and is not an associated person of the US broker-dealer and therefore may not be subject to FINRA Rule 2241 restrictions on communications with a subject company, public appearances, and trading securities held by a research analyst account.

**Global Research Notes:** Stifel Global Research (Cross-Border Research) notes are intended for use only by Institutional or Professional Clients. Research analysts contributing content to these reports are subject to different regulatory requirements based on the jurisdiction in which they operate. Clients seeking additional information should contact the Stifel entity through which they conduct business.

**SEBA & STSA Sponsored research:** At SEBA & STSA, analysts may produce issuer paid research ('sponsored research'). This research is produced by analysts in accordance with local regulatory requirements relating to such research. In certain jurisdictions, this issuer paid research may be deemed to be independent research albeit not produced to the same conflicts of interest standards required by all jurisdictions for independent research. Where research has been paid for by an issuer, this will be clearly labelled. Please see our European Policy for Managing Research Conflicts of Interest for additional information.

**Country Specific and Jurisdictional Disclosures**

**United States:** Research produced and distributed by Stifel Europe is distributed by Stifel Europe to "Major US Institutional Investors" as defined in Rule 15a-6 under the US Securities Exchange Act of 1934, as amended. SNC may also distribute research prepared by Stifel Europe directly to US clients, including US clients that are not Major US Institutional Investors. In these instances, SNC accepts responsibility for the content. Stifel Europe is a non-US broker-dealer and accordingly, any transaction by a US client in the securities discussed in the document must be effected by SNC. US clients wishing to place an order should contact their SNC representative.

**UK:** This report is distributed in the UK by SNEL, which is authorised and regulated by the Financial Conduct Authority (FCA). In these instances, SNEL accepts responsibility for the content. Research produced by Stifel Europe is not intended for use by and should not be made available to retail clients as defined by the FCA.

**European Economic Area (EEA)**: This report is distributed in the EEA by SEBA, which is authorized and regulated by the German Federal Financial Supervisory Authority (Bundesanstalt für Finanzdienstleistungsaufsicht; "BaFin"). In these instances, SEBA accepts responsibility for the content. Research produced by Stifel Europe is not intended for use by and should not be made available to retail clients as defined under MiFID II.

The complete preceding 12-month recommendations history related to recommendation(s) in this research report is available at https://stifel2.bluematrix.com/sellside/MAR.action

**Australia:** Research produced by Stifel is distributed by SNEL under the Australian Securities and Investments Commission ("ASIC") Class Order [CO 03/1099] exemption from the requirement to hold an Australian Financial Services Licence ("AFSL"). This research may only be distributed to a "Wholesale Client" within the meaning of section 761G of the Corporations Act 2001 (Cth).

**Brunei:** This document has not been delivered to, registered with or approved by the Brunei Darussalam Registrar of Companies, Registrar of International Business Companies, the Brunei Darussalam Ministry of Finance or the Autoriti Monetari Brunei Darussalam. This document and the information contained within will not be registered with any relevant Brunei Authorities under the relevant securities laws of Brunei Darussalam. The interests in the document have not been and will not be offered, transferred, delivered or sold in or from any part of Brunei Darussalam. This document and the information contained within is strictly private and confidential and is being distributed to a limited number of accredited investors, expert investors and institutional investors under the Securities Markets Order, 2013 ("Relevant Persons") upon their request and confirmation that they fully understand that neither the document nor the information contained within have been approved or licensed by or registered with the Brunei Darussalam Registrar of Companies, Registrar of International Business Companies, the Brunei Darussalam Ministry of Finance, the Autoriti Monetari Brunei Darussalam or any other relevant governmental agencies within Brunei Darussalam. This document and the information contained within must not be acted on or relied on by persons who are not Relevant Persons. Any investment or investment activity to which the document or information contained within is only available to, and will be engaged in only with Relevant Persons.

**Canadian Distribution:** Research produced by Stifel Europe is distributed in Canada by SNC in reliance on the international dealer exemption. This material is intended for use only by professional or institutional investors. None of the investments or investment services mentioned or described herein is available to other persons or to anyone in Canada who is not a "permitted client" as defined under applicable Canadian securities laws.

**Republic of South Africa:** Research produced by Stifel is distributed by SNEL to "Clients" as defined in FSCA FAIS Notice 20 of 2018 (the "FAIS Notice") issued by the Financial Services Conduct Authority. Research distributed by SNEL is pursuant to an exemption from the licensing requirements under Section 7(1) of the Financial Advisory and Intermediary Services Act, 2002.

In jurisdictions where Stifel is not already licensed or registered to trade securities, transactions will only be affected in accordance with local securities legislation which will vary from jurisdiction to jurisdiction and may require that a transaction is carried out in accordance with applicable exemptions from registration and licensing requirements. Non-US customers wishing to effect transactions should contact a representative of the Stifel entity in their regional jurisdiction except where governing law permits otherwise. US customers wishing to effect transactions should contact their US salesperson.

The securities discussed in this report may not be available for sale in all jurisdictions and may have adverse tax implications for investors. Clients are advised to speak with their legal or tax advisor prior to making an investment decision.

**Additional Information Is Available Upon Request**



The recommendation contained in this report was produced at 8 March 2021 16:05EDT and disseminated at 8 March 2021 16:05EDT