RENEWABLE NATURAL GAS (RNG) FOR TRANSPORTATION

Frequently Asked Questions

BASICS

What is RNG?

RNG (renewable natural gas) is a key emerging fuel derived from waste.

As organic waste decomposes, it releases a biogas that is 40% to 60% methane (CH_4). This biogas can be captured and refined to remove contaminants and increase its heat content. The resulting gas, RNG, can be used in place of or mingled with geologic or fossil natural gas (NG) in pipelines, fueling stations, and storage tanks, or as a "drop-in" fuel requiring no engine modifications in NG vehicles.

What's the difference between biogas, biomethane, and RNG?

Biogas is the raw gas produced by the breakdown of organic materials in an oxygen-free (anaerobic) environment. After removal of contaminants and other gases, biogas becomes RNG, which is typically 90%+ methane. Biomethane is another name for RNG.

What happens to biogas that's not converted to RNG?

It depends on the source. On farms, animal waste is often allowed to decompose in pits or ponds, where it produces methane. This methane, a powerful greenhouse gas (GHG) with 25 times the global warming potential of carbon dioxide (CO_2), is often released to the atmosphere.

At landfills and water resource recovery facilities (WRRFs), biogas is produced from the breakdown of organic waste and typically "flared" to convert its methane content to CO_2, which reduces (but does not eliminate) its global warming potential. Food waste from restaurants, institutions, and industrial food processors that is not delivered to biogas digesters or composted usually goes to landfills where it, too, can release methane and CO_2 into the atmosphere.

How is RNG used? RNG can be used wherever pipeline-supplied NG is used, including as transportation fuel and to generate electricity.

Who currently uses RNG? RNG is used primarily as a transportation fuel in NG vehicles.

What types of vehicles/engines can run on RNG? Any engine that operates on NG can run on RNG.

What infrastructure is needed to transport and dispense RNG? Infrastructure for transporting and dispensing NG can be used for RNG. RNG is a "drop-in" fuel for NG vehicles.

BENEFITS

Converts waste to a valuable product. RNG extracts value from decomposing waste, which can be used by the producer in a closed-loop process or sold. Even the byproducts of RNG processing—nutrient-rich solids and liquids—have value as a fertilizer.

Reduces GHG emissions. On a lifecycle basis, RNG can reduce GHG emissions by 95% as compared to diesel, giving it a nearly net zero carbon impact. In cases where biogas would otherwise be released to the atmosphere (e.g., open lagoons), RNG can have a negative carbon impact.

BENEFITS OF RNG

- ✓ Converts waste to a valuable product
- ✓ Reduces GHG emissions
- ✓ Produces domestic, renewable fuel from plentiful feedstocks
- ✓ Reduces odor and runoff
- ✓ Creates jobs
- ✓ Enhances fuel diversity
- ✓ Provides a steady supply of renewable energy
- ✓ Supports organizations' and fleets' sustainability goals
- ✓ Uses existing technologies and natural gas infrastructure

Produces domestic, renewable fuel from plentiful feedstocks. According to the U.S. Environmental Protection Agency (EPA), the U.S. generated 267.8 million tons of municipal solid waste in 2017 (or 4.51 pounds per person per day), more than half of which (139 million tons) was landfilled. The remainder was either recycled, composted, or combusted for energy recovery. Food waste accounted for the largest share (~22%) of tonnage sent to landfills (EPA undated). According to the U.S. Department of Agriculture (USDA), animals at feeding operations—including feedlots and other confinement facilities—produce 335 million tons of manure (dry weight) annually in the U.S. (USDA undated).

U.S. DEPARTMENT OF ENERGY Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

Reduces odor and runoff. Compared with uncovered manure storage, RNG usually eliminates odors. For farm and livestock operations, anaerobic digestion can also reduce nitrogen and phosphorus runoff to groundwater and downstream waters.

Creates jobs. RNG production can create technical and support jobs in the development and operation of digesters and associated equipment.

Enhances fuel diversity. RNG can be made from various feedstocks that are in common supply. Unlike petroleum, RNG price is not tied to uncertain or volatile fuel markets.

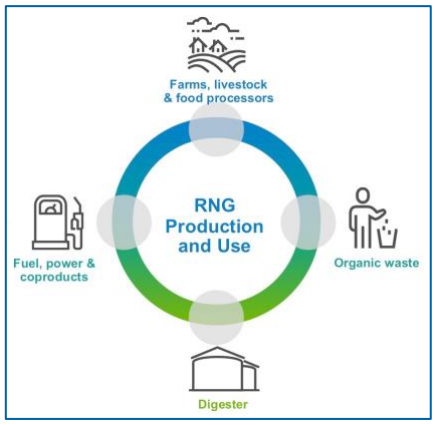
Provides a steady supply of renewable energy. Unlike wind or solar power, weather and climate conditions do not affect RNG production.

Supports organizations' and fleets' sustainability goals. Compared to conventional gasoline and diesel, RNG can reduce GHG emissions by 95%.

Uses existing technologies and infrastructure. Biogas can be upgraded to RNG with existing cleanup technologies, transported in existing NG pipelines, compressed and dispensed at existing compressed NG (CNG) stations, and used in conventional CNG vehicles.

WHO CAN BENEFIT FROM RNG?

- Waste generators (e.g., livestock operators, food processers and wholesalers, supermarkets, campuses, restaurants, hospitals) can gain a sustainable outlet for their waste and may be able to turn disposal costs into revenue opportunities.
- Landfills and WRRFs can gain a revenue stream as well as potential cost savings from heat and/or power generation.
- CNG project developers and equipment builders, owners, and operators can see new business.
- NG providers/utilities can gain a renewable fuel supply to not only reduce their system-wide carbon content, but also provide customers with a voluntary, renewable fuel option.
- Fleets/vehicle operators can gain a drop-in renewable fuel for their NG vehicles as well as an attractive renewable alternative to diesel fuel for potential conversions.
- Communities can improve the sustainability of waste disposal and vehicular fuel use, thereby enabling a circular economy.



RNG can be produced and used in a closed-loop process. Biogas systems use anaerobic digestion to recycle organic waste, turning it into energy and liquid and solid coproducts valuable in agriculture.

RNG PRODUCTION AND SUPPLY

How is RNG made?

RNG is made from decomposing organic matter. In the U.S., it is most commonly produced through anaerobic (oxygen-free) digestion. The RNG feedstock—wastewater sludge, animal manure, or food waste—is placed in a closed, oxygen-free tank where micro-organisms break it down into a gas. The resulting biogas is primarily methane and CO_2.

Because a lot of organic matter (e.g., food waste, paper, textiles) ends up in landfills, landfills themselves act as digesters, producing landfill gas (LFG). LFG is composed of methane and CO_2, as well as contaminants. Landfills are a major source of raw biogas.

Before it can become usable RNG, the biogas produced through anaerobic digestion must be upgraded and conditioned. First, hydrogen sulfide and water are removed. Then, CO_2 is removed via chemical, pressure, or membrane processes.

For transportation use, the resulting RNG can be compressed to make renewable CNG or super-cooled to make renewable liquefied NG (LNG).

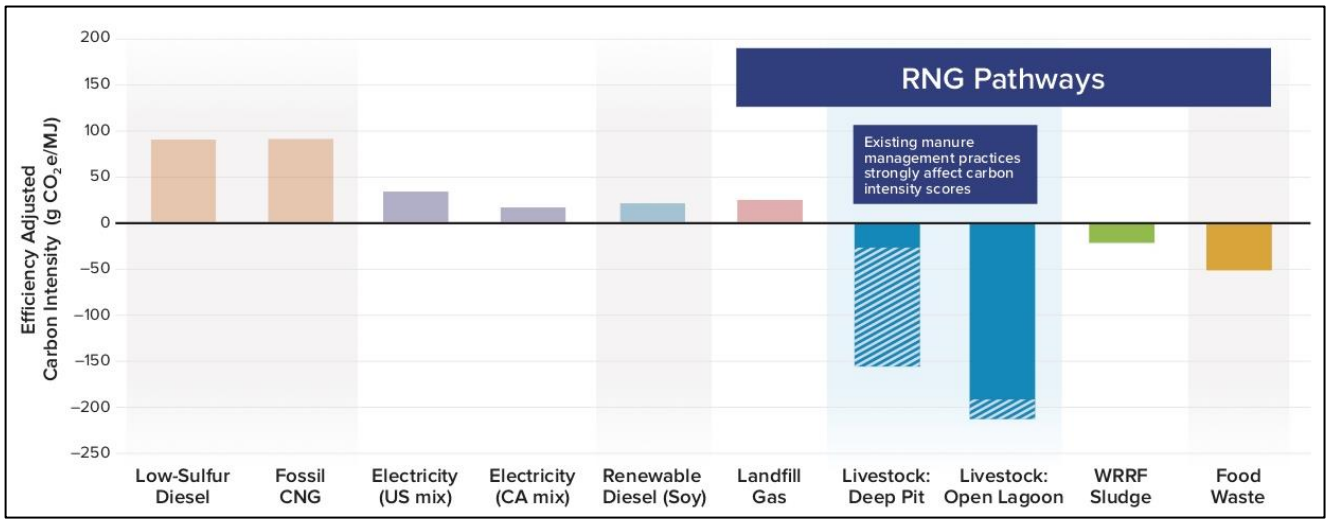
What are the sources of RNG supply?

Most U.S. projects are at landfills, but the number of projects associated with livestock operations and waste water is growing. Food manufacturers and wholesalers, supermarkets, restaurants, campuses, and hospitals are also potential sources for RNG.

Landfills Landfills account for more than 75% of RNG production potential while accounting for 56% of currently operational RNG projects (ANL 2020).

Livestock operations Animal manure can be collected on a single large farm or combined from several "cluster" farms and delivered to a single anaerobic digester for RNG production. If manure is stored in open lagoons that emit methane, moving it to enclosed digesters prevents those emissions. The RNG produced also displaces fossil NG that would have been consumed by NG vehicles, thereby reducing CO_2 emissions. Avoided methane emissions and displaced fossil CO_2 emissions can produce large reductions in carbon intensity.

Water resource recovery facilities Approximately 7% of the U.S.'s 16,000+ wastewater treatment plants use anaerobic digestion to produce biogas, most of which is flared or used to heat the digester and onsite facilities or generate power. Only 14 WRRFS currently produce RNG that can be used for transportation (WEF 2018).



Some RNG pathways have very low carbon intensity (CI) scores because they capture emissions that would otherwise be released to the atmosphere. For farms with manure lagoons that currently emit high levels of methane, RNG production can yield negative CI scores. The diagonal-line overlays on bars represent the *range* of carbon intensity scores that can be achieved with corresponding RNG projects. (CA = California; CNG = compressed natural gas; CO_2e = carbon dioxide equivalent; g = gram; MJ = megajoule; RD = renewable diesel; WRRF = water resource recovery facility.) (ANL GREET)

Other biomass sources RNG can be produced from crop residues and energy crops through thermochemical conversion, co-digestion, and dry fermentation. These technologies are used in Europe, but have had limited application in the U.S. RNG also can be produced from food waste, either alone or combined with biosolids from livestock operations or WRRFs.

Where Is RNG available? Until recently, RNG was available primarily in California, where its very low carbon intensity made it a valuable option for meeting that state's Low Carbon Fuel Standard (LCFS). With RNG production growing in California, and other states—and utilities—seeking to reduce the carbon content of fuels, RNG is becoming more widely available. Some nationwide fuel retailers are beginning to supply RNG to their fleet customers outside of California, and major fleets like Anheuser-Busch and New York's Metropolitan Transportation Authority have announced plans to use RNG.

Where are RNG projects located? While RNG is produced all over the U.S., some states are more active than others. Landfill-based projects are concentrated in the central and Appalachian states. Farm-based projects tend to be concentrated where livestock support large industries—the dairy industry in California, New York, and Wisconsin; the pork industry in Iowa, Missouri, and North Carolina; and the poultry industry in Delaware and North Carolina. WRRF-based projects tend to be at larger facilities located in or near metropolitan areas.

How many RNG projects are currently in operation, under construction, and planned? By the end of 2020, more than 150 projects are expected to be operational, roughly 80 will be under construction, and 80 more projects will be in various stages of development in the U.S. Farm-based projects represent the largest share of planned projects. California has the most projects currently under construction, followed by New York and Missouri (ANL 2020).

ECONOMIC INCENTIVES AND COSTS

What are the economic incentives for stakeholders?

Waste generators Disposing of waste is costly. Converting it to RNG can turn that cost into revenue, especially with the use of investment and production tax credits and tradable credits for certified renewable or low-carbon fuels.

Investors, equipment suppliers, and developers Demand for RNG is growing, and RNG production requires a wide range of equipment to process, store, and transport the fuel. Producing, installing, and operating that equipment creates additional sources of revenue, as well as employment opportunities.

RNG retailers, resellers, or utilities Because of its low carbon intensity, RNG can contribute to organizations' sustainability goals. It can also offset the use of higher carbon, harder-to-displace fuels like fossil NG and diesel. For utilities, resellers, and retailers with significant investments in the latter fuels, the addition of RNG offers the possibility of reducing their products' net carbon intensity.

Fleets and other end users Many organizations are deepening their commitment to sustainability. When used in heavy-duty trucks, RNG is typically no more—and potentially less—expensive than fossil NG or diesel. RNG is also attractive for its low carbon intensity and "drop in" capability for fossil NG vehicles. Plus, RNG's advantages are not tied to uncertain or volatile fuel markets, unproven technologies, or the need for extensive new infrastructure.

Communities and local officials Manufacturing, installing, and operating equipment to process, store, and transport RNG creates jobs. Those jobs generate tax revenues, with the effects rippling through the economy. For individual livestock projects, replacing open manure pits or ponds with covered digesters reduces odors and possible groundwater contamination.

Are there incentives for *producing* RNG? Yes. RNG qualifies for several types of tax credits and other incentives.

Federal incentives The Internal Revenue Service Section 45 Production Tax Credit is available to producers who convert biogas to electricity, while the Alternative Fuel Excise Tax Credit is available to producers of vehicle fuel.

RNG produced from landfill gas or from biogas produced at farms or WRRFs qualifies as a cellulosic biofuel under the Renewable Fuel Standard (RFS), enabling it to receive Renewable Identification Numbers (RINs). RINs can be traded to companies obligated to produce or sell renewable fuels. RNG produced from food waste qualifies for a less-valuable advanced biofuel RIN, which can also be traded to obligated parties.

State incentives RNG may also qualify for state incentives, the most valuable of which are credits under California's Low Carbon Fuel Standard (LCFS) and Oregon's Clean Fuel Standard (CFS). Both provide significant price support for RNG produced with a low carbon intensity (or reduction in CO_2 emissions as compared with the status quo). While the value of these credits will depend on market forces, they are expected to remain at approximately $200/ton for the LCFS, somewhat less for the CFS.

Are there incentives for *using* RNG? States are beginning to incentivize the use of RNG. In October 2019, the California Air Resources Board amended the state's Heavy-Duty Vehicle Incentive Program, which subsidizes the replacement of older, higher-polluting vehicles with cleaner alternatives. One restriction for NG vehicles is that they must be fueled with California-produced RNG. Several other states are encouraging utilities to offer RNG to their customers to help meet state climate goals.

Increasingly, communities and businesses view RNG as a key tactic for meeting their sustainability goals and demonstrating their commitment to GHG reduction.

How do incentives affect the cost of producing RNG? On a project level, incentives can mean the difference between profit or loss. Over many projects, incentives can bring the average cost of supplying RNG on par with that of NG from fossil sources.

How does the source of RNG affect its cost? Because of their size and ability to produce biogas without a free-standing digester, landfills can produce RNG at an average cost of roughly $0.90–$1.00/diesel gal equivalent (dge). For individual projects, the cost can range from $0.40/dge to $2.00/dge. The cost of RNG produced from anaerobic digestion of livestock manure, wastewater, or food waste tends to be higher and more variable. Reported values range from less than $0.30/dge to nearly $4.00/dge. Prices for other alternative fuels can be found in the most-recent Clean Cities Alternative Fuel Price Report.

RNG engages a broad community of stakeholders and generates substantial environmental and economic benefits. By turning waste into products, RNG can provide jobs and revenue to local economies, a drop-in fuel to fleets, and a bridge to a low-carbon future using existing vehicles and infrastructure.

References

ANL (Argonne National Laboratory), Renewable Natural Gas Database (2020), accessed 9-29-20.

ANL, GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model) (2019).

EPA (U.S. Environmental Protection Agency), Advancing Sustainable Materials Management: 2017 Fact Sheet (2019), accessed 10-28-20.

USDA (U.S. Department of Agriculture), Natural Resources Conservation Service, Estimates of Recoverable and Non-Recoverable Manure Nutrients Based on the Census of Agriculture (undated), accessed 9-22-20.

(WEF) Water Environment Federation, Energy: Water Resource Recovery Facilities—Energy Generation Trends and Highlights (2018), accessed 9-29-20.

Other Useful Resources

U.S. DOE, Alternative Fuels Data Center, Renewable Natural Gas Production

U.S. EPA, AgSTAR: Biogas Recovery in the Agriculture Sector

U.S. EPA, Landfill Methane Outreach Program (LMOP)

ANL, AFLEET tool (Alternative Fuel Life-Cycle Environmental and Economic Transportation tool)

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