RNG: Zero Scope 1 Emissions and Negative CI

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If we want to get serious about climate change, it is critical we address our overreliance on fossil fuels, which are a primary driver of greenhouse gas emissions. Whether it's diesel, gasoline, kerosene, propane, or coal, burning these sources of fuel emits carbon into the atmosphere, disrupts the naturally-occurring carbon cycle in our ecosystem, and fundamentally threatens our way of life.

However, recycling the carbon already in the atmosphere prevents the extraction and combustion of fossilized carbon sources.

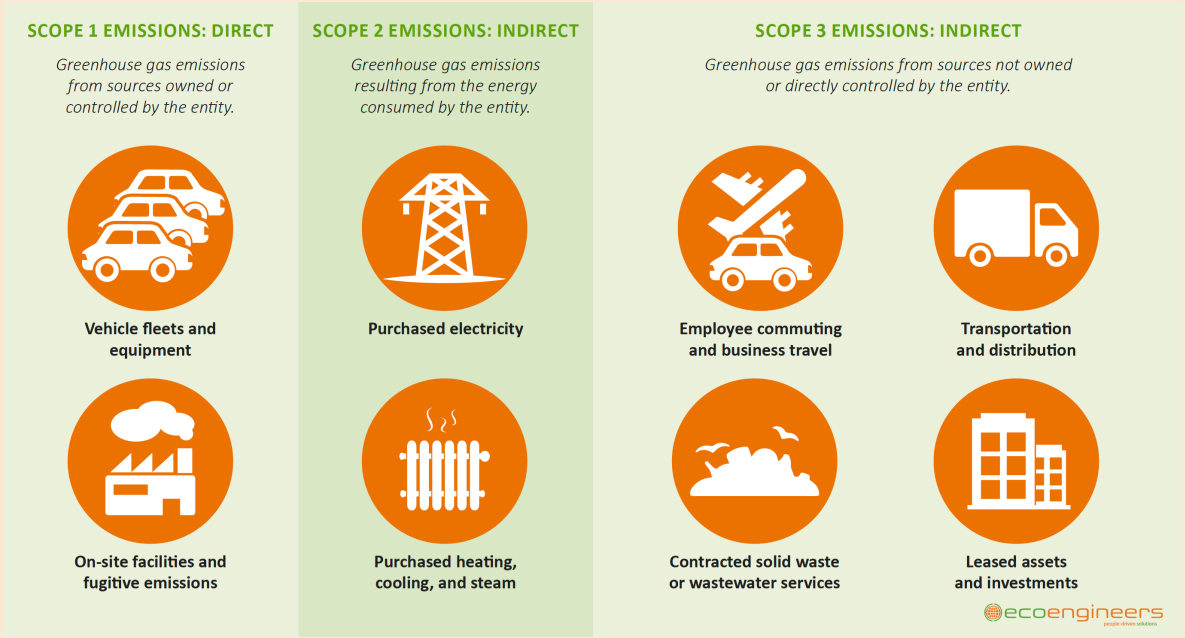
Think of an aquifer below the ground that holds water; let's say you want to limit your dependence on it. You would try to use rainwater and other surface water as much as possible to meet your daily needs. If you can switch 100% of your water use to surface water, you will not draw any new water from the aquifer.

Recycling carbon is the same concept. By using carbon that is already on the earth's surface and the atmosphere, we are not extracting new sources of carbon from fossil fuels that have been buried in the ground for millions of years. Renewable Natural Gas or RNG is a fuel source that recycles carbon in the atmosphere and reduces our dependence on fossil natural gas.

To illustrate the point, if all the natural gas consumed in the U.S. was RNG, there would be no new carbon emission from fossil gas sources. The resulting Scope 1 emissions for entities burning RNG would be zero.

For greater context, it is important to understand that there are three types of carbon emissions:

- **The first is called Scope 1 emissions**, which includes direct emissions from sources that are owned or controlled by you, the individual consumer, or a company. This includes emissions resulting from hot water heaters, a furnace, a factory smokestack, etc.



YOU CAN'T IMPROVE WHAT YOU DON'T MEASURE

- **The second is Scope 2 emissions**. These are emissions that result from the generation of electricity (or heat) purchased by a company, individuals, or households from a utility provider. You cannot control theses unless you have the ability to switch to a different provider who sells low-carbon power.

- **The final is called Scope 3 emissions**, which is generated from sources outside your control, but are still a result of your activities. For example, when you buy a sweater online, it is flown to you from the manufacturer or distributor and typically driven to your home in a gasoline-fueled van. The resulting emissions are outside your direct control, but are a result of your purchase. Emissions from employees commuting or raw material sourcing is considered Scope 3 for a company. Cleaning up Scope 3 means re-evaluating raw material supply and vendor emissions and re-tooling the supply chain — all of which is no easy task.

Purchased electricity is often the easiest route for individuals or companies to reduce emissions since zero-carbon sources, such as solar and wind power, are increasing in availability. Even if you, as an individual, don't install the solar panels or a windmill on site, you can purchase relatively inexpensive, renewable electricity credits from an offsite project and claim carbon neutrality for your Scope 2 emissions.

Scope 1 emissions are within your direct control, but they are often more difficult to reduce because there are fewer cost-effective alternatives that apply to your current home or work infrastructure, which often relies heavily on natural gas. An effective solution to this is renewable natural gas, or RNG.

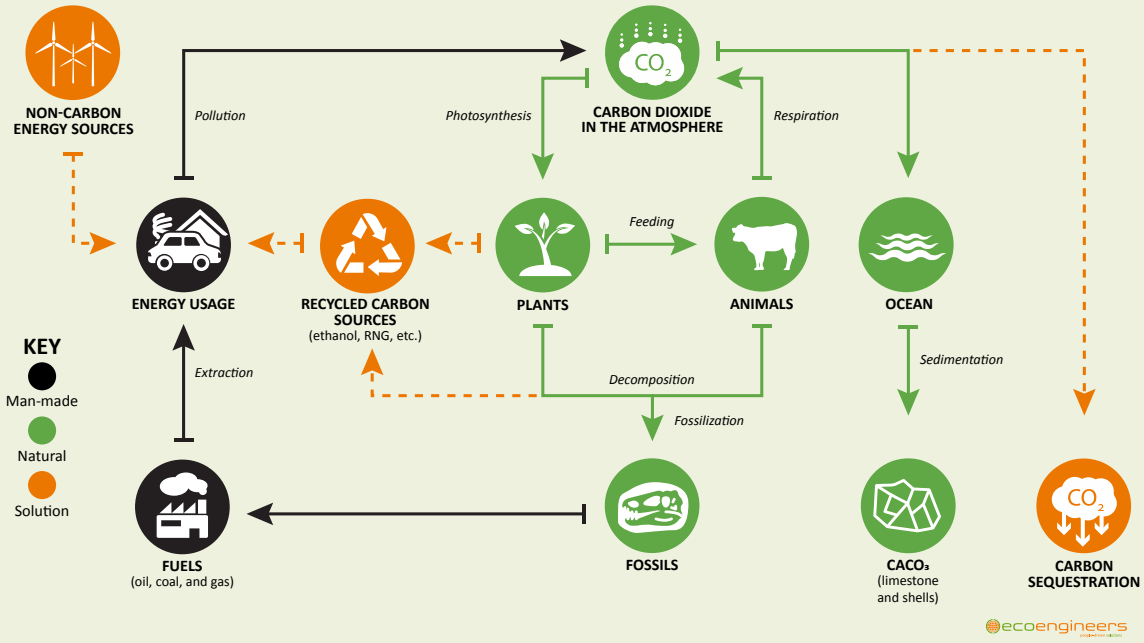
The Carbon Cycle

Anthropogenic greenhouse emissions are mainly caused by the burning of fossil fuels.

The natural carbon cycle - the flow of carbon between the earth, the atmosphere and the oceans - has been in place for billions of years. Carbon is present in the atmosphere, oceans, rocks, and in all living things. Plants absorb carbon through photosynthesis, and animals exhale carbon into the air through respiration. Oceans both absorb and emit carbon. Decomposition and fossilization of plant and animal matter releases and sequesters carbon in the ground.

Now the Earth is out of balance. Human activity has caused an imbalance in this cycle with a high demand for fossilized sources of carbon. By extracting and consuming fossil fuels, we are releasing large quantities of carbon into the atmosphere that would otherwise have remained in the ground. The carbon dioxide created from burning fossil fuels acts as a greenhouse gas. The Earth is now gaining more heat from the sun than it is losing to space. As the earth warms, the atmosphere becomes 'wetter,' storms larger, and the seas rise. This results in higher and higher concentrations of carbon in the atmosphere, which in turn causes increasingly erratic climate patterns.

Dense fossil sources of energy have driven human development, but we can no longer afford to use them without considering the environmental damage they cause. In order to restore balance in the carbon cycle, or, at least, prevent further imbalance, we must find alternate sources of energy to replace fossil fuels. Options include non-carbon sources, such as solar and wind power, or recycled carbon sources, such as RNG. Recycled carbon sources are fuels made from atmospheric carbon as opposed to fossilized carbon, which contributes additional carbon into the atmosphere.



While conventional natural gas is extracted from fossilized sources deep in the earth, RNG recycles carbon that is already in the atmosphere.

Because RNG performs like natural gas without being a fossil fuel, RNG provides a practical, cost-efficient, and replicable source of clean energy for our homes and businesses, while also reducing the environmental impact of the waste.

All communities continuously produce different forms of waste – whether through landfills, wastewater treatment plants, or animal feedlots – and as these sources of waste naturally decompose, they emit methane. RNG is produced from the decomposition of organic waste, captures this methane, and transforms it into a clean source of fuel without increasing carbon emissions from burning fossil fuels.

RNG can fuel heating, transportation, and electricity production and even help to create hydrogen. It needs no new equipment or infrastructure to capture and transport it, since it is completely compatible with existing natural gas infrastructure.

RNG can be used to replace fossil-based natural gas for all applications to heat a home, without requiring any upgrades or adjustments to power existing appliances, including stoves, furnaces, or boilers.

Life-Cycle Analysis (LCA)

According to the United States Environmental Protection Agency (USEPA), "a life-cycle assessment (LCA) is a comprehensive method for assessing a range of environmental impacts across the full life cycle of a product system, from materials acquisition to manufacturing, use, and final disposition." There are several different methods to perform an LCA. ISO has developed international standards to cover LCA: ISO 14040 (LCA-Principals and guidelines), ISO 14041 (LCA-Life Inventory Analysis), ISO 14042 (LCA-Impact Assessment) and ISO 14043 (LCA-Interpretation). California uses the Greenhouse Gases, Regulated Emissions and Energy use in Transportation (GREET) model developed by the Department of Energy's Argonne National Laboratory (Argonne) as its LCA tool.

These models calculate the emissions from a fuel's entire life cycle and provide a score called carbon intensity or CI. The CI of burning a fuel is the net grams of carbon dioxide equivalent (CO2e) emitted per megajoule of energy. The CI score of a fuel includes Scope 1, 2, and 3 emissions for that fuel. Therefore, even if your Scope 1 is zero from burning RNG, your net emissions from the CI score could be positive, zero (if you have a carbon-neutral fuel), or sometimes negative (if the process of producing the fuel results in a net carbon reduction).

RNG has one of the lowest CIs of any clean energy source available today. Manure-to-RNG fuel pathways have CI scores ranging from -100 to -400 gCO2e/MJ, which means the process of producing it results in a net carbon reduction. By comparison, petroleum

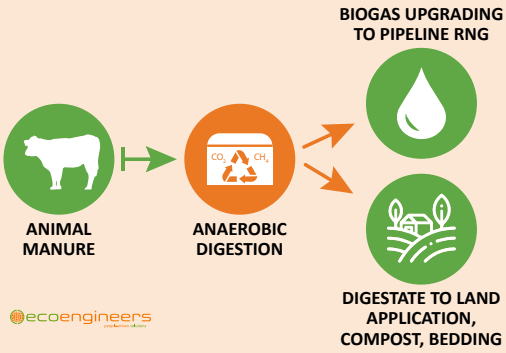
diesel typically has a CI of 100 gCO2e/MJ, and fossil natural gas has a CI of 70 gCO2e/MJ. This means that combusting a megajoule of petroleum diesel or fossil natural gas releases about 100 gCO2e and 70 gCO2e, respectively; whereas, combusting a megajoule of RNG from manure prevents the release of 100 to 400 gCO2e into the atmosphere.

RNG's ultralow CI scores are possible because the process of producing the gas from manure requires the diversion of manure from open lagoons that would otherwise vent methane to the atmosphere. Methane, even though it is short-lived in the atmosphere compared to CO2, is much more effective at holding heat. Preventing one molecule of methane reaching the atmosphere is equivalent to 32 molecules of CO2. Accounting for the prevented methane emissions allows the fuel to achieve a negative CI value.

In 2020, approximately 3.5 million metric tons of CO2e emissions was avoided as a result of RNG use as vehicle fuel in the U.S. – the equivalent of taking 756,000 cars off the road or negating the electricity consumption of nearly 600,000 homes (according to the USEPA's Greenhouse Gas Equivalencies Calculator).

On the farm, RNG gives farmers a way to responsibly and profitably handle waste products or crop and livestock residues that have traditionally been problematic. With the increased focus on carbon accounting, animal manure and crop residues are being used by many farmers to access new revenue streams by producing and selling RNG. By using anaerobic digestion to produce RNG, farmers also generate potentially valuable co-products, such as fertilizers or animal bedding. These co-products can be used on the farm to offset expenses or sold to others for new income.

In addition to creating new revenue sources for farmers, RNG can be used to fuel farm-to-table delivery vehicles, which provide savings throughout the food production and delivery system. This in turn can be passed along to the consumer while reducing the carbon footprint of the food industry.



A SIMPLE LOOK AT BENEFITS OF ANAEROBIC DIGESTION

Similarly, municipalities can convert municipal solid waste and wastewater sludge into RNG and access new sources of income, which can reduce the tax burden of their citizens.

Moving from petroleum-based natural gas to RNG will allow consumers and businesses to choose a clean energy alternative. Currently, less than 1% of the natural gas in the country is RNG. This low-carbon fuel may never be the sole clean energy source for the world, but it can, and should, be a key part of the portfolio of clean energy solutions that can be leveraged to combat climate change.

For more information about RNG, contact EcoEngineers at www.EcoEngineers.us or the Coalition for Renewable Natural Gas at www.RNGCoalition.com. You can also email the author, Mr. Shashi Menon, at smenon@ecoengineers.