The Value-Adding Coproducts of RNG Production: Generating New Sources of Revenue from Agricultural Waste

This article is Part 4 in a series on how Renewable Natural Gas (RNG) can help unlock environmental and economic benefits across the US economy.[i]

Guidehouse, The Coalition for Renewable Natural Gas

RNG production, as this article will illustrate, plays an important role in realizing a circular economy for organic material and mitigating the uncontrolled release of methane emissions from agricultural activity [ii] and from other organic waste streams. The production of RNG and its associated coproducts helps to provide and maximize the value of waste resources within a given economy, displacing demand for carbon-intensive alternatives in the process.

The U.S. has committed to reducing its methane emissions 30% by 2030, in recognition of the climate impacts of this greenhouse gas (GHG).[iii] Agriculture is one of the top sources of methane emissions in the US, partly due to organic waste management.[iv] Organic materials decomposing on U.S. farms contribute to significant "fugitive" methane emissions: livestock and poultry produce 1.4 billion tons of manure annually, while at the same time some 10 million to 22 million tons of food loss and waste occurs on-farm every year, accounting for 17-37% of national food waste overall.[v]

Implementing controlled anaerobic digestion technology (decomposition in the absence of oxygen) can help manage these wastes by capturing methane that would otherwise escape into the atmosphere. This "biogas" can be used to generate electricity and heat on-site or can be upgraded to pipeline quality RNG which offers more diverse end uses and greater transportation flexibility. Either route yields value-adding coproducts such as carbon dioxide and "digestate," discussed in more detail below.

<u>Carbon Dioxide</u>

RNG is produced by upgrading the biogas captured when organic matter is broken down by microbes under anaerobic conditions. The upgrading process removes moisture and scrubs the biogas of CO2 and contaminants such as hydrogen sulfide, hydrogen, volatile organic compounds (VOCs) and siloxanes. Upgrading reduces the CO2 content of the biogas from 35%-50% to 1-5% in the final RNG product, which is 95% or more pure methane; it is chemically indistinguishable from, and can be used as a drop-in replacement for, fossil-derived natural gas.

Alternatively, RNG can be made by upgrading synthetic gas (syngas) produced during the pyrolysis (application of high temperature in the absence of oxygen) of organic material[vi].

In both cases, RNG production yields CO2, which can in turn be treated to meet the purity requirements of various industries, such as food and beverage, metal fabrication, fire suppression equipment manufacture and agriculture (where CO2 can be used to stimulate plant growth in greenhouses).[x] The food and beverage sector uses CO2, in liquid and solid form, to dry and refrigerate products, extend the shelf life of fruit and vegetables, and carbonate drinks, among other uses.[vii] There is a synergy in that farmers' main customers — dairies and meat processing companies — are also key markets for this coproduct from farm waste management.

While there is already broad demand for CO2 across the economy, future technological advances, and demand for new products, such as low carbon fuels, may unlock other end uses. Recent developments have shown that generation of SAF from CO2 and green hydrogen is now a promising potential pathway to decarbonize the aviation sector.[viii]

Long-term sequestration in geological formations is another climate-positive option for CO_2 that some farm-based anaerobic digestion operations employ.[ix] This is a form of bioenergy with carbon capture and storage (BECCS)[x] — a developing technology that can help reduce GHG emissions in the atmosphere.

Even when CO_2 is released into the atmosphere because there is no commercially viable way to capture it during biogas upgrading, by isolating methane for productive reuse anaerobic digestion still reduces the climate impact of agricultural waste by over 95%[xi]. Environmental necessity, and the growth of CO_2 as a product in its own right, can be expected to lead to the scaling of capture technology in the future.

Digestate

During anaerobic digestion the solids content of agricultural and other organic wastes is reduced by about 75% and transformed into biogas. The solids and liquids that remain after the anaerobic digestion process are collectively known as "digestate," which comes out of the digester as a thick liquid with significant fiber and solids content. Digestate can either be used in its raw form, or further processed into liquid and solids fractions for different end uses.

Raw digestate can be applied on land by farmers, reusing vital nutrients such as nitrogen, phosphate, and potassium to reduce or eliminate their demand for mineral fertilizers. Furthermore, the organic (carbon-based) content of the digestate (~75%) can build up the humus content of soils and improve agricultural yields, particularly on arid and semi-arid land.[xii]

The liquid digestate fraction can be used as a fertilizer and is considered superior to raw, unprocessed manure, due to the higher nitrogen content resulting from reactions that occurred during anaerobic digestion. Odor associated with spreading raw manure is also greatly reduced with liquid digestate.[xiii] When compared to mineral fertilizers, the nitrogen release to plants from digestate is steadier, which reduces the risk of nitrogen leaching into nearby waterways. [xiv]

Solid digestate fraction can be used as a soil amendment, compost, or processed into bedding materials for animals — often representing significant savings for farmers compared to purchasing alternatives such as sand or wood chips for the same purpose. Additionally, bedding derived from digestate has low pathogen levels and benefits in terms of reducing GHG emissions.[xv]

Another potential avenue for revenue generation from digestate is to use it as a feedstock for pyrolysis. Through pyrolysis, digestate and other organic wastes can be transformed into a high-carbon, porous material known as biochar (as well as syngas, a renewable fuel).[xvi] Biochar contributes to long-term carbon sequestration and improves the soil's ability to retain water and nutrients.[xvii]

Coproducts From Advanced Anaerobic Digestion

"Advanced" anaerobic digestion technologies optimize the biochemical reactions involved to improve the biomethane potential by introducing additional controls and processing steps. Some of these technologies are also targeting the generation of coproducts such as hydrogen, ammonia and bioethanol through pre- and post-processing steps that can be bolted onto existing AD facilities or integrated into new facilities.

Currently the hydrogen produced is typically added back into the anaerobic digestion process to react with the CO_2 and increase methane concentration in the biogas.[xviii] However hydrogen can be a carbon-negative fuel source in its own right and can be blended in, along with RNG, to networked natural gas supplies to reduce overall carbon intensity.

An ammonia stripping process is carried out on certain high-nitrogen feedstocks, such as poultry manure, to make them more amenable to the anaerobic digestion process. The ammonia stripped from the digestate can be further reacted with CO2 to form a solid that can be used as a low carbon fertilizer.[xix]

RNG and bioethanol can also be considered coproducts of one another in certain consecutive[xx] and contiguous[xxi] processes and is an area of ongoing development.

Case Study: Dallman East River Dairy and Why It Has Switched From Producing Electricity to RNG

Dallman East River Dairy, a Wisconsin-based farm of 4,400 milking cows, has had a manure digester onsite since 2012.[xxii] Up until 2019 it used the biogas to generate electricity, which it sold to the local utility company. Over that period the price the utility paid for the electricity dropped from 15-16 cents per kWh to 2-3 cents per kWh, rendering the enterprise unprofitable. The digester operation was then sold to a new company, U.S. Energy (at the time U.S. Gain), which installed gas upgrading equipment to produce RNG that is transported via truck to a nearby gas pipeline injection point.

The ability to generate environmental attribute credits under both the federal Renewable Fuel Standard (RFS) and state-level Low Carbon Fuel Standard (LCFS) programs means that U.S. Energy's RNG output attracts a significantly higher price than is paid for fossil-based natural gas.

In addition to the RNG produced, the operation at Dallman East River Dairy has a system to recover solids from the digestate for animal bedding. By passing some of the digester outputs though a screw press separator, enough animal bedding is produced to meet the farms' needs and that of some of their neighbors. Selling the recycled bedding material to nearby farms, and avoiding the need to buy sand for bedding themselves, gives this coproduct a positive impact on Dallman East's bottom line.

Last Words

While RNG itself remains a valuable tool for supporting decarbonization at a wide range of companies, the coproducts of its production process also offer economic and environmental benefits. New markets are opening for CO2, a necessary coproduct of biogas upgrading, and advanced biogas processing technologies that can produce additional high-value byproducts such as hydrogen and ammonia are becoming more mature. The anaerobic digestion process produces a substantial amount of digestate, which can be used in a variety of applications from fertilizer to animal bedding. The value of these coproducts should also be considered when evaluating investments in RNG production.

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[i] RNG, also known as biomethane, is a commercially available, low carbon fuel derived from the decay of bio-based wastes in anaerobic environments. RNG is chemically identical to, and can be used interchangeably with, conventional natural gas. RNG is currently mostly utilized in transportation end uses, but it has the potential to reduce GHG emissions in other sectors, as well.

[ii] https://www.whitehouse.gov/wp-content/uploads/2022/11/US-Methane-Emissions-Reduction-Action-Plan-Update.pdf

[iii] https://www.whitehouse.gov/wp-content/uploads/2022/11/US-Methane-Emissions-Reduction-Action-Plan-Update.pdf

[iv] https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane

[v] https://www.epa.gov/system/files/documents/2021-11/from-farm-to-kitchen-the-environmental-impacts-of-u.s.-food-waste_508-tagged.pdf and https://www.ars.usda.gov/research/publications/publication/?seqNo115=364421#:~:text=In%20the%20United%20States%2C%20as,nutrient%20source%20for%20crop%20production. Note that crop residues and other

agricultural wastes not treated by AD were not producing methane emissions (as the manure was), but rather were degrading aerobically directly to CO2.

[vi] CharTech Solutions and Synagro Announce Partnership For High Temperature Pyrolysis Demonstration Project to Eliminate PFAS from Biosolids and Generate Biochar - CHAR Technologies

[vii] https://www.nexair.com/learning-center/carbon-dioxide-in-food-and-beverage-2/

[viii] https://www.reuters.com/business/sustainable-business/honeywell-announces-tech-turn-hydrogen-co2-into-lower-carbon-aviation-fuel-2023-05-10/

[ix] https://ethanolproducer.com/articles/aemetis-hosts-california-ag-secretary-at-biorefinery-rng-sites-19977

[x] https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/bioenergy-with-carbon-capture-and-storage

[xi] Guidehouse Analysis

[xii] https://www.europeanbiogas.eu/wp-content/uploads/2019/07/Digestate-paper-final.pdf

[xiii] https://www.sciencedirect.com/science/article/pii/S0301479723006035

[xiv] https://www.europeanbiogas.eu/wp-content/uploads/2019/07/Digestate-paper-final.pdf

[xv] https://www.sciencedirect.com/science/article/pii/S2667378922000529

[xvi] CharTech Solutions and Synagro Announce Partnership For High Temperature Pyrolysis Demonstration Project to Eliminate PFAS from Biosolids and Generate Biochar - CHAR Technologies

[xvii] https://biochar.international/the-biochar-opportunity/what-is-biochar/

[xviii] https://www.alpsecoscience.co.uk/biohydrogen-production/ and https://www.alpsecoscience.co.uk/fermentative-hydrogen/

[xix] https://lpelc.org/economical-recovery-of-ammonia-from-anaerobic-digestate/

[xx] https://www.canadianbiomassmagazine.ca/fields-of-energy-calgary-project-to-turn-low-grade-wheat-into-ethanol-and-rng/

[xxi] https://www.alpsecoscience.co.uk/ethanol-fermentation-project/

[xxii] https://www3.uwsp.edu/cnr-ap/clue/Documents/Energy/WI%20Biogas%20Case%20Studies%20Report%2011-11-2022_WebR.pdf