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ISSUE BRIEF

A PIPE DREAM OR CLIMATE SOLUTION?
THE OPPORTUNITIES AND LIMITS OF BIOGAS AND SYNTHETIC GAS TO REPLACE FOSSIL GAS

Reducing the greenhouse gas (GHG) emissions driving the climate crisis will require replacing highly polluting fossil fuels such as natural gas (more accurately described as “fossil gas”) with low-carbon or zero-carbon energy sources. As we more fully embrace substitution of fossil fuels with resources like wind and solar energy, some argue that biogas and synthetic gas are “renewable” alternatives that could someday replace fossil gas in America’s pipelines. Biogas is primarily methane produced from organic sources such as food scraps or animal waste, and synthetic gas is methane or hydrogen created using electrical power. This Issue Brief examines the opportunities and limitations of biogas and synthetic gas to displace fossil gas as part of the solution to climate change.

Workers inspect an anaerobic digestion solid waste processing facility that converts food and green organic waste into biogas.

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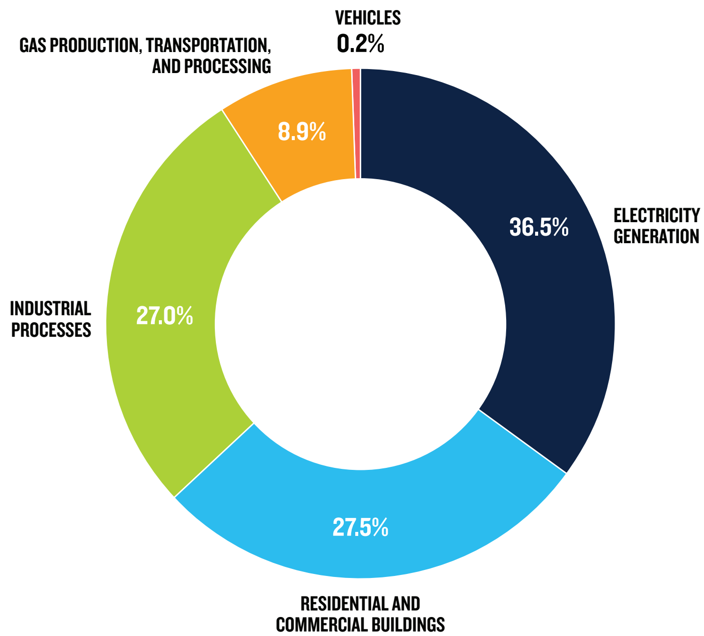
KEY FINDINGS

While biogas and synthetic gas can be a part of the climate solution toolbox, they come with a host of limitations, such as resource availability, cost, and human health and environmental impacts. Most significantly, the potential availability of biogas and synthetic gas is dwarfed by the current level of fossil gas consumption in the United States. NRDC estimates biogas and synthetic gas from ecologically sound sources may be able to replace only roughly 3 to 7 percent of today's gas use, at projected costs that are many times the current price for fossil gas. In addition, biogas and synthetic gas produce the same health-harming pollutants as fossil gas when burned, and leaks will still release methane—an especially harmful greenhouse gas—directly into the atmosphere.

As a result, biogas and synthetic gas should be used sparingly and strategically to meet on-site gas and electricity needs (to avoid transporting methane and building new pipelines), and to reduce emissions from activities that are most difficult to power with renewable electricity, such as industrial processes, aviation, long-distance transportation, and electricity generation to balance seasonal wind and solar resources.

FIGURE 1: U.S. GAS CONSUMPTION (EIA 2019)



CURRENT USES AND IMPACTS OF FOSSIL GAS

The United States uses more than 31,000 trillion British thermal units (TBtus) of fossil gas annually.[1] Commonly known as natural gas, fossil gas consists primarily of methane (CH_4) and is used for generating electricity (36.5 percent); heating and cooking in residential and commercial buildings (27.5 percent); industrial processes (27 percent); producing, transporting, and processing gas (8.9 percent); and fueling vehicles (less than 1 percent) (Figure 1). To achieve at least a 40 percent cut in GHG emissions by 2030, and net-zero GHG emissions by 2050, the United States must aim to replace the use of fossil gas in all sectors with clean energy, and emissions from any remaining gas should be permanently captured and sequestered.

Carbon dioxide (CO_2) and other harmful pollutants are emitted when methane burns, contributing to climate and air pollution.[2] Even more troubling, when methane is released directly into the atmosphere, it is a highly potent greenhouse gas. Methane traps about 30 times more heat than carbon dioxide over 100 years, and more than 80 times the amount of heat over a 20-year period.[3] Unfortunately, a significant amount of methane leaks directly into the atmosphere throughout the extraction, processing, distribution, and delivery of fossil gas, resulting in damaging climate disruption.[4] Additionally, the extraction, production, transportation, and combustion of gas does not just increase climate disruption; it poses a myriad of threats to human health, clean air, clean water, wildlife, landscapes and ecosystems, and communities.[5]

WHAT IS BIOGAS?

We use the term *biogas* to refer to methane derived from biogenic (organic) sources such as landfills, sewage treatment facilities, forests, livestock operations, and farms. Biogas is produced through either anaerobic digestion or thermal gasification.

Anaerobic digestion creates biogas when wet, organic material breaks down in environments without oxygen, such as when dairy cow manure is processed in an enclosed container called a digester.[6] If left to decompose in an aerobic environment—an environment with oxygen—these organic sources would primarily release carbon dioxide (CO_2) instead of methane. Anaerobic digestion (AD) is a simple process that has been used to generate gas for many years, although currently only at a very small scale. It can be an effective approach to extracting energy from food and animal waste, but it has potential pitfalls. For instance, it removes organic material that, if left to decompose naturally, can contribute to soil health.[7]

Thermal gasification is a process that breaks down dry biomass—such as waste wood, forestry and agricultural residues, and used paper and cardboard—in a high-heat, low-oxygen, controlled environment to create methane or other gases.[8] In the absence of thermal processing, these dry organic sources would biodegrade over many years and produce mostly CO_2. Thermal gasification is a relatively new technology with limited commercial use thus far. A fundamental issue with gasification is that it can create methane where none or little would have naturally occurred. In addition, instead of gasifying biomass to create methane, there are other more benign and potentially beneficial alternatives that are in development.

For example, thermal gasification processes can produce hydrogen (instead of methane), which has many uses and is not a climate-harming greenhouse gas.[9] Alternatively, dry biomass can be processed into liquid fuels—such as drop-in replacements for fossil gasoline, diesel, and jet fuel—which is likely a higher value use of this material.[10]

For both biogas processes, it is important to carefully consider the range of possible environmental impacts of sourcing the organic material. It is also essential to monitor and limit the methane leaking from the biogas processing itself, as leakage rates from biogas facilities can be even higher than from fossil gas extraction and processing.[11] Figure 2 describes the potential sources of biogas and NRDC's recommendations for each.

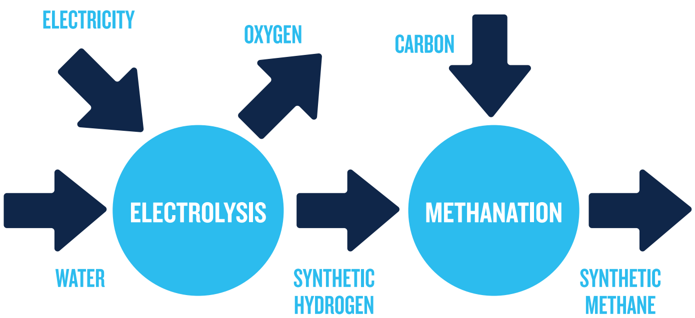
FIGURE 2: BIOGAS SOURCES AND RECOMMENDATIONS

SOURCE	RECOMMENDATIONS
LANDFILL GAS is generated from residential, industrial, and commercial organic waste—like leftover food, yard clippings, or paper—breaking down in landfills.	**Support in the near term only**, given the organics already in existing landfills. Landfill gas is not a renewable resource. This is a viable source of biogas in the near term, but going forward organic materials should be diverted from landfills to make best use of these materials. When biogas is processed so that it can be injected into a pipeline, leakage occurs in processing and transportation. These accidental methane emissions must be monitored and controlled.
ANIMAL MANURE can generate methane when digesters process it in anaerobic conditions.	**Strong caution.** There are very limited quantities of gas that can be sustainably produced from animal manure. Livestock operations can and should manage manure in ways that protect environmental and human health, but often large livestock operations cause significant human and environmental harm, and using manure to produce methane is economical only for large-scale, concentrated livestock operations.[12] Large concentrated manure sources should be required to reduce their methane emissions and to work with local communities to avoid environmental harms. On-site use of gas should be considered instead of extending pipelines. Small operations with sustainable grazing practices and other sustainable manure management practices that prevent methane creation should be encouraged over large-scale operations.
WASTEWATER TREATMENT plants break down biosolids from wastewater using anaerobic digestion.	**Support.** Methane is already produced through wastewater processing, making such plants a good source of biogas. When biogas is processed so that it can be injected into a pipeline, leakage occurs in the processing and transportation. These accidental methane emissions must be monitored and controlled.
ORGANIC COMPONENTS OF MUNICIPAL SOLID WASTE like leftover food, used paper, and yard waste are generated daily in homes, businesses, and other institutions and can be a source for anaerobic digestion.	**Limited support.** Much of this resource should be diverted from waste streams through food waste prevention, surplus food rescue, composting, and recycling. Anaerobic digestion of food scraps should be done only using source-separated organics, and the leftover organic material from anaerobic digestion should be treated and applied to soil.
AGRICULTURAL RESIDUE—including crop residues from orchards and vineyards, field and seed crops, food processing, and vegetable crops—can be a source for thermal gasification.	**Limited support.** Agricultural residue is largely woody, and biogas would most commonly need to be produced through thermal gasification. Before considering gasification, those who manage agricultural residue should focus on food waste prevention and surplus food rescue; maintaining nutrient cycling in soils; and productively using these sources as animal feedstocks, animal bedding, or fertilizers. Vegetable crops are best used by incorporating them back into soil or using them as animal feed.
FORESTRY AND FOREST PRODUCT RESIDUE, including tree branches, brush, sawmill wastes, and non-merchantable trees from logging and thinning, can be a source for thermal gasification.	**Strong caution.** These resources would be processed through gasification, and access often requires energy-intensive collection and transportation. In cases where the emissions from collection and processing are managed so there is a net decrease in climate and air pollution, only these sources are acceptable: ■ Trees removed for safety reasons from within 200 feet of homes, built infrastructure (such as power lines), and other man-made structures. Outside of removals from these areas to protect people and property, NRDC does not support the use of trees as an energy feedstock. ■ Small-diameter logging slash (e.g., branches and leaves) if these would otherwise be burned on site. However, these sources are limited, logistically challenging, and expensive to collect. ■ Sawmill residues.
ENERGY CROPS are grown specifically to produce energy.	**Strong caution.** Energy crops are often a poor use of land and should not be supported where they compete with food production or biologically diverse landscapes.

WHAT IS SYNTHETIC GAS?

The term *synthetic gas* (sometimes called "power-to-gas") refers to hydrogen or methane created through a series of controlled chemical reactions. The process begins with electrolysis, which splits water into hydrogen and oxygen. When that hydrogen is produced with renewable energy, it is called renewable or "green" hydrogen. Through a process called methanation, this hydrogen can be combined with carbon monoxide or carbon dioxide and converted into synthetic methane, as shown in Figure 3.[13]

FIGURE 3: SYNTHETIC GAS PRODUCTION PROCESS



Electrolysis requires a significant amount of energy. To generate truly "renewable" synthetic gas, that energy would need to be powered entirely by renewable resources such as wind, geothermal, and solar. However, the financial and technical viability of an electrolysis plant that could function economically on renewable energy is an open question because almost all synthetic gas today is produced with fossil gas or coal.[14] Additionally, "renewable" synthetic methane would require renewable sources of carbon dioxide. While synthetic gas can play a role in reducing our global greenhouse gas emissions, it is likely that this role will be played primarily by hydrogen rather than synthetic methane. A forthcoming NRDC publication will explore power-to-gas and the role of hydrogen in greater depth.

FIGURE 4: RENEWABLE SYNTHETIC METHANE POLICY RECOMMENDATION

	SOURCE	POLICY RECOMMENDATION
CH_4	**RENEWABLE SYNTHETIC METHANE** is generated through methanation of renewable hydrogen using a biogenic or air-captured source of carbon.	**Limited support.** Renewable synthetic methane can directly replace any existing use of fossil gas because it is the same chemical compound (CH_4). However, due to the extra chemical conversion step (methanation) and the need for a source of carbon, synthetic methane is significantly more complex and expensive to produce than hydrogen. Given the many possible uses of renewable hydrogen (e.g., to replace hydrogen currently used by industry, as a transportation fuel, or for the seasonal management of renewable electricity), it may be preferable to use hydrogen directly rather than convert it to methane. Producing synthetic methane also creates the potential for leakage, which could undermine the climate benefits.

The potential supply of biogas and synthetic gas is dwarfed by the United States' current level of fossil gas consumption. Roughly 3 to 7 percent of the country's current gas use could be replaced by ecologically sound biogas and synthetic gas.

THE POTENTIAL CHALLENGES OF BIOGAS AND SYNTHETIC GAS

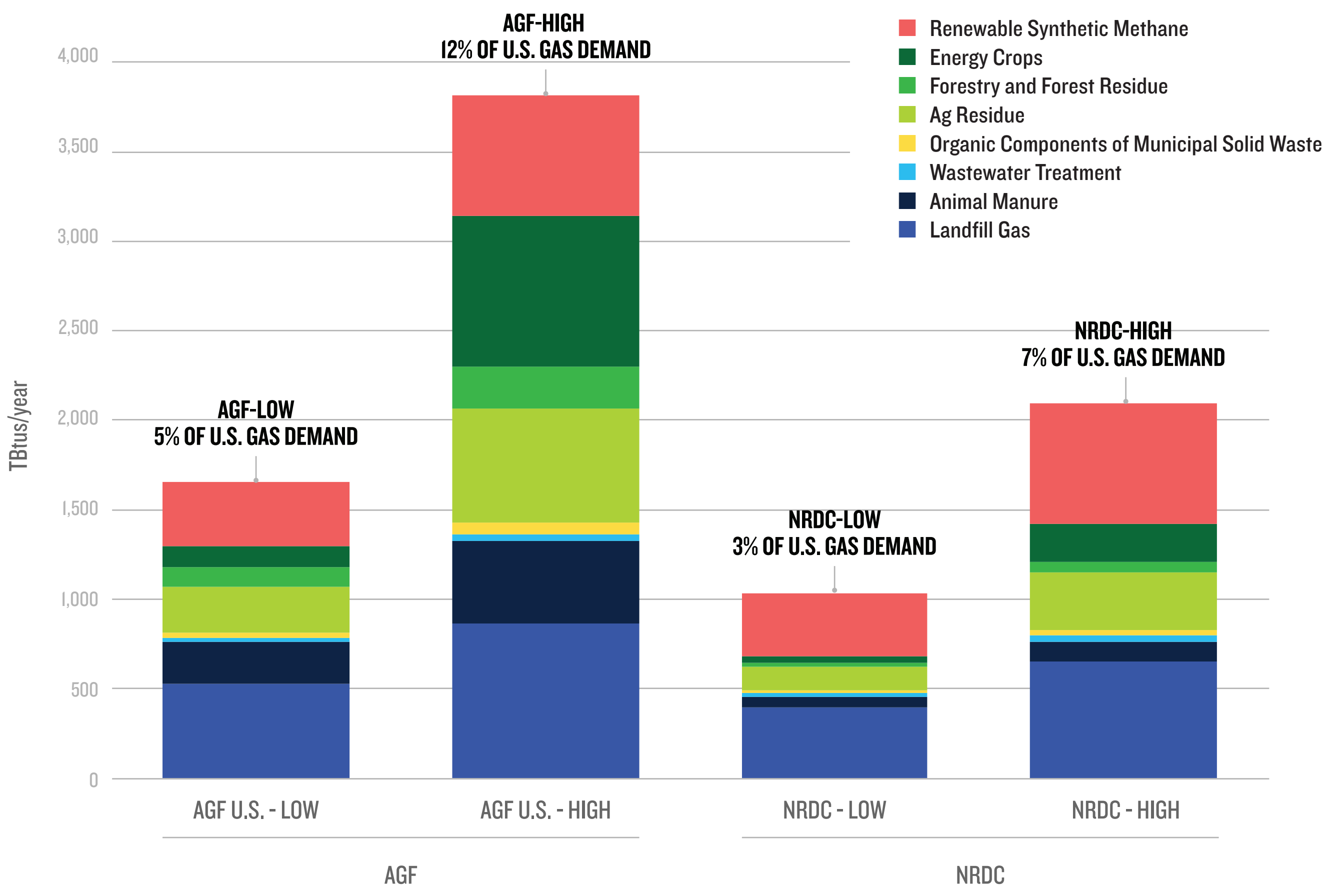
Inadequate Supply

The potential supply of biogas and synthetic gas is dwarfed by the United States' current level of fossil gas use. According to a study sponsored by the American Gas Foundation (AGF) and conducted by ICF International, the United States could produce 1,660 to 3,820 TBtus of biogas and synthetic gas annually by 2040.[15] On the basis of these numbers, NRDC applied its own screens to project that ecologically sound biogas and synthetic gas could replace roughly 3 to 7 percent of the country's 2019 gas use, with biogas replacing 2 to 5 percent and synthetic methane replacing 1 to 2 percent.[16] While those contributions would be significant, they do not justify reliance on biogas and synthetic gas as the sole or primary strategy to replace fossil gas use.

Figure 5 shows the AGF study's low and high estimates of potential biogas and synthetic gas supply by 2040, along with NRDC's rough estimates of ecologically sound gas potential. These numbers are an average across the United States; it is worth noting that the availability of biogas will vary significantly by region, depending on the local resources available.

FIGURE 5: AMERICAN GAS FOUNDATION AND NRDC HIGH AND LOW ESTIMATES OF BIOGAS AND SYNTHETIC GAS POTENTIAL*

(TBtus per year by 2040, and as percentage of 2019 U.S. gas demand)



* NRDC estimates are based on the AGF results, adjusted for our biogas resource policy recommendations given in Figure 2. We use the AGF high and low estimates for synthetic methane produced with renewable electricity.

Workers at the Waste Management facility in North Brooklyn, N.Y., process sewage into bio-slurry for conversion into methane gas.

These estimates rely on projections about current knowledge and technology for an industry that is still very young.[17] We anticipate significant learning over the next decade: It may turn out to be harder or more costly to produce biogas and synthetic gas, or new technologies and scale (especially for synthetic gas) could bring costs down and increase the potential supply.

If total gas demand declines over time, these percentages would increase. However, there may also be competing uses for these resources. For example, long-distance transportation may transition to biogas or hydrogen. And many of these biomass resources could also be converted to liquid fuels to serve other sectors. New demand for this same resource would compete with existing demand for gas for heating and cooking in buildings, industrial processes, and electricity generation.

Affordability

The cost of biogas and synthetic gas is much higher than today's price for fossil gas. The AGF estimates that biogas and synthetic gas will cost $7 to $45 per million British thermal units (MMBtus), which is 3 to 18 times more costly than the current market price for fossil gas, trading around $2.50 per MMBtu.[18] A California Energy Commission study estimates that biogas will cost $8 to $40 per MMBtu and that synthetic methane will cost $37 to almost $90 per MMBtu at scale in 2050.[19]

Environmental Impact

The emissions from biogas and synthetic gas must be carefully examined in determining whether different types of sourcing will have a net positive environmental impact. Biogas is often considered "zero carbon" because its fuel sources—organic material—have absorbed carbon from the atmosphere and would have released that carbon as part of a natural carbon cycle. However, evaluating the climate impacts of both biogas and synthetic gas must take into account the energy required to produce it, whether the source creates new methane where none or little would have existed otherwise, and how much methane leaks during production. All processes that generate methane should require an emissions management plan because without careful monitoring and oversight, these fuels could cause more harm than benefit to the climate.

Human Health

Just like fossil gas, biogas and synthetic methane continue the use of methane, which causes the formation of nitrogen oxides (NO_x) and other harmful air pollutants when burned.[20] NO_x pollution can lead to respiratory problems, from coughing and wheezing to decreased lung function, and can contribute to hospitalizations and even premature death.[21] In other words, biogas and synthetic methane do not avoid the many health harms of fossil gas.

POLICY RECOMMENDATIONS

These policy recommendations are based on our initial findings about the potential and limitations of biogas and synthetic gas:

- **Target on-site use and hard-to-electrify sectors.** Available biogas and synthetic gas resources should be directed to on-site use where possible (to avoid the leakage associated with transportation and the cost of new pipelines), with any excess directed to hard-to-electrify sectors such as industry, long-distance transportation, aviation, and use in electricity generation to balance seasonal wind and solar resources.
- **Transition to clean electricity.** The limited supply of biogas and synthetic gas cannot replace the current use of fossil gas by a long shot. Given the need to substitute clean energy for fossil gas in all sectors to meet climate goals, abundant renewable electricity will be the fuel of choice in most sectors. Gas use and investment in gas infrastructure will need to decline. All states and regions urgently need to begin planning for a smaller gas footprint to avoid the significant costs of under-used pipeline infrastructure.
- **Start small.** Given the nascent state of this market, policies that aim to replace fossil gas with biogas and synthetic gas should start small and grow only if the resource proves to be available, economical, and environmentally sound.
- **Establish and enforce emissions standards, monitoring, and reporting.** Any policy supporting the development of biogas and synthetic gas must include environmental requirements to screen the resources used, and differentiate among them through active monitoring and reporting of life-cycle carbon dioxide and methane emissions, accounting for both short-term and long-term climate impacts.

CONCLUSION

While biogas and synthetic gas have a role to play in avoiding the detrimental use of some fossil gas, it will be limited. These gas sources are often not as climate-friendly as claimed, and burning fuels like methane still creates harmful air pollutants. The limited supply and high cost of these fuels also inherently limit what they can contribute. Across the United States we will need to be strategic about how and where we deploy these resources to ensure they are used to complement, and not detract from, our primary focus on ramping up scalable renewable electricity resources for the sake of our health and the climate.

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ENDNOTES

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16 NRDC roughly estimated the portion of the AGF potential gas supply that could be considered "ecologically sound" based on our experts' review of each resource. Our estimate includes 100 percent of the AGF's projected 2040 supply of synthetic methane. The estimate for biogas that we use aligns with the policy recommendations in Figure 2. We include 100 percent of the AGF estimate for feedstocks for which we recommend "Support" (wastewater treatment), 75 percent of the feedstocks for which we advocate "Support in the near term" (landfill gas), 50 percent of the feedstocks needing "Limited Support" (organic components of municipal solid waste, agricultural residue), and 25 percent of the feedstocks requiring "Strong Caution" (animal manure, forestry and forest residues, energy crops).

17 The report notes: "ICF estimates that there were about 17.5 tBtu of RNG produced for pipeline injection in 2016 and that there will be about 50 tBtu of RNG produced for pipeline injection in 2020." Ibid., 10.

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