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“Realizing the Full Potential of Winter-Hardy Cover Crops and Prairie Biomass through the Production of Renewable Natural Gas”

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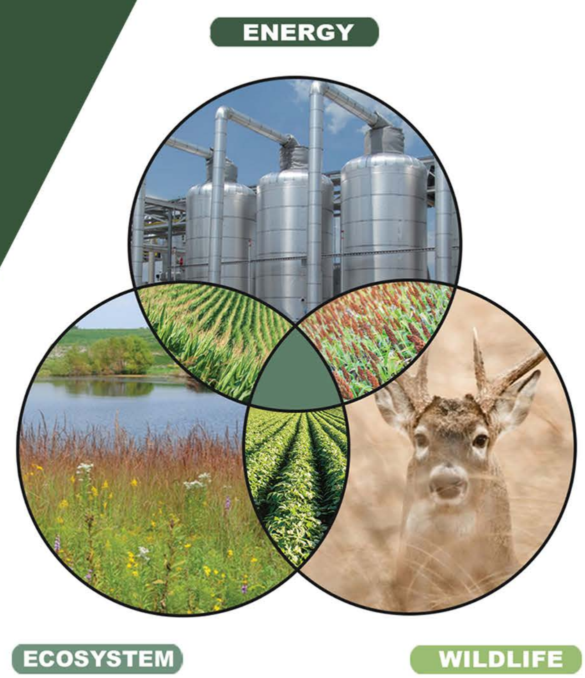

White Paper: Realizing the Full Potential of Winter-Hardy Cover Crops and Prairie Biomass through the Production of Renewable Natural Gas
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I. Background on Anaerobic Digestion and Renewable Natural Gas

America is in the midst of an energy transition that is impacting all sectors of our society, changing the way we power our industries, heat our homes, fuel our cars, and grow our food. The energy systems of the future must continue to be reliable, abundant and affordable, while also addressing climate change and other environmental challenges. Progress is being made to decarbonize the electric grid, where renewables plus nuclear energy now constitute over 42% of the energy supply[1]. However, there is another energy grid, the natural gas grid, where renewables represent less than 0.5% of the supply[2,3]. Renewable Natural Gas (RNG), produced from organic wastes and biomass through the process of anaerobic digestion, can play several unique and critical roles in the energy transition. Among other benefits, RNG can reduce greenhouse gas emissions in otherwise difficult to decarbonize sectors of the economy while also serving as an engine of economic growth and rural development, and improving the environmental sustainability of food and agricultural systems.

Anaerobic digestion is a natural process of organic matter decomposition that in the absence of oxygen produces biogas, a mixture of about 60% methane and 40% carbon dioxide. Humans have been using biogas for cooking and heating water for over 2000 years, and there are millions of small scale digesters in tropical regions of the world[4]. Anaerobic digestion works fastest at temperatures above 90F, so in temperate climates most digesters are buried in the ground and often heated. Despite this extra complexity and cost, over the past few decades thousands of digesters have been built in the U.S. and Europe to process livestock manure, food waste, sewage sludge and other organic material. One of the important advantages of anaerobic digestion is that, under these conditions, anaerobic microorganisms can process almost any kind of biomass including prairie grasses, cover crops, and crop residues. While traditionally biogas has been used on site for heat or electricity production, by separating the carbon dioxide and purifying the methane to meet pipeline standards, biogas can be converted to RNG and then injected into the natural gas grid[5].

II. The many roles of RNG in America's energy future

Most pipeline natural gas is 85% to 95% methane, and those methane molecules are chemically identical to the biobased methane in RNG. As a result, when RNG is injected into the natural gas grid it blends seamlessly into over 3 million miles of existing pipeline infrastructure, including about 2 months of long-term gas storage, and is accessible to over 77 million natural gas customers across the U.S.[6,7] While RNG incentives in the U.S. are currently limited to transportation in natural gas vehicles, these customers can also use RNG for residential and commercial cooking and building heat, industrial process heat, chemical manufacturing, and electric power production, all without any modifications to their current facilities. In the case of electricity generation, existing long term gas storage allows RNG to be used to produce "dispatchable" renewable electricity, filling in the gaps for intermittent sources such as solar and wind, and providing a much lower cost alternative to battery storage[8].

As the current energy transition continues to unfold, RNG can also play a critical role in the emerging hydrogen, sustainable aviation fuel, bioplastics, and carbon capture industries. Hydrogen can be made from RNG through conventional steam methane reforming and other technologies at a much lower cost than by electrolysis of water and without diverting massive amounts of renewable electricity needed to decarbonize other sectors of the economy[9]. Moreover, RNG, as well as hydrogen derived from RNG, can also be processed into sustainable aviation fuel, bioplastics and other fuels and materials. Coupled with carbon capture and storage of the carbon dioxide associated with RNG separation and these various industrial uses, expanding production of RNG can not only reduce emissions from waste management and fossil energy systems but also sequester atmospheric carbon dioxide[8,10].

III. Grass to Gas: Growing RNG production to meet demand

While the last few years have seen a rapid increase in the number of anaerobic digestors in the US, high capital costs and economies of scale have focused most of this investment on large livestock farms. The US Environmental Protection Agency (EPA) estimates that anaerobic digestion is currently cost-effective for swine operations with more than 2,000 head and dairies with more than 500 cows[11], with a total biogas potential[12] of 170 million mmBTU yr^{-1}. Food waste, which is currently co-digested in about 15% of farm digesters because of profitable tipping fees, could produce an additional 180 million mmBTU yr^{-1} of RNG[13], resulting in a current total of 350 million mmBTU yr^{-1} With these high-protein feedstocks providing process stability and adding value to coproducts, farms can add biomass from cover crops and perennial crops to achieve economies of scale, even for farms without livestock or with limited acres in annual crops[14,15].

Roeslein's Horizon II strategy, adding winter crops and prairie biomass to digesters to achieve economies of scale for smaller farms and those without livestock, could expand this potential by a factor of four or more. Incorporating a winter biomass cover crop like cereal rye or triticale on the approximately 100 million acres of winter fallow currently available across the U.S. Corn Belt would result in at least 120 million dry tons of additional biomass[16]. Horizon II also aims to revegetate 30 million acres of prairie, where harvesting an average of 3.5 tons $acre^{-1}$ on alternate years would supply an additional 50 million dry tons of biomass annually. Assuming a 60% energy yield of biomass to RNG, these winter crops and prairie biomass feedstocks could produce 1500 million mmBTU yr^{-1} of RNG.

To put these numbers in perspective, today RNG from landfills and manure supplies about 0.4% of U.S. natural gas demand[2,3], which is estimated by the U.S. Energy Information Agency to reach 8.2 billion mmBTU's in 2024[17]. Digesting manure and food waste could increase this supply to just over 4% of current U.S. natural gas demand. Adding in the winter cover crops and prairie biomass needed to achieve the Horizon II vision could supply over 17% of all U.S. natural gas demand. Horizon II estimates full implementation of its strategy by 2040 would generate $70 billion in new revenue, and provide a carbon emissions reduction of 250 million metric tons of CO_2e annually[18], providing with renewable energy, rural economic development, and a major climate solution to present and future global challenges.

IV. Sustainable energy can incentivize sustainable agriculture

While RNG can play a critical role in a sustainable energy future, its role in sustainable agriculture may be even greater. In the US, Europe, and in many other countries around the world, implementing anaerobic digestion on farms has been shown to enhance crop and livestock production, reduce GHG emissions, recycle nutrients, improve water quality, and increase biodiversity[19,20,21]. Many farmers with digesters see it as a keystone technology for their farm, with synergies that enhance the circular economy of the farm and reward regenerative agricultural practices. While these benefits have thus far have largely been limited to large livestock farms, the ability of digesters to process virtually any plant biomass opens up this technology to many more farms, greatly increasing its economic and environmental benefits.

In addition to increasing soil carbon and enhancing soil health, both cover crops and prairie reconstruction can reduce nutrient loss from farm fields by 50 to 90%, protecting valuable water supplies and aquatic ecosystems. In the upper Midwest, growing cover crops on an additional 20 million acres (one fifth of the Horizon II goal) would reduce nitrogen loading to the Gulf of Mexico by 27%[22]. Moreover, strategically locating prairie strips on just 10% of a field has been shown to reduce total P and total N loss from annual cropland by 84% and 90% respectively[23]. There are many positive benefits of reconstructed prairie for biodiversity, including as habitat for the critically listed monarch butterfly, other pollinators, and grassland birds[24,25,26]. By creating new, local, and flexible markets for cover crops and prairie biomass, Horizon II digestors will incentivize growers to increase their acreage of conservation plantings. Additionally, with appropriate nutrient stewardship and harvest rates and timing, the ecosystem services provided by these conservation practices can be retained, and sometimes even enhanced, when these crops are harvested for bioenergy[27,28].

V. Policy innovation is needed to drive RNG performance

While the contributions RNG can make to the energy transition, climate solutions, rural development and regenerative agriculture are extraordinary, they will not happen without appropriate policy support. Current federal policy and financial incentives for RNG are very narrow, and their near term future is uncertain. The primary incentives for RNG are as a transportation biofuel, specifically through the federal Renewable Fuel Standard (RFS2), California's Low Carbon Fuel Standard (LCFS). RNG has the lowest (best) LCFS carbon intensity scores and makes up over 99% of the highest trading RFS2 category (cellulosic D3 RINs), but these incentives require that the RNG is used in natural gas vehicles. In 2020, RNG provided 52% of the fuel for on-road natural gas vehicles across the U.S., and that share increased to 69% in 2022. At these growth rates the transportation market for RNG will be saturated sometime in 2026 or 2027, and the primary driver for RNG growth will be questionable. While this is a phenomenal success story, it also demonstrates the risk of narrowly targeted policies, and the immediate need for a more broad-based set of market incentives if RNG is to achieve its potential.

One such broad-based policy option is tax credits for investments in RNG infrastructure. This should include digesters as well as the gas conditioning and clean up equipment needed to upgrade biogas to pipeline quality, and gathering pipelines to transport RNG from farm to market. Capital costs are the primary reason digesters are out of reach of small and mid-sized farms, and represent a massive barrier to increasing the fraction of RNG in the natural gas grid beyond 1%. While tax-credits are not the only broad based incentive possible, they are widely used across other energy sectors and have been proven themselves effective.

While investment tax credits are important, other programs can address the capital cost challenge and may be more beneficial to smaller farms with sufficient profit for tax credits to be meaningful. These include existing USDA programs like the Rural Energy for America Program (REAP)[29] and the Environmental Quality Incentives Program (EQIP)[30] that provide cost-share on the capital costs, but where current program requirements can be challenging and available funding is not sufficient for many farms. Other approaches that have proven successful for small and midsized farms across Europe include feed-in tarrifs, which are long-term contracts with guaranteed access to the grid and a floor price for the renewable natural gas product[31,32,33,34]. Farmers and ranchers can take these contracts to their banks to get loans against future revenue.

Incentives to RNG should also be structured in ways that encourage digester owners and operators as well as pipeline distributors and end users to eliminate fugitive methane leaks. When the feedstock for digesters is manure or food waste that would otherwise be producing methane in open lagoons or landfills, even a poorly maintained and leaky digester can reduce methane emissions by 80 to 95%. However, for plant biomass that would have otherwise decomposed aerobically to carbon dioxide, putting it in a digester and converting it to methane increases its global warming potential (GWP) by a factor of 23 over a 20 year timeframe (GWP_{20}). While other metrics may be more appropriate for short-lived GHG like methane in the livestock sector where historical emissions are high[35,36], for new methane resources like grass to gas, leakage rates need to be close to zero as even a small leak can have a major impact[37]. Third party audits and carbon intensity scoring such as is used in the LCFS can provide a good framework for cradle-to-cradle GHG emissions accounting. But these performance-based incentives need to be extended beyond transportation to encourage efficient and climate smart use of RNG in a broad range of end uses.

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Finally, if the natural gas grid is going to truly serve as a low carbon renewable energy grid, those 3 million miles of pipeline will need gas-tight upgrades, close attention, and careful maintenance[38].

Over the last three years, the RNG industry has averaged a 24% annual growth rate[39]. In another three years, natural gas vehicles are likely to be the first sector of the U.S. economy to achieve 100% conversion to renewables. While this is an incredible achievement, it also comes with an incredible risk. Transportation is less than 1% of the potential RNG market, yet is the only part of that market with adequate policy support.

Continued growth of the RNG industry can decarbonize America's second energy grid, leveraging a vast resource of pipeline and end user infrastructure. That grid can provide renewable heat and power for homes and businesses, reliable and cost effective energy storage, and help decarbonize challenging industrial sectors like steel, cement, hydrogen, aviation fuel, and plastics. Remarkably, anaerobic digestion can also be the keystone technology connecting both sustainable energy and sustainable agriculture, improving soil health and water quality, enhancing biodiversity, and reducing GHG emissions on thousands of farms across America. A thriving RNG sector can generate $70 billion a year of revenue, create tens of thousands of new jobs, and serve as an engine for rural development.

Nonetheless, this sector will not grow on its own. It needs supportive policy, with broad-based incentives such as tax credits to help small and medium sized farms, project developers, and pipeline companies invest in the needed facilities and infrastructure. Besides, the sector needs guardrails, simple but effective measurement and monitoring to assure safe and strong system performance. Every party along the value chain from farmer/producer to consumer/user needs to know that the entire system performs as it should, and that decarbonization of the natural gas grid is not only possible, but actual.

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