gevo®
FUELING THE FUTURE

SUSTAINABLE FARMING PRACTICES AND ADVANCED RENEWABLE FUELS

Intertwining science and nature to create fuel for the future.

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SUSTAINABLE FARMING PRACTICES

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"Like anything new, a sustainable energy system and the transformation process to get to it can present new opportunities. At Gevo, we look at the situation from a whole new angle."

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Introduction

Agriculture enabled some of humankind's earliest organized settlements, allowing disparate, roaming hunter-gatherer networks to stay in one place. Communities would form where the soil was healthy and water was close. With some hard work, learning, and ingenuity, the food supply became reliable and renewable year after year, without the need to travel to find more resources.

Many of these core ideas apply today, and the stakes today are much larger: Nothing less than the ability of our planet to continue to support life is at risk.

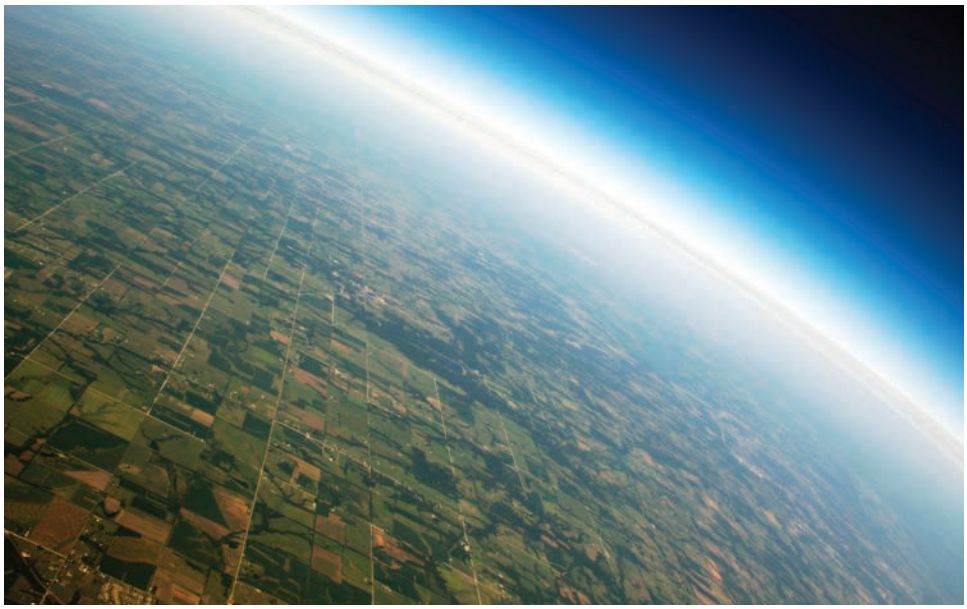
The challenge of sustaining life on Earth would seem a daunting task, due to its scale and importance. At Gevo, Inc., we believe that human enterprise, intelligence, and industriousness can overcome any obstacle, and that's because we're able to focus on the details and leave no stone unturned in pursuing our goals. We consider innumerable factors as we build an economically and environmentally sustainable system to create our advanced renewable fuels.

Gevo has invented our own proprietary process to make renewable fuels that utilizes carbon captured from the atmosphere by plants. The same mechanisms that allow your grass to grow, and nurture the trees outside your house have been perfected over hundreds of millions of years of evolution: This is the best carbon-capture technology available. Gevo has chosen to leverage this efficient and scalable biological system. There's plenty of carbon in the atmosphere right now, and its concentration level is growing every day—why not make use of it? Think about it: Every day we dig up more carbon or pump it out of the ground. The carbon contained in fossil fuels was sequestered in the earth millions of years ago, and humans have diligently worked to release it to the atmosphere, particularly over the last 120 years. Why? Because it was a concentrated and easy-to-use energy form, and immensely profitable to do so in our society. Now that carbon in the atmosphere is too great for Earth's natural systems to find their equilibrium. We need to help the planet reduce the carbon in the atmosphere in ways that won't harm other life on Earth. One way to do that, is to use the carbon that is already in the atmosphere as a resource, rather than continue to be reliant on the carbon that's buried deep in the Earth.

Fossil carbon is a linear path: It comes in the form of petroleum, natural gas, and coal that was removed from the ground, transported and refined by means of energy-intensive processes, combusted in an engine or boiler, and released to the atmosphere. This is a non-sustainable, non-renewable cycle, similar to a fire hose—an intense one-way flow of carbon out of the earth and into the air we breathe. Like any business, the petroleum industry has worked to get more efficient over the last century, but that means it's become better at releasing carbon dioxide into the atmosphere and making more money doing it. Those petroleum efficiency improvements don't offer a path to fully transform our energy sector into a sustainable system, because they will never address the true issue: the source of the carbon. None of the ideas are enough. Instead it requires a whole new way of thinking to design a sustainable energy system. As Albert Einstein said: "We cannot solve our problems with the same thinking we used when we created them."

Like anything new, a sustainable energy system and the transformation process to get to it can present new opportunities. At Gevo, we look at the situation from a whole new angle. Carbon is the resource we need to produce energy. Since there's plenty of carbon dioxide in the atmosphere now, free for the taking, why not use that to make our fuel? We make isobutanol from No. 2 yellow dent corn. The corn we use draws carbon from the atmosphere and uses photosynthesis to fix it into energy-rich molecules that end up in the grain

THERE'S PLENTY OF CARBON ALREADY IN THE ATMOSPHERE, AND IT'S AVAILABLE FOR THE TAKING.



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itself, and are also excreted through its roots. Isobutanol is a four-carbon alcohol that is the primary building block of our renewable fuels. To build our combustible fuel molecules, we use the carbon in the carbohydrates from that corn. It's an industrial crop used historically to feed livestock and is not used to feed people directly. Corn grows by collecting carbon dioxide and solar energy from the atmosphere through photosynthesis, and utilizes that carbon to build carbohydrates, proteins, and fiber.

The advanced renewable fuels that we make work exactly the same way as those derived from petroleum. They're fungible and are proven to react synonymously in the same engines and boilers, but in our case the carbon in those hydrocarbons has been recycled from the atmosphere. They are the same atoms in the molecules, just coming from the air rather than deep in the ground. When you burn the fuel, the carbon goes back into the atmosphere, where plants can take in that same carbon again and Gevo can build another molecule for you to burn. And as a bonus – anywhere between 15 and 30 percent of the carbon the crop draws from the atmosphere is excreted into the soil around its roots. This carbon feeds microbes important to crop growth and transform carbon nutrients into soil organic matter. The result is a dual benefit: increased soil fertility and significant amounts of what was once atmospheric carbon gets locked away in the soil. Given that there are close to 90 million acres of corn grown in the U.S. every year that is a remarkable pool of carbon locked into soil on an annual basis.

Think of our whole process of using carbon as a fountain, where the carbon in the atmosphere is the water in the pool at the fountain's base. It is drawn up into the fountain and falls back into the pool. The carbon is recycled, and therefore our fuels do not put additional carbon into the atmosphere, they just use the carbon that is already there. Each spring the corn grows from seedlings to stalks over six feet tall, drawing in atmospheric carbon, and storing energy in each kernel of corn. And of course, since it's nature's system, there's no waste, every part of the plant plays a role. The plant accumulates carbon above ground and its roots release carbon into the soil. The whole system works together to create more healthy soil and placing even more carbon deep into the ground as organic matter where it further enriches and regenerates the productivity of the soil and its ability to hold water and nutrients.

These farmers are the stewards of their land. They know every inch of their landscape, study it, examine how the water flows over it, under it, and throught it.

THE ROOTS OF EVERY CORN STOCK SEQUESTER CARBON IN THE SOIL.

Just like the production of petroleum, farming has become more efficient over the years. Unlike the production of petroleum, farming has also increased its level of sustainability throughout the process. Why has this happened? Again, it has served to improve profitability. Farmers know that they need to grow healthy soils in order for their farms to not only be successful now, but also for the next generations. Economically speaking, efficiency and sustainability are the parallel paths to success on a farm. Gevo works with our partner farmers to help improve their sustainability, because it reduces the carbon intensity of our fuel, helps the farmers be better stewards of the land, increases their yield per acre, and sequesters more carbon in the soil. The result is that our partners are there, season after season, year in and year out, caring for the land. This matters to Gevo, as the geography of our suppliers is a significant factor in the efficiency and sustainability of our business.

With advanced renewable fuels, the sustainability of all the applicable processes adds together to create value. The sustainable, regenerative agricultural techniques used to ensure a steady supply of feedstock reduce the carbon intensity of the fuels. Gevo is creating a system to create fuels with net-zero carbon or better, and our farmers are the cornerstone of our strategy to achieve that goal.

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Part I: Background

Farming has taken its knocks over the last century: From the time of the Dust Bowl during the 1930s, poor soil management, overgrazing, and drought in the southern plains combined to cause huge dust storms. Throughout American history, farms have been the subject of political gamesmanship over subsidies, accusations of land mismanagement, corporate ownership and agribusiness as multinational entities buy up huge swaths of the richest farmland in the world, the perception of indiscriminate use of pesticides and excess fertilizer, and responsibility for high food prices.

From Gevo's point of view, there's a very different story that is not being heard and we see it every day in our partner farmers. These farmers are the stewards of their land. They know every inch of their landscape, study it, examine how the water flows over it, under it, and through it. They understand soil quality and select seed varieties and cover crops that will improve and build the soil and allow the water to be filtered before it approaches waterways. They plant corn because that's the crop they saw in every direction when they were children, and it courses through their veins. But they've grown up and have also grown wise and smart. They learn about how to make their land more productive than their parents and grandparents could ever imagine. They understand that they need to care for their land in order for their land to take care of them, and the generations of their families that follow. They explore different methods, read the science, and use the tools and techniques that can make a difference. And it does make a difference, as these measurements attest:

- In the United States in the last 30 years, the value of agriculture production has more than doubled from $148.55 billion in 1991 to $327.5 billion in 2016 [source: Our World in Data Value of Agriculture Production 2016, based on data from the Food and Agriculture Organization of the United Nations (FAO) 2020].
- The value of agriculture per worker in the U.S. in that time has grown from $31,002 in 1997 to $83,735 in 2016, a 170-percent increase [source: Our World in Data, based on data from World Bank – World Development Indicators].
- Since 1961, less land is being committed to agriculture in the U.S., down 9 percent of total land area, and yet production of corn has increased per hectare by 174 percent. [source: Our World in Data, based on data from World Bank – World Development Indicators].
- From 1866 to 2014, U.S. farmers increased their yield by 557 percent, producing more than 9 additional tons of corn per hectare. [source: Our World in Data, based on datasets from United States Department of Agriculture (USDA) and the UN Food and Agricultural Organization (FAO].

These farmers understand where the roots meet the soil better than anyone. And no one toils harder to make their business work. So when we use the term sustainable, these generational landholders hear exactly what we mean. They want to learn more, they want to try new techniques, and they want to share the information with their friends and neighbors. The word is in their blood as they preserve their birthright for their children, and it means keeping the land and letting the land keep them.

Part II: Soil Management

In America's Heartland, farmers raise No. 2 yellow dent corn in huge quantities. These farmers are stewards of the land, and many of their families have been on the same land for generations. They understand how to get the most out of their land and they know every square inch of their plots. For these farmers, their land is their asset to make money, and they are always looking for ideas that will help their land produce sustainably.

Like any business, farmers pay attention to trends and collect data. They use modern science and technology—and it has been helping them to increase the yield of each acre, preserve water, and enrich their soil, which allows them to reduce fertilizer use and other inputs.

Look to the Stars

Farmers can gain access to satellite imagery to look at their fields and the overhead vantage point provides a distinct advantage. They can spot target problem areas in fields where there may be insects, or drainage problems, or other factors that may have an adverse effect on the health of plants. The treatments can be targeted too, with

COVER CROPS HELP REDUCE THE CARBON INTENSITY OF AGRICULTURE.

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sophisticated systems for fertilizer application, pesticide delivery, and water management. The farmer can direct the solutions to the specific target area, improving efficiency and reducing time, labor, and cost.

Farmers also have satellite guidance systems that allow their tractors and harvesters to optimize the land they farm. By programming their tractors and harvesters with GPS-controlled precision, farmers make the most of the geometry and topography of their fields, and have a deep understanding of their drainage, wind and sun exposure, and more. That means that today, many farms have different land inputs on every square foot of field, only adding just the right amount of fertilizer or pesticide for that specific location in their fields. This will continue to increase in importance as more targeted agriculture methods and solutions are delivered by technology in a future that may be nearer than many of us think.

"Growing" Soil

Because the soil is a key factor in their success each year, good farmers work to preserve and replenish their soil, and build up this rich

KEEPING CORN STOVER IN THE FIELD SAVES VALUABLE NUTRIENTS.

combination of minerals, microbes and organic matter, replenishing it with proven methods, refined and upgraded season after season.

Gevo's partner farmers use no-till or low-till techniques. Sometimes called strip-tilling or zone-tilling, this method tills a narrow strip of soil, four inches wide, where the seeds are planted and the fertilizer is applied only in this specific location so it can aid in the early growth of foliage and roots following seed germination.

Because zone-tilling is precision guided by farm equipment with satellite navigation, the strips can be placed between the rows of last year's crops, leaving the existing root structure to hold the soil together as it decays. This additional organic matter feeds soil microbes and represents amplified sequestered carbon, drawn down from the atmospheric carbon pools. Measuring this carbon sequestration is part of the equation of reducing the carbon intensity of every gallon of fuel. Gevo's sustainable aviation fuel captures somewhere from 1¾ to nearly 9 pounds (0.8 to 4 kilograms) of atmospheric carbon dioxide equivalents in the soil for every gallon of jet fuel produced.

Increasing carbon in the soil helps to offset the impact of fossil fuels, but also increases feed and food production capabilities for the growing global population. The use of this natural storehouse could allow us to sequester an additional 1 billion to 3 billion tons of carbon annually. That's equivalent to roughly 3.5 billion to 11 billion tons of carbon dioxide emissions.

One aspect of sustainability that often gets discounted in the discussion is economic sustainability. Fertilizer is expensive for farmers to buy and apply to their fields. Purchasing the nutrients and employing the labor and equipment to spread them is a pricey proposition, and over thousands of acres, it adds up. By leaving the organic matter from last year's corn and diverse cover crops in the soil, that field also preserves nutrients from last year, held in the root and stalk of the corn and cover crops left in the field after harvest, as well as the microbial biomass represented as soil organic matter that holds more water, more nutrients and aerates the soil. This complex ecosystem of nutrient-rich soil will help next season's plants grow, and require less applied fertilizer to support this increased productivity. Most of the biomass used to produce Gevo's advanced fuels comes from sources that use regenerative farming techniques that build soil organic carbon.

Drain Tiles and Water Flow

As rainwater flows in spring, it can rob the topsoil from corn fields, and can take valuable nutrients with it, while also making early-season fieldwork challenging. Many farmers employ drain tiles to control drainage. Water control systems can be added to let them preserve water for later in the season, when soil moisture on its own can't keep up with crop water demand. Water control structures stem the flow in drain tiles by raising the level of water retained. Using these devices, farmers can set the water levels they want,

allowing more drainage early in the season to allow field work while keeping soil from eroding. Then, farmers can raise the water level, using the drain-tile system to hold more water in the field soil, preventing nutrient losses.

Nitrate losses and runoff from farms have been blamed for water-quality issues and hypoxia events downstream—including widely publicized "dead zones" in the Gulf of Mexico. Preventing the nutrients from running into rivers where the common perceptions indicate detrimental effects is another aspect of sustainability. Instead, use of drain tiles combined with increased soil organic matter, reduced tillage and cover crops work with water-level control structures to keep the nutrients on the property, where farmers can benefit by helping them achieve yield targets, and reducing the need for additional and excessive fertilizer and water.

Engineered water-control systems show improved yield that can help defray the cost of the system installation in as little as two years, while reducing yield losses from farms that have extended periods where fields are too wet or too dry in the growing cycle.

Part III: Reducing and Offsetting Greenhouse Gas Emissions

Reducing global greenhouse gas emissions through sustainable or regenerative agriculture has until recently been poorly understood and often overlooked. Agriculture can leverage Earth's natural systems to pull significant levels of carbon and other gases with global warming potentials from the atmosphere. When sustainability is not considered, agriculture can also release GHG emissions, such as carbon dioxide and nitrous oxide. Carbon emissions from petroleum fuel sources and combustion engines continue to grow year over year and are the driving force behind atmospheric carbon levels, but agriculture can also be part of the problem or, if managed correctly, the solution. Reducing the GHG emissions from soil, livestock, and manure sources helps reduce carbon intensity and improve the sustainability of Gevo's feedstock and fuel production.

Improved high-potency microbial soil amendments—or soil "probiotics"—can be used to stimulate enhanced crop vigor, increased nutrient uptake, enhanced photosynthesis, and the substantial expansion of crop roots. The augmented microbial populations associated with these larger root systems result in elevated levels of complex carbohydrates being exuded from them.

Farmers who keep livestock as a complement to growing corn also have a source of organic, inexpensive fertilizer in the form of manure... which keeps the nutrients from the corn on their farms, without needing to buy or truck in synthetic fertilizers.

CAPTURING LIVESTOCK METHANE EMISSIONS HELPS SUSTAINABILITY.

Gevo's partner farmers can use solutions such as Rhyzolizer® from Locus AG Solutions to improve yield, increase soil carbon, and reduce the soil's naturally occurring emissions of nitrous oxide, which has 300 times the GHG impact as carbon dioxide. By improving photosynthesis and root growth in corn crops, Locus AG Solutions has shown its products increase a plants' ability to absorb nutrients, increase crop yields, reduce soil nitrous oxide emissions, and amplify soil carbon sequestration to reduce the carbon footprint of the grain harvested from fields. Farmers apply this proprietary combination of fungal and bacterial microbes through irrigation or placement in the root zone at planting, and have seen improved yield to the tune of up to 20 percent or 11 more bushels per acre and a 24 percent increase in root weight. More mass means greater root volume to capture nutrients and also to supply complex carbohydrates to feed the elevated microbial populations, resulting in more carbon sequestered in the soil with each growth cycle. According to Locus AG Solutions, corn is shown to sequester as much as five additional tons of carbon dioxide equivalents per acre annually.

The ethanol plants that can be converted to use Gevo's proprietary GIFT system for producing isobutanol are situated among the farms and corn fields. These same farms will supply the feedstock to the plants that will produce Gevo's advanced renewable fuels,

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meaning that suppliers don't have to truck their crops over long distances to deliver them to the plant. In Luverne, Minnesota, where Gevo operates its pilot isobutanol plant, many of the farmers are near enough to haul their trailers full of harvested corn with a tractor, instead of a highway-ready tractor-trailer.

As an added benefit, many of these farmers also become Gevo's customers as well. Gevo's process yields a high-protein animal feed, which many farmers surrounding the Luverne facility purchase to feed the livestock they keep on their farms. This feed reduces the starch intake for the livestock, resulting in leaner, healthier animals who produce less gas, such as burps and flatulence, as a result of their diet. While those cow burps—enteric fermentation in animals—may seem small, those emissions account for 28 percent of the agriculture emissions overall in the U.S., according the EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2006 (2008). Reducing this methane output is still another GHG emission reduction.

Farmers who keep livestock as a complement to growing corn also have a source of organic, inexpensive fertilizer in the form of manure. By employing this manure, farmers keep the nutrients from the corn on their farms, without needing to buy or truck in synthetic fertilizers.

The manure also can be placed in digesters that use natural yeasts to break down the manure, releasing methane which is then captured and used for energy as renewable natural gas—called biogas. Gevo is planning to install these digesters at farms in the area and use the biogas to offset even more of the energy use at the production plant, making the most of this renewable resource. The use of biogas will have the advantage of reducing GHG emissions from the manure, while also reducing the dependence on petroleum-based natural gas for energy, and this is all taken into account in the fuels' carbon intensity.

Life-Cycle Assessment and Argonne GREET

GHG emissions for renewable fuels are most commonly evaluated through a life-cycle assessment (LCA), which calculates the amount of greenhouse gases that are released per unit of energy, including emissions and carbon sequestration. Emissions reductions are highest for advanced biofuels. (Environmental Energy and Study Institute, "Biofuels Vs. Gasoline: The Emissions Gap Is Widening," September 2016). Gevo's product line focuses on decarbonization of the process at every step to give each of its advanced renewable fuels, chemicals, and co-products the lowest carbon LCA possible. The LCA was long considered to be the best yardstick of carbon intensity in fuels and chemicals produced to replace those derived from fossil fuels.

At Gevo, we're always looking for a better way to do things. The Argonne GREET 2020 Model (The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) provides a standard of measurement for the real impact of transportation fuel, measuring a fuel from feedstock to production to combustion, with key factors taken into account, such as land use with respect to food production and habitat, water-quality impacts, and more, all in a Life Cycle Inventory (LCI) measurement. The GREET model has been used and put to the test in the California Air Resources Board Low Carbon Fuel Standard (CARB LCFS) where it has demonstrated accurate assessment of comparisons in transportation systems.

As Gevo explores additional markets for advanced renewable fuels around the world, other regeneratively grown feedstock options will become possibilities, from sugar beets to sugarcane, to lignocellulosic sources such as rice straw, bagasse, and even woodslash.

We need consistent, fair, scientific methods to document LCI and in particular carbon savings. We need a system that can accommodate improvements at the farm level and be useful in creating incentives for farmers to adopt even better growing practices. By doing so, we should be able to produce more raw materials for fuels, while we produce protein that ultimately goes into the food supply, all while the systems implemented capture more and more carbon dioxide from the air into soil. The GREET Life Cycle Inventory is the measurement that needs to be adopted as the industry standard.

Think of a tank of Gevo's advanced bio-based renewable fuels as a battery that stores renewable energy. All the additions to the fuel's carbon score measured by the GREET LCI are taken into account, because this metric tracks carbon emissions and sequestration from all steps of the process, including the final combustion of the fuel. Every gallon of Gevo advanced renewable fuel coming from sustainably grown corn sequesters more carbon in the soil than is contained in the fuel itself. The carbon dioxide that's released when the fuel is combusted is in turn consumed by the cornfields as millions and millions of corn stocks grow from seed to more than six feet tall, storing energy in every stalk and root, leaves, soil microbes and most importantly, every grain in every ear of corn. And these fields of corn draw more carbon from the atmosphere as new seed is planted each spring and stalks grow to maturity each year. Consider the fields that grow the feedstock for this fuel to be solar collectors that work in concert with our process to create a low impact and perpetual energy source that renews itself annually. Also Gevo uses renewable energy in our production process, in the form of wind power turbines and biogas manure digesters. All of those sources reduce our carbon intensity

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and put energy into the battery that are the liquid fuels that are ready to drop into any existing vehicle, engine, or system that runs on conventional petroleum-based fuels.

Tracking Sustainability

While it's great to beat the drum of "sustainability," it must be tracked and certified to be an effective way to combat GHG emissions. There is simply too much risk of false sustainability claims and "green washing." Distributed Ledger Technology, or DLT, is an immutable tool that allows tracking of data with a product and the transactions associated with the product. Gevo partnered with Blocksize capital to create Verity Tracking to develop the DLT tool using blockchain technology, and will let Gevo make the most of the key metrics for sustainability by attaching these metrics to each gallon of advanced renewable fuel produced, enabling a "sustainability" assurance that has not yet been seen in the industry. This technology minimizes the risk of fraudulent claims. As this sustainability assurance is digitized through blockchain, the goal is to tokenize those attributes, and create true value that will be shareable through market mechanisms. Again, economics enters the picture, lending its positive force to the encouragement and funding of sustainability. Enabling a market of sustainability that is traceable and immutable allows people to truly make sustainable investments. Corporations who wish to make sustainability claims can then be held accountable to those claims.

OTHER BIO-BASED FEEDSTOCKS, SUCH AS SUGARCANE MAY INCREASE GLOBAL IMPACT.

Other Feedstocks Mean Other Models of Sustainability

As Gevo explores additional markets for advanced renewable fuels around the world, other regeneratively grown feedstock options will become possibilities, from sugar beets to sugarcane, to lignocellulosic sources such as rice straw, bagasse, and even woodslash. The necessity of adapting the system to crops around the world is reinforced by the geography—shipping fuel around the world in tankers or trucks will add carbon intensity to any life cycle. The value of the system being developed by Gevo is that communities will be able to avoid importing fuels from distant locations by "growing" the fuel locally – lowering carbon intensity, creating jobs, preserving local capital for local use, and adding to their energy independence. Also consider that the idea of using these additional feedstocks means that many of the advantages of corn as a feedstock will not translate, but other ideas to increase sustainability and reduce the carbon intensity of the other feedstocks will percolate as Gevo takes an inventive approach. Remember carbon-negative feedstocks are only possible from feedstocks that are grown in with practices that specifically sequester carbon, so this is impossible from waste feedstocks like used cooking oil. These feedstocks will begin to reveal their own carbon-intensity-reducing properties as Gevo and its partners begin to investigate and further develop these systems.

Conclusion

Every business is staring down the barrel of environmental and economic sustainability, whether their principals know it or not. Producers of advanced renewable fuels and farmers make decisions every day that can have a positive impact on sustainability, positive environmental outcomes, and the economic benefits that they and their communities derive from it. The idea is to take these solutions and metrics to consumers and help them to understand the impact every purchasing decision they make has on the greater world. After all sustainability is a global problem that requires a global solution and global participation.

As our work draws carbon from the atmosphere to make fuel and also increase the amount of carbon sequestered in soil, we continue to seek agreements around the world that will expand the reach and the adoption of our advanced renewable fuels. Every challenge is an opportunity, and all solutions are going to be needed if we are going to effect real change in the trajectory of the world's climate. One cannot be afraid of the challenge in order to find greater solutions, and we all have to meet the challenge head on.