

HEALTHY SOILS AND THE CLIMATE CONNECTION

A Path to Economic Recovery on America's Farms



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INTRODUCTION: AN OPPORTUNITY ON FOUR FRONTS

Most initiatives to fight climate change today focus on reducing fossil fuel emissions from electricity generation, transportation, and buildings. But to avoid the worst impacts of climate change we must also significantly reduce the atmospheric carbon that has already been emitted. While efforts are underway to develop new and high tech mechanisms to accomplish this, there is an immediately available and economically viable pathway for atmospheric carbon removal—one that provides a compelling new value proposition for farmers to revitalize their soils and get paid for doing it.

Regenerative agriculture methods such as cover cropping, crop rotation, low-till or no-till practices, and reduced reliance on fossil-fuel based inputs can mitigate climate change by drawing down atmospheric CO₂ and sequestering that carbon in the soil, while improving microbial soil health, and increasing soil fertility, crop yield and resilience. These practices also produce multiple additional economic and environmental benefits.

For most of the past decade, agriculture has been one of the most challenging sectors of the U.S. economy. American farmers have had to endure plummeting crop prices, trade-war tariffs, rising costs for inputs like fertilizer, and increasing crop and livestock losses from extreme weather events and less predictable growing seasons—an estimated 85% of U.S. crop losses are due to extreme weather events.¹ Then came COVID-19, disrupting supply chains, upending markets such as restaurants, schools, and institutional food, and further dimming farmers' prospects with a likely extended recession. According to the Food and Agriculture Policy Research Institute at the University of Missouri, net farm income could plunge by 19% (\$20 billion) in 2020.²

But climate-smart agriculture and soil carbon drawdown are in the nascent stages of ushering in a potentially game-changing chapter in 21st century agriculture. Through strategic direction of Farm Bill funds and other state and federal policies, partnerships with private sector companies seeking to go carbon-negative, and increased consumer demand for low-carbon food, fiber and fuel, regenerative cultivation practices can deliver four significant economic, environmental, and political opportunities for the U.S. farm economy.

FARM PROFITS AND ECONOMIC RECOVERY



Climate-smart agricultural practices offer a path to economic recovery and long-term profitability for hard-hit farmers by delivering increased and more consistent crop yields, reduced costs for inputs (fertilizer, fuel, pesticides) and crop insurance, and the opportunity to participate in markets for soil-based carbon removal. ‘Reduced carbon’ or ‘negative carbon’ crop outputs and the products derived from them may also have increased market value as consumer awareness and demand increases for products with these attributes.³ Healthier soils also make farms and ranches more resilient in the face of increasingly common extreme weather events.

AG TECH AND JOB CREATION



“Ag tech” is one of the fastest-growing technology sectors, with investors from across the financial sector funding startup companies creating highly skilled jobs in technologies such as microbial soil additives, advanced sensors, drones, monitoring software, GPS mapping, genomics, AI, and data analytics. The demand for accurate soil data measurement and analysis is strong, and college programs to train new ag tech professionals are growing throughout the Farm Belt. Additional innovation is taking place in the creation of agricultural carbon trading platforms, establishing carbon as a new farm commodity.

VALUING CARBON REMOVAL AND ECOSYSTEM SERVICES



While storing carbon from the atmosphere in agricultural soils can be a key factor in the battle against climate change, the practices that sequester carbon also deliver a wide range of other environmental benefits—including improved water quality and conservation, improved air quality, greater biodiversity, and reduced toxic inputs. Markets and other opportunities that monetize these practices are emerging, creating new revenue streams for farmers and ranchers across the U.S.

BRIDGING PARTISAN DIVIDES



Support for policies to incentivize agricultural carbon sequestration has bridged the historically contentious divide between the environmental and agricultural communities because the practices that restore and enhance soil carbon produce both economic benefits for farmers and natural resource benefits to society. In 2017, for instance, an unprecedented coalition of environmental, business, and farm industry groups helped forge and recruit bipartisan Congressional support for the Soil Health Demonstration Trial in the 2018 Farm Bill, a key soil health enhancement and soil carbon measurement program. Since then, numerous policies building on that provision have been proposed at the state and federal levels by lawmakers on both sides of the political aisle, as diverse stakeholders recognize the benefits of valuing agricultural carbon removal.

THE CHALLENGE OF A DEPRESSED FARM ECONOMY BATTERED BY CLIMATE CHANGE

Even before the COVID-19 pandemic, the American agriculture sector was arguably suffering from the worst economic conditions since the Farm Crisis of the 1980s. American farmers have been caught in a fierce confluence of global economic, political, and environmental pressures, to the point where breaking even is considered a successful crop year.

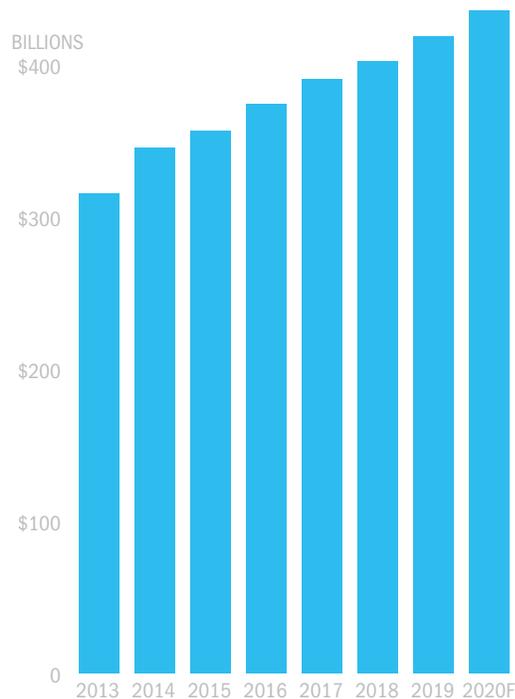
FARM DEBT IN THE U.S. EXCEEDS \$420 BILLION, AN ALL-TIME HIGH

In the Midwest, Chapter 12 farm bankruptcies increased by 12% in the year ending June 2019, and by 50% in the Northwest in the same period. More than half of U.S. farmers have been in the red every year since 2013.⁴ Not surprisingly, this bleak economic landscape has caused would-be producers to seek other lines of work, often ending multi-generational farms dating to the 1800s. Between 2011 and 2018, more than 100,000 U.S. farms ceased operations.⁵

More than half of U.S. farmers have been in the red every year since 2013.

For farmers in some areas, the most devastating economic impact in recent years has come from the frequency and severity of extreme weather events and increasingly unpredictable growing seasons. In 2019, the wettest year on record in the U.S., farmers in parts of 12 states couldn't plant crops with their fields under water from record spring rains. Crops could not be seeded on an astounding 19.4 million acres, the most prevented plant acres since the USDA's Farm Service Agency began tracking such data in 2007.⁶

FIGURE 1: U.S. FARM SECTOR TOTAL DEBT, 2013-2020¹¹



Source: U.S. Department of Agriculture, Economic Research Service

And 2019 was not a one-off. In Missouri, for example, 24 of the last 39 years have had above-average rainfall. Much of it falls in the early spring planting season, delaying or even preventing planting altogether.⁷ The Fourth National Climate Assessment in 2018 predicted that “yields from major U.S. crops are expected to decline as a consequence of increases in temperatures and possibly changes in water availability, soil erosion, and disease and pest outbreaks.”⁸

At the same time, the agriculture sector continues to be a significant contributor to greenhouse gases and other detrimental environmental impacts. Farming and ranching account for roughly one third of GHG emissions globally, and more than 9% in the U.S.—nearly as much as all residential and commercial buildings (11.6%).⁹ Those numbers don't even include ag-related life-cycle emissions from the production of synthetic fertilizers, pesticides, and other fossil fuel-intensive processes.¹⁰

Poor soil and livestock management practices result in nutrient and manure runoff, impairing riparian ecosystems and fish populations, spurring algal blooms and the associated hypoxic ocean dead zones, and contaminating drinking water sources across rural regions.

Policies and implementation in each of the four opportunities mapped out in this report, we believe, will produce positive outcomes in farm sector economic recovery, climate change mitigation, and environmental improvement.

OPPORTUNITY NO. 1

FARM ECONOMICS: SAVING COSTS AND BOOSTING PROFITS THROUGH REGENERATIVE AGRICULTURE

Regenerative agriculture and soil health conservation are broad terms, but generally refer to farming techniques that draw from indigenous and traditional cultivation practices and focus on building the health of the soil. As soil health increases, farms can both sequester additional carbon and reduce their reliance on fossil fuel-derived inputs. Enhanced soil health makes the soil more fertile and productive, supporting crops that are more resilient to pests, invasive plants, erosion and runoff, extreme weather events, and other stresses. Many key regenerative practices predate the 20th century post-war expansion of large-scale agriculture, but they are now being deployed on farms that range in size from a few to thousands of acres, supporting a wide variety of production systems, including row crops such as corn, soybeans, wheat, and cotton, livestock operations, and specialty crop farms. The National Academy of Sciences estimates that deployment of carbon removal practices on agricultural land could sequester 250 million metric tons of carbon dioxide-equivalent greenhouse gases, which is comparable to removing the annual emissions of 64 coal-fired power plants.¹²

The preponderance of data from farms adopting these techniques shows consistently positive economic benefits. Notable case studies conducted across the U.S. by the National Association of Conservation Districts (2017)¹³ and American Farmland Trust (2019)¹⁴ have yielded impressive financial results. In the NACD study, four corn and soybean farmers in the Upper Mississippi River Basin saw these average gains, mainly from using no-till and cover cropping:

- // Increased crop yield revenue by up to \$76 per acre
- // Reduction of fertilizer costs of up to \$50 per acre
- // Reduced outlays for erosion repair by up to \$16 per acre

In the AFT study, six field crop farmers and two almond growers in four states averaged \$41 per acre in increased net income. Average savings included \$36 per acre for fertilizer and \$35 per acre for machinery use, fuel, and labor from reduced tillage.

Another 2018 study by the nonprofit Ecdysis Foundation in South Dakota reported a dramatic 78% increase in net income on 20 farms that adopted regenerative techniques.¹⁵

“Agriculture is often overlooked as a solution to climate change. Policies that recognize the value of carbon sequestration from certain cultivation practices are a huge step in the right direction. With the right policies in place, helping the environment can also be very financially rewarding to farmers. Agriculture’s next cash crop is carbon farming.”

–David Kolsrud, South Dakota farmer and entrepreneur

FIGURE 2: KEY REGENERATIVE PRACTICES

Practice	Description	Benefits
Cover crops	Plants used for the specific purpose of improving soil health. Often planted in the off-season for annual crops or in between rows of permanent crops. Can be a mix of species including rye, buckwheat, radishes, peas, and many others.	Carbon removal; erosion protection; crop resilience; water quality
Diverse cropping systems	Rotating multiple crops, and potentially also including perennials and grazing animals, rather than planting just the same one or two crops year after year. Indigenous cultures have planted crops in this way for generations, most famously the “three sisters” growing of maize, squash, and beans together.	Water quality; carbon removal; reduced synthetic inputs; weed, pest and disease prevention
Avoiding synthetic inputs	Using natural fertilizers and weed and pest control methods, rather than relying on fossil fuel-derived chemicals	Reduced emissions; water quality; biodiversity
Low- and No-Till	Reducing or eliminating mechanical disturbance of the soil (e.g., plowing)	Reduced emissions; carbon storage
Intensive Rotational Grazing	Moving livestock between pastures on a regular basis to allow feed crops to regrow and soils to recover. An Indigenous practice, this mimics the way herd animals move through grasslands.	Forage resilience; biodiversity; potential carbon removal in some cases
Composting	Turning waste (from manure or food) into a product that can improve soil health	Resilience; carbon removal; emissions reductions
Riparian buffers	Planting trees, shrubs, or other perennial vegetation along streams and rivers	Carbon removal; resilience; water quality; downstream flood control; wildlife habitat

Keith Alverson is a sixth-generation corn and soybean grower in Chester, South Dakota, and former board member of the 36,000-member National Corn Growers Association. A staunch advocate for climate action, Alverson was the chair of NCGA’s Climate Task Force formed in 2017. His 2,500-acre family farm has been using regenerative techniques by experimenting with cover crops in recent years and using low-till and carbon-rich crop rotations for decades. One of the many benefits he extolls is soil water retention. With a changing climate causing more intense rain events (four to five inches per deluge) every year, Alverson says that every 1% increase in soil organic matter—thus soil carbon content—has added 1.4 acre-inches (approximately 38,000 gallons) of water-holding capacity. That helps in both wet and dry times.

“We can get through two dry summer weeks a lot better,” he says. “It’s made the cropping season much more resilient.” The healthier soils have increased Alverson’s yield potential by 14 bushels per acre—an increase of about 7% over his average production—giving him the possibility to earn \$45 more per acre at current corn prices. Applying this 7% increase in yield potential across the 84 million acres of corn expected to be harvested in 2020¹⁶ suggests that a possible \$3.8 billion in additional revenue could flow to the farm economy from corn production alone through the adoption of these regenerative practices.

“We can get through two dry summer weeks a lot better. It’s made the cropping season much more resilient.”

—Keith Alverson, South Dakota corn and soybean farmer

REWARDING FARMERS FOR CROP RISK REDUCTION

Federal crop insurance is the largest federal farm subsidy, and an important consideration for farmers as they make their production decisions each year. Federal crop insurance covers more than 90% of U.S. cropland, costing taxpayers up to \$10 billion each year.



Despite the fact that regenerative farming reduces the risk of crop loss, there are currently no incentives built into the Federal Crop Insurance Program to encourage farmers to adopt regenerative practices. This presents a missed opportunity for enhanced climate resilience and mitigation.¹⁷ But now farmers in two states, Iowa and Illinois, can receive a \$5 per acre break on federal crop insurance premiums if they plant cover crops, thanks to a partnership between the federal Risk Management Agency (which administers federal crop insurance) and the states' departments of agriculture. These programs have proven to be popular and cost-effective, with the Illinois program reaching its maximum enrollment in the first two weeks that signups were available. Wisconsin is now considering a similar measure. Expansion of such incentives to farmers in more states and at the federal level presents a key opportunity to monetize the value of healthier soils.

BUILDING MARKET DEMAND FOR AG PRODUCTS THAT REMOVE CARBON

The economic promise of regenerative farming has gained the attention of some of the food industry's largest players, most notably General Mills. The \$17 billion company is aiming to source its commodity crops from one million regeneratively farmed acres—about a quarter of the land from which it sources products in North America—by 2030. In 2019, the Minneapolis-based company launched two major pilot programs to help train growers in regenerative and carbon removal techniques. Participants include 45 oats farmers comprising 170,000 acres in North Dakota, Minnesota, Manitoba, and Saskatchewan, and 39 wheat growers on 85,000 acres in Kansas and Nebraska.¹⁸

By helping its growers increase yields, cut costs, and sequester carbon, the company is also advancing its corporate sustainability goals. General Mills was the first large food company to set GHG emissions targets for its entire supply chain,¹⁹ and more than half of that carbon footprint comes from agriculture activities, according to Jeff Hanratty, the company's applied sustainability manager. General Mills has committed to reduce supply-chain emissions by 28% (from 2010 levels) by 2025.

Other large food/ag companies that have launched regenerative initiatives with their suppliers include Bunge, Danone, Land O'Lakes, Anheuser-Busch, Cargill, and Bayer. In April 2020, Cargill launched the Soil & Water Outcomes Fund in partnership with the Iowa Soybean Association. The fund will pay participating farmers for carbon sequestration (an estimated \$35-\$40 per ton of CO₂) and reduced water runoff; Cargill will buy a bulk of the carbon credits to offset GHG emissions from its operations.²⁰ In July 2020, Bayer announced the Bayer Carbon Initiative; it will pay some 1,200 row crop farmers in the U.S. and Brazil for carbon removal using the company's Climate FieldView digital farming platform.²¹ These actions indicate that agribusiness is showing interest in soil carbon sequestration, but transparency and verification are critical to ensuring that resulting carbon removal is not offset by increased fossil-based inputs.



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FIGURE 3: SOME OF THE MAJOR FOOD COMPANIES THAT HAVE RECENTLY LAUNCHED REGENERATIVE INITIATIVES IN THE U.S.

Anheuser-Busch	Cargill	Land O'Lakes
Bayer	Danone	Nature's Path
Bunge	General Mills	Whole Foods

Food companies such as these foresee growth in demand from environmentally-minded consumers for products made with regeneratively farmed ingredients, following the path carved by organic foods. Whole Foods Market rated regenerative agriculture as its No.1 food trend of 2020,²² and some brands such as Nature's Path Organic Foods and General Mills' EPIC Provisions already have regenerative-certified products on the market.

There is also innovation in the private sector marketplace for carbon-negative agriculture. One example is the Zero FoodPrint program, created by award-winning restaurateurs Anthony Myint and Karen Liebowitz, which allows consumers to opt in to a 1% surcharge on meals at participating restaurants or a dollar per month surcharge on their home waste hauling bills. Based on successful renewable energy policy models, this program allows citizens to "improve the grid of farming" by directly funding producers to increase regenerative practices and carbon removal.²³

"This approach is available to every single diner and every city and regional provider of waste removal services," says Myint, "since it is optional and is not constrained by budgets, and does not rely on regulatory/carbon markets. Currently, over 100 cities and states are on track for 100% renewable energy, and those same regions could establish renewable food economies."

Despite the promise that regenerative practices hold, inertia persists as many farmers' appetite for taking a risk on a new practice in uncertain times is low. However, innovative public policy initiatives and growing private sector engagement in this space are increasingly persuasive indicators of the emergence of carbon removal as a new agricultural commodity—one that offers a new revenue stream and economic recovery opportunity for farmers, while creating new ag-related jobs in the process.

INNOVATORS ON THE FRONTLINES: LOCUS AG HELPING FARMERS MONETIZE CARBON STORED IN SOIL

Soils and human digestive systems have something in common: probiotic microbes that improve the health of both. Locus Agricultural Solutions, a Solon, Ohio-based innovator, creates products that significantly improve soil health, crop productivity, and soil carbon sequestration capabilities for a fast-growing number of American farmers.

Rhizolizer Duo, the company's flagship product, is an organic mixture containing fungal and bacterial microbes that amplify soil's natural microbial processes. That leads to bigger and stronger root systems, increased plant nutrient uptake, and notable increases in the deposition of soil carbon.

"Microbes work with crops to drive carbon sequestration which in turn creates healthier soil, and our product amplifies those natural processes," says Paul Zorner, Locus AG's original CEO and now chief agronomist. Farmers use Rhizolizer Duo to enhance the growth and yield of corn, soybeans, wheat, almonds, potatoes, cotton, citrus trees, and multiple other crops. The product was used on about 60,000 acres of U.S. cropland in 2020, and Zorner expects usage to grow to about 350,000 acres this year.

Rhizolizer Duo, named as a metaphor for a natural 'rhizosphere fertilizer', essentially increases soil microbial activity—boosting crop yields and reducing inorganic fertilizer needs. Its users have seen on-farm income increase from 30 to 50% from a combination of increased yield and lower fertilizer inputs, and the company estimates that on-farm income can potentially be doubled if their sequestered carbon is monetized.

Locus AG is focused on helping farmers amplify and monetize the CO₂ extracted from the atmosphere and deposited in their soils. In January 2020, the company partnered with agricultural carbon marketplace operator Nori and in January 2021 added an additional partnership with Bluesource—the largest carbon and environmental marketplace developer in the U.S. Locus AG's CarbonNOW program, launched in 2020, is currently providing growers with \$15 for each ton of CO₂ equivalent stored in their soils from recently implemented regenerative practices.



Under the CarbonNOW program, Locus AG recently became the first company to fully qualify and help one of its growers market a significant number of soil carbon credits associated with their current regenerative practices—20,000 metric tons for a market value of just over \$340,000. "It's exciting," says Zorner. "The industry has been talking about doing this forever, and now it's actually happening."

The company has won numerous national and global awards, including the 2019 Best New Product in the Global Crop Science Awards and the 2020 NREL Outstanding Venture Award. Locus AG is also one of the few agricultural product companies with B Corp certification for sustainable and socially responsible practices.

OPPORTUNITY NO. 2

AG TECH: A 21st CENTURY JOB CREATOR

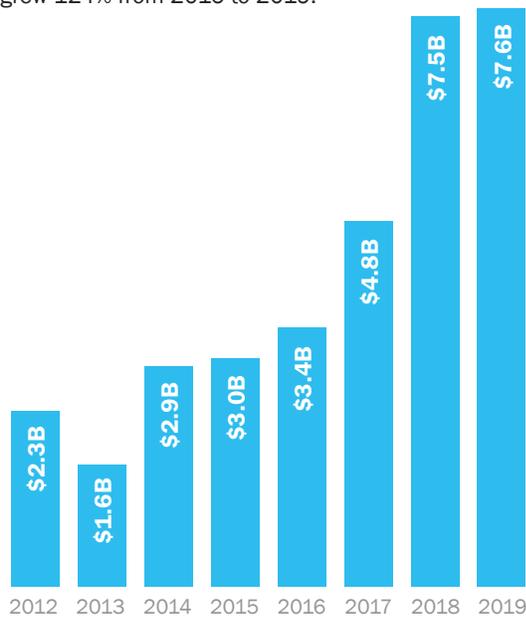
Precision ag technologies that measure soil composition and crop health on an increasing number of data points using ever-more precise coordinates—down to the individual plant in some cases—have made great strides in recent years. This is one key niche in the burgeoning sector of ag tech, which encompasses technologies like advanced sensors, drones, internet-enabled monitoring tools, robotics, GPS mapping, genomics, AI, machine learning, and data analytics.

It's a hot sector—ag tech startups garnered \$7.6 billion in funding in 2019, a more than fourfold increase since 2012, according to the annual industry investment report from leading venture capital firm AgFunder.²⁴ The number of discrete investment deals increased fivefold in the same period, from 200 in 2012 to 1,039 in 2019. There were 1,336 different investors in the sector, including venture capital, private equity, Fortune 500 corporations, impact investment funds, and sovereign wealth funds. Two sub-sectors that dominated early-stage seed funding in 2019, according to AgFunder, were Ag Biotechnology (on-farm inputs for crop & animal ag including genetics, soil composition known as microbiome, livestock health and breeding) and Farm Robotics (on-farm machinery, automation, drones, and precision measurement equipment.)

These new ag innovation companies—such as the three profiled in this report—are boosting employment numbers to aid economic recovery in the ag sector while attracting younger, tech-savvy workers into agriculture. U.S. farmers, ranchers, and other agricultural managers are 56.4 years old, on average, while 60% of tech-sector agricultural engineers are under 34.²⁵

FIGURE 4: ANNUAL INVESTMENTS IN UPSTREAM AG STARTUPS, 2012–2019²⁸

Investment in startups operating upstream, closer to the farmer and before the retailer, grew 124% from 2016 to 2019.



Ag tech also represents a strong employment opportunity for military veterans. Forty percent of those who serve in the U.S. military come from the small segment (19%) of Americans who live in rural/agricultural counties, according to retired Marine Corps Lt. Gen. John Castellaw, co-founder and CEO of Farmspace Systems, which is equipping unmanned aerial vehicles to collect “precision ag” soil health data (see profile on page 12). “They need good jobs to come home to,” says Castellaw, “and helping them find jobs in precision ag just makes sense.” The USDA’s Enhancing Agricultural Opportunities for Military Veterans (AgVets) program awards grants to non-profits across the U.S. that train veterans for ag careers.²⁶ One grantee, Tennessee-based Veterans Employed in Technology and Service in Agriculture, focuses on ag-related technical skills in computers, remote sensing, data management, GIS/GPS, and mechanics.

In recent years, two-year colleges throughout the Farm Belt have launched dozens of ag tech programs, offering degrees in subjects like agricultural geospatial technology (Kirkwood Community College in Cedar Rapids, Iowa) and precision agronomy management (Chippewa Technical College in Eau Claire, Wisconsin).²⁷ In 2016, South Dakota State University became the first university in the U.S. to offer a bachelor’s degree in precision agriculture. In California, the new Center for Regenerative Agriculture and Resilient Systems at Cal State University-Chico runs a Master’s program in regenerative ag.

“[U.S. military veterans] need good jobs to come home to and helping them find in precision ag jobs just makes sense.”

—Lt. Gen. John Castellaw (Ret), co-founder and CEO of Farmspace Systems

Many state and local economic development efforts are seeking to leverage this newly qualified workforce to attract established ag tech players and new innovative startups. North Carolina has made ag tech an economic development priority, and it's now a key part of the state's overall ag industry, which employs 728,000 people and accounts for 17% of state GDP. The state is home to more than 165 ag tech companies.²⁹

In Indiana, the state's Economic Development Corporation and AgriNovus Indiana, its initiative for promoting and accelerating the growth of ag tech, are working together to attract companies in what it terms agbioscience—the confluence of production agriculture, life sciences, advanced manufacturing, logistics, and tech. Indiana is already home to 75,000 such jobs with a goal for that number to grow exponentially. “We think a lot about next-generation talent,” said Beth Bechdol, AgriNovus president and CEO, at the Agbioscience Innovation Summit in November 2019.³⁰

Indiana was able to attract Solinftec, a Brazil-based digital ag and data science company, to open a facility at Purdue University's Research Park in 2018. A year later, the company's global headquarters followed, bringing with it 90 jobs in 2020 and plans to create more than 300 jobs by 2023. The Research Park also houses a second location for Cambridge, Mass.-based seed tech company Inari.³¹

Startup accelerators, a fixture in industry sectors like clean tech and biotech, are springing up for ag tech in states across the U.S. with substantial farming economies. One is run by the Dairy Farmers of America at its Kansas City headquarters, where young rural ag tech entrepreneurs participate in a 90-day training and mentorship program.³²

Job growth in this sector is clearly enhanced by increased market creation for carbon-negative ag products, contributing to economic recovery in rural America.

INNOVATORS ON THE FRONTLINES: FARMSPACE SYSTEMS AND PRECISION CARBON MEASUREMENT

If you heard about a startup company that uses AI and image-processing software to analyze data gathered by remote sensor-equipped drones, you might picture a team of Silicon Valley tech entrepreneurs. You probably wouldn't think of a retired U.S. Marine Corps lieutenant general working out of the town of Alamo (population 2,500) in western Tennessee.



But that's where you'll find Lt. Gen. John "Glad" Castellaw, USMC (Ret) and his company, Farmspace Systems. Farmspace is on the leading edge of soil health data collection and analysis, a tech niche poised for growth to meet demand for more accurate (and cheaper) data as the market for soil carbon sequestration increases. Farmspace has added unmanned aerial vehicles (UAVs) to the arsenal of existing precision-ag data collection tools such as satellites, airplanes, and on-ground sampling.

Castellaw served 36 years in the Marine Corps, but he grew up in a family that has been farming in America for 300 years, so it makes sense that he returned to the family farm after his retirement. He sees good symmetry between military technical training and precision agriculture. His company was founded by veterans and Farmspace, through education, outreach, and participation in VETSA (Veterans Employed in Service and Technology in Agriculture), promotes farm careers for

veterans. Castellaw often points out that 40% of those who serve in the U.S. military come from the small segment (19%) of Americans who live in rural/agricultural counties. “We need veterans to come back to rural areas with their leadership experience and technical skills. And precision agriculture can provide those good paying jobs they deserve. When this happens we all win.”

Castellaw's military experience, coupled with his work in climate security as a civilian, provides a deep hands-on understanding of climate change as a major national security threat. He sees farmers using regenerative agricultural practices playing a major role in sequestering carbon in the next decades, helping to slow and reverse climate change and opening new revenue sources for themselves in the process. Farmspace Systems is poised to play a major role.

OPPORTUNITY NO. 3

VALUING CARBON REMOVAL AND ECOSYSTEM SERVICES: CARBON AS THE NEXT CASH CROP

In the context of the vast costs of climate change that we are only beginning to attempt to calculate, mitigating climate impacts by removing carbon from the atmosphere is a service or product with enormous inherent value. There are multiple pathways to monetize that product through public and private markets, state and federal policies, and consumer demand.

Transitioning to the practices that yield healthier soils can draw down potentially game-changing amounts of carbon from the atmosphere. A 2017 study in the scientific journal *Nature*³³ reported that global regenerative practices could store up to an additional 1.85 gigatons of CO₂ per year—roughly the amount emitted annually by the global transportation sector. As an economic opportunity, becoming carbon-negative can open the door for farmers to the marketplace of carbon credits, where carbon producers purchase credits to offset their levels of CO₂ emissions or to achieve carbon-negativity by offsetting their legacy emissions. Higher and more predictable farm profits can also be realized through the valuation of ecosystem services—through water quality markets, for example—as well as tax credits, and lower loan, rent, and insurance rates in recognition of climate and crop risk mitigation and other environmental services.

“Among countries of the world, the United States showed the highest total annual potential in soil organic carbon.”

—Nature, November 2017

When soil health is restored, the amount of carbon it can contain increases. Thus the same regenerative farming and ranching techniques that improve soil health and crop production also positively impact the greenhouse-gas calculus. Healthier root systems, for example, draw more CO₂ out of the atmosphere and keep more carbon in the ground. These practices also greatly reduce nitrogen and pesticide runoff in waterways, lessen particulate air pollution, and preserve greater biodiversity.

Earning credits for the composition of the soil itself is a new and potentially big revenue source for farmers—which in turn would help to revitalize their local economies. A market that financially rewards land-based carbon removal also unlocks new opportunities in wealth and job creation for entrepreneurial innovators, investors, scientific researchers, and data analysts. But the hurdles to creating viable markets, appropriate policies, and especially reliable metrics are not trivial and still challenging for growers to understand and deploy from both technical and accounting perspectives.

The buying and selling of renewable energy credits (RECs) and carbon offsets like reforestation projects have been a staple of the clean economy for more than two decades, with California’s cap-and-trade market, launched in 2013, as a prime example. The emissions trading system has helped California achieve ambitious decarbonization goals, though it has generated significant criticism from communities directly affected by environmental impacts of fossil-intensive industries. But creating credits for atmospheric carbon removal through land-based systems is an entirely new value proposition on two parameters. First, current REC credits are based on *reducing or avoiding greenhouse gas emissions* (by replacing coal-fired power with renewable generation, for example), rather than *removing CO₂ from the atmosphere* by absorbing and sequestering it as plants in healthy soils do.

The second key distinction between valuing emissions reductions versus atmospheric carbon removal is the methodology for data collection and verification. Obtaining affordable and accurate metrics for how much atmospheric carbon is removed and sequestered in the ag sector is more challenging than measuring reduced smokestack emissions. The science and technology for soil carbon detection is still evolving, taking into account the many variables that occur in natural systems. Verifiable measurement of agricultural carbon removal, however, is necessary for managing and monetizing this new agricultural commodity and the key to establishing robust markets.

But challenge equals opportunity, and there is progress on both the marketplace and measurement fronts. Entrepreneurs, NGOs, and corporate players are working with farmers to create soil carbon marketplaces, while fueling the business opportunity for better, faster, cheaper, and more standardized data collection and analysis.

CARBON MARKETS AND METRICS

Three of the leading soil carbon marketplaces in development are:

The **Ecosystem Services Market Consortium (ESMC)**, founded in 2017, is a partnership of farmers' trade associations, large food and agribusiness companies, and NGOs working on ways to monetize environmentally-sound and climate-positive farming and ranching operations. Funders include General Mills, the United Soybean Board, The Nature Conservancy, and the USDA's Natural Resources Conservation Service. The consortium plans to launch a marketplace in 2022 for both carbon credits and other ecosystem services such as water retention and reduced fertilizer and pesticide runoff.

Market demand for U.S. carbon and ecosystem services credits could be as high as \$13.9 billion, according to an ESMC-commissioned study in 2019.³⁴ A key goal for the consortium is to help develop accurate and standardized measurement protocols for soil health, including carbon storage, water retention, microbial activity, and nutrient content. In one pilot program, ESMC and partners General Mills and the Kansas Department of Health and Environment are working with Southern Great Plains row crop farmers on such measurements.³⁵

The startup company **Nori** (see profile on page 16) has developed a blockchain-enabled marketplace for carbon specifically earned by the agriculture sector. The Nori Marketplace will pay farmers an estimated \$15 per ton of CO₂ that their fields draw from the atmosphere. Approximately 150 operations, farming more than 500,000 acres spanning the Midwest, Pacific Northwest, and California, have applied to take part in Nori's pilot program.

Indigo Ag's core business is selling seed coatings and other products that increase crop yields and improve soil health, and they are now developing a carbon credits marketplace called Indigo Carbon. The company has raised \$1.2 billion in capital from high-profile investors that include potential carbon credits buyers FedEx and Great Western Bank. While developing its marketplace, Indigo Ag has launched a national "Carbon Cup" contest, with farmers and ranchers from 15 states competing to achieve the highest soil carbon content in 2020.³⁶

Smaller-scale carbon exchange efforts already underway include the Montana Grasslands Carbon Initiative,³⁷ in which carbon offset provider NativeEnergy will issue carbon credits to the state's cattle ranchers, and Texas-based startup nonprofit Soil Value Exchange,³⁸ which will also focus on ranchers.

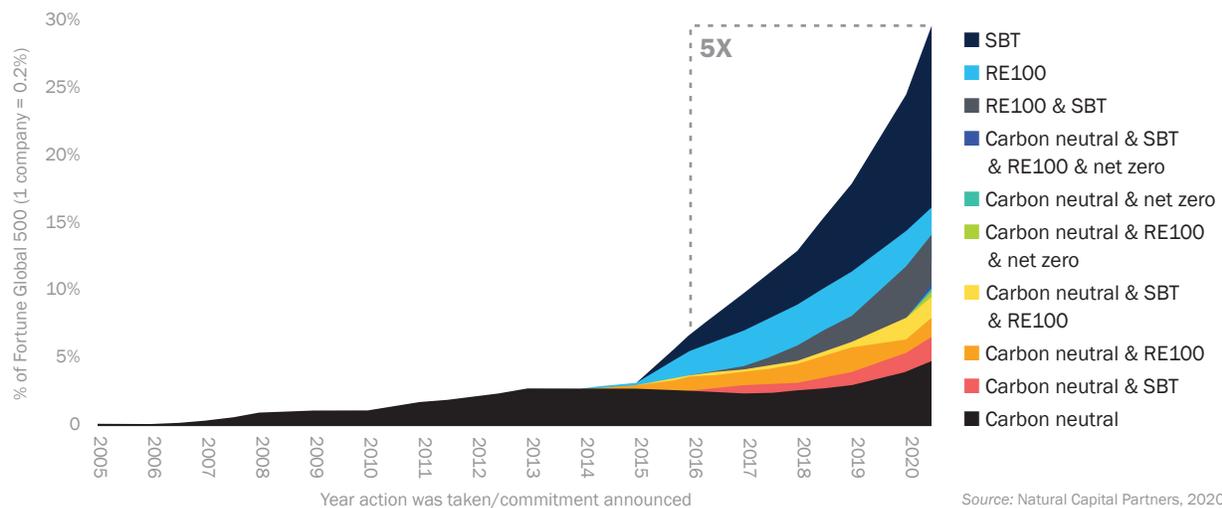
For corn and other feedstock growers selling to ethanol refiners, another possible revenue source from healthier soils is the potential to earn additional credits for the production of feedstock for low carbon fuels. California and Oregon have enacted a Low Carbon Fuel Standard to reduce transportation emissions, with several other states considering doing so, particularly in the Midwest where much of the feedstock for low carbon fuels is produced. While the carbon accounting to qualify as low carbon ethanol has focused on reducing the lifecycle emissions associated with its production, farmers could potentially earn additional value by demonstrating negative emissions from carbon sequestration in their soils.



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For corporations that have committed to become carbon-neutral or even carbon-negative, the idea of paying for carbon removal—i.e. going a step beyond traditional carbon offsets—is starting to gain traction. Microsoft, most notably, launched the Climate Innovation Fund in January 2020 to invest \$1 billion over the next four years in carbon removal companies, technologies, and projects. Online payment company Stripe has invested \$1 million in four carbon removal projects to date. Nearly one quarter of Fortune Global 500 companies³⁹ have committed to be carbon-neutral by 2030, while Microsoft has pledged to be carbon-negative by the same year. Since 2016, the number of Fortune Global 500 companies that have made a public commitment that they are, or will be by 2030, carbon neutral, using 100% renewable power, or meeting a science-based emission reduction target (SBT) have increased 500% (see Figure 5).

FIGURE 5: 30% OF FORTUNE GLOBAL 500 COMPANIES HAVE MADE A PUBLIC COMMITMENT THAT THEY ARE OR WILL BE BY 2030 CARBON NEUTRAL, MEETING AN RE100, SBT OR NET ZERO TARGET⁴⁰



These large-scale corporate efforts, along with hundreds of public sector carbon neutrality commitments around the world, create a nearly incalculable demand for carbon reduction. Many R&D initiatives are seeking to create technologies that draw carbon from the atmosphere, but regenerative farming practices that exist today will readily find demand for their carbon removal results.

THE SOIL CARBON ACCOUNTING CHALLENGE

Measuring soil carbon sequestration is a complex undertaking, more challenging than quantifying the tons of CO₂ in fossil-fuel emissions displaced by clean energy generation or low-carbon transportation fuels. But accurate measures of the “before and after” results of regenerative practices are critical to certifying soil’s efficacy as a carbon sink. Some standard measurement tools are available, but the need (and economic opportunity) for R&D in soil carbon measurement is perhaps the biggest challenge to scaling up agricultural carbon markets. Improving and applying effective metrics is a critical piece of the USDA’s first round of Soil Health Demonstration Trial projects launched in 2019.⁴¹

A commonly used carbon quantification tool—the USDA’s standard measurement product since 2017—is COMET-Planner, developed by Colorado State University and the USDA’s Natural Resources Conservation Service. The COMET team is also working with key state-level CO₂ reduction efforts, such as California’s Healthy Soils Initiative and the U.S. Climate Alliance of 17 bipartisan governors.

Farmers who use COMET-Planner enter data such as location, soil characteristics, land use, tillage practices, and nutrient inputs into the online tool. Using sophisticated modeling algorithms that extrapolate from weather data, soil maps, and land management use history, COMET-Planner estimates soil carbon levels. The tool can be applied to croplands, livestock operations, orchards, vineyards, and agroforestry.

“This is not black magic that we don’t understand,” says Keith Paustian, professor of soil and crop sciences at Colorado State University and the main developer of COMET-Planner. “Better soil management pays for itself in the long run, and you’re holding more carbon in the ground. This is the way it makes sense to farm.”

“Better soil management pays for itself in the long run, and you’re holding more carbon in the ground. This is the way it makes sense to farm.”

– Keith Paustian, professor of soil and crop sciences at Colorado State University

INNOVATORS ON THE FRONTLINES: NORI, BLOCKCHAIN, AND CARBON MARKETS

As U.S. farmers increasingly adopt growing methods that draw carbon from the atmosphere, the obvious question is how will they get paid for doing so—in the absence of a nationwide price on carbon?

Seattle-based startup Nori believes it has an answer. Nori has developed a blockchain-enabled marketplace for carbon credits specifically earned by the agriculture sector. Currently the Nori Marketplace has had three projects verified and listed; these projects have paid an estimated \$15 per metric ton of incremental CO₂ (dubbed a Nori Carbon Removal Ton or NRT) that their fields draw from the atmosphere. The price for each NRT is set by the farmer. These credits will mainly be purchased by individual consumers, corporations, and other organizations such as universities that buy carbon offsets to help reach sustainability goals such as net-zero carbon emissions.

Carbon offset markets date to the mid-2000s, but the credits are mainly earned by renewable energy generation or reforestation projects around the world. Nori is among the companies at the forefront of bringing this model to regenerative farmers, creating a potentially substantial revenue source for soils-based carbon removal. “We call it climate-smart agriculture—thinking of carbon removal like a crop,” says Christophe Jospe, a Nori co-founder.

Approximately 150 operations, farming more than 500,000 acres spanning the Midwest, Pacific Northwest, and California, have applied to take part in Nori’s pilot program. Applicants use a USDA-backed soil carbon data collection tool called COMET-Planner to estimate their CO₂ sequestration levels. For successful applicants, Nori is administering a more detailed quantification process to verify their CO₂ and related payment amounts.

On the carbon credits purchasing side, some of Nori’s targeted sectors—airlines, cruise lines, and event producers—have been among the industries hardest hit by the COVID-19 pandemic. But its trajectory continues to move ahead. Nori is working with multiple partners on both the supply and demand side. “Right now, it’s actually a blessing to be in our pilot phase and not have millions of credits out there,” says Jospe. “We’re just going to keep hunkering, building, and scaling.”



1

FARMERS SUBMIT DATA

Farmers implementing regenerative farming methods submit land management and operation data to Nori’s platform.



2

CARBON REMOVALS QUANTIFIED

Carbon quantification tool (CQT) 3rd party partner uses project input data to estimate CO₂e removal and sends the data output to Nori.



3

PROJECT DATA VERIFIED

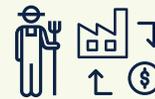
Farmers hire an independent 3rd party to audit their data that was submitted to Nori and used by CQT to estimate the amount of CO₂e removal within the project.



4

CARBON REMOVALS ISSUED

Upon receipt of verification assurances, Nori issues Nori Carbon Removal Tonnes (NRTs) based on the CQT results. One NRT represents one ton of CO₂e removed and stored.



5

NRTs PURCHASED AND RETIRED

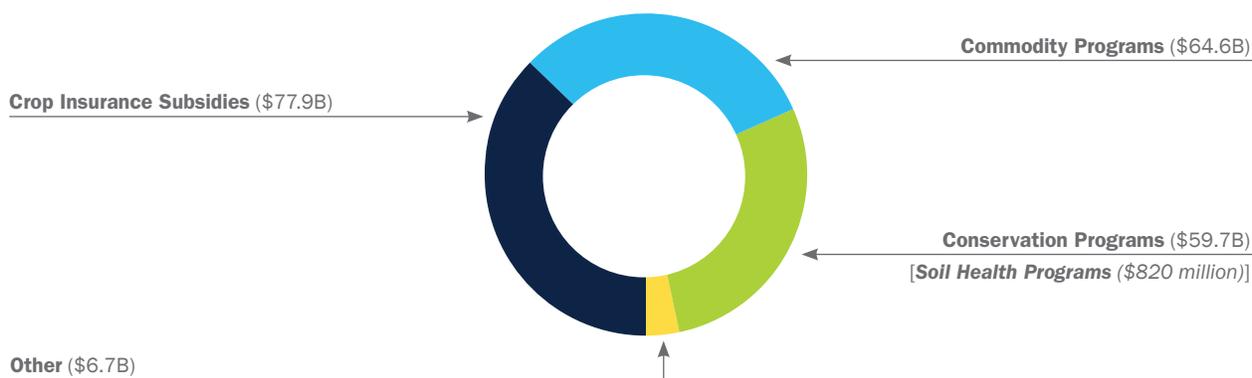
Farmers sell their NRTs through Nori’s marketplace to individuals and organizations. Nori charges a transaction fee.

OPPORTUNITY NO. 4

BRIDGING THE PARTISAN DIVIDE BY LEVERAGING THE HEALTHY SOILS AND CLIMATE CONNECTION

In the midst of an interwoven set of expanding global emergencies—economic devastation, a pandemic, and an accelerating climate crisis—farmers now have an opportunity to provide greater prosperity and security for themselves and for the country. In the context of enormous anticipated losses from climate change, agriculture is poised for a renaissance that can bolster farm profits and performance by shifting to cultivation practices that lower risk and input costs by sequestering carbon from the atmosphere. It’s time to support the transition to regenerative agricultural practices that can help struggling farm communities while also helping to reduce the costs of climate change to the rest of the economy. By rebalancing our current investments in the agriculture sector (approximately \$20 billion annually through federal Farm Bill programs), we can promote this transition while protecting farmers, growing economic opportunities and jobs in rural America, and encouraging private sector innovation and job creation.

FIGURE 6: PROJECTED 10-YEAR FARM BILL SPENDING (IN BILLIONS)



STRATEGIC POLICY LEVERS TO ADVANCE REGENERATIVE AGRICULTURE

The preponderance of legislative activity on healthy soils and carbon removal in Congress shows that this is an initiative that can create value for all stakeholders and bridge the partisan divide on climate policy.

Forward-thinking state and federal policy measures, if enacted, could greatly advance the knowledge, innovation, and implementation of regenerative farming practices for healthier soils and carbon removal.

Among them are:

// **Reform Federal Crop Insurance.** One of the largest annual public expenditures on the agricultural sector is the Federal Crop Insurance Program, which covers around 90% of U.S. cropland and costs \$7 to \$10 billion annually. Despite being the largest component of the farm “safety net,” Federal Crop Insurance is not currently structured to encourage farmers to adopt practices that mitigate one of the biggest risks to agriculture: climate change. Crop insurance should be revised to provide a true risk management tool that helps farmers reduce emissions and survive in a changing climate, incentivizing cover crops to improve resilience and sequester carbon. This is already happening at the state level, as several Midwestern states have adopted or are considering investing in cover crop incentives that are delivered through Federal Crop Insurance. These types of programs could be enacted in any state, and investment from the federal level (as recommended by the recent House Select Committee on the Climate Crisis) could spur greater adoption.

- // **Leverage public dollars to finance transitions to regenerative practices.** Any costs savings from subsidy reform should be reinvested back into the agricultural community, helping to spur a strong response to climate change. The existing Commodity Credit Corporation⁴² provides a potential framework for this investment. Examples include low- or no-interest loans to support transition to regenerative agriculture, and financing high-impact projects such as compost infrastructure, processing facilities for grain and livestock, and high-cost practices such as agroforestry. Additionally, the CCC could be used to bolster emerging carbon markets, including by setting a price floor for carbon, capitalizing the cost of measurement and accounting, and potentially offering a bonus for carbon sequestration that also secures significant co-benefits, such as water quality or biodiversity protection.⁴³
- // **Increase funding and expand the scope of the Soil Health Demonstration Trial in the 2018 Farm Bill.** Since its passage, several bills have been introduced in the Senate and House that build on and amplify this breakthrough program. It incentivizes farmers across the U.S. through grants to adopt regenerative practices and track their results, creating a valuable knowledge base for future use and innovation. With major new funding, the program can expand to cover new geographic areas and a wider range of farm sizes and cropping systems, speed the development of soil carbon detection and tracking technologies, and qualify farmers to participate in carbon markets.
- // **Increase investment in carbon removal projects** in the USDA's Environmental Quality Incentives Program (EQIP). Although EQIP awards grants for a wide range of regenerative practices⁴⁴ that include composting, cover cropping, and erosion control, its effectiveness could be improved by prioritizing “bundles” of practices that together lead to greater carbon sequestration.
- // **Invest in a rural restoration economy.** Robust state and federal restoration policies, modeled on the Civilian Conservation Corps established after the Great Depression, could create a wave of good new jobs in rural communities. Existing state and federal programs and partnerships, such as AmeriCorps, provide a framework for such an effort; pending federal legislation, including the bipartisan CORPS Act, would dramatically increase investment in public works projects. Efforts to bolster these public works programs should include jobs implementing regenerative agriculture practices.
- // **Increase accessibility to carbon credit marketplaces.** The nascent field of carbon credit marketplaces can be complex and daunting for farmers exploring this economic opportunity. There are now both federal and state initiatives to enhance and standardize carbon accounting methods to qualify producers to participate in both private and public carbon markets. Additional focus on policy in this arena is needed to amplify and monetize agricultural carbon removal services and reduce fossil emissions. Policies should be designed to ensure farmers of all sizes can effectively participate, and care should be taken to avoid exacerbating pollution in vulnerable communities.
- // **Scale up certification.** Existing federal standards for organic agriculture require many regenerative practices, including reduced chemical use, cover cropping, crop rotation, and use of compost, with third-party verification. However, the value of carbon removal resulting from these practices is not apparent to consumers at the point of sale, and is not typically associated with an organic label. The National Organic Program should be strengthened to include more specific soil health requirements, in parallel with efforts to enhance consumer awareness and preference for carbon-negative products. Additional third-party standards are also being developed, including Regenerative Organic Certified (ROC) and Land to Market Ecological Outcome Verification (EOV), which would expand consumer options for climate beneficial food products. New standard design should take care to ensure meaningful verification and avoidance of duplication in the food labels marketplace.
- // **Develop markets for low carbon ag products.** In addition to climate-beneficial food, another example could be feedstock for transportation fuel that earns credits under a Low Carbon Fuel Standard, based on both the reduction in energy inputs and the sequestration of carbon in the soil during feedstock production. The feedstock farmer would be eligible for higher sales values due to their verified contribution to the fuel's high credit generation.





A WIN-WIN-WIN

A robust and equitable economic recovery in America must include our farmers and rural communities. Developing markets and incentives for agricultural carbon removal is a strategic pathway to achieve multiple benefits for agricultural producers, for the climate, and for a host of other environmental priorities.

Policy support from measures such as these will help move the emerging sector of land-based carbon removal from innovation and investment to widespread mainstream adoption. In the near term this will lead to improved profitability in the hard-hit farming sector, drive rural job creation in the growing ag tech field, and provide a platform for much needed bipartisan collaboration on agriculture and environmental performance.

At scale, agricultural carbon removal will significantly mitigate the destructive impacts of climate change.

American economic recovery cannot move forward without our farmers. The combined forces of strategic federal and state policies with private sector programs from businesses in and outside of the agriculture sector will speed this transition, helping America build back its economy and weather the challenges ahead. It's a win across the board—for farmers, for the economy, and for the environment.

About E2

[E2 \(Environmental Entrepreneurs\)](#) is a national, nonpartisan group of business leaders, investors, and professionals from every sector of the economy who advocate for smart policies that are good for the economy and good for the environment. E2 members have founded or funded more than 2,500 companies, created more than 600,000 jobs, and manage more than \$100 billion in venture and private equity capital.

For additional insight into E2's other reports, visit e2.org/reports.

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