BATTEN BRIEFING
IMPROVING THE WORLD THROUGH ENTREPRENEURSHIP AND INNOVATION

PATH TO 2060:

Decarbonizing the Agriculture Industry

Innovation's Role in Sustainable Growth

CONTRIBUTORS

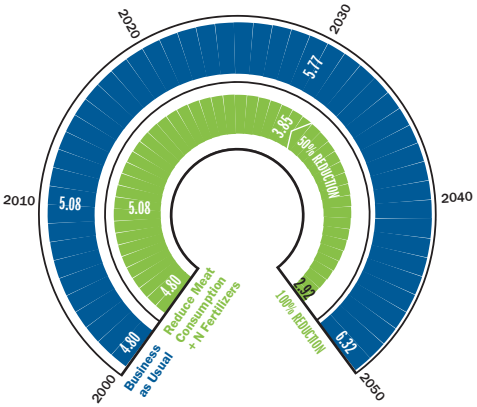
Rebecca Duff
Senior Research Associate, Batten Institute
for Entrepreneurship and Innovation
UVA Darden School of Business
duffr@darden.virginia.edu

Michael Lenox
Tayloe Murphy Professor of Business
UVA Darden School of Business
lenoxm@darden.virginia.edu

The agriculture, forestry, and other land-use sector accounts for 24% of global greenhouse gas (GHG) emissions.[1] Agriculture represents the majority of those emissions. Climate change mitigation will be critical to our ability to feed another 2 billion people worldwide by 2050. Farmers are already feeling the effects of extreme weather events and depleted land resources. To decarbonize agriculture, key actors will need to think differently about how we grow, produce, and consume food—and innovation will play a leading role in this transformation.

This *Batten Briefing* summarizes the key findings from our latest research report, "Path to 2060: Decarbonizing the Agriculture Industry." Here, we examine the two most significant sources of GHG emissions from this industry—livestock farming and soil management—and explore best practices and technologies that can reduce global emissions. We also discuss accelerators and possible roadblocks to decarbonizing the agriculture sector by 2060.

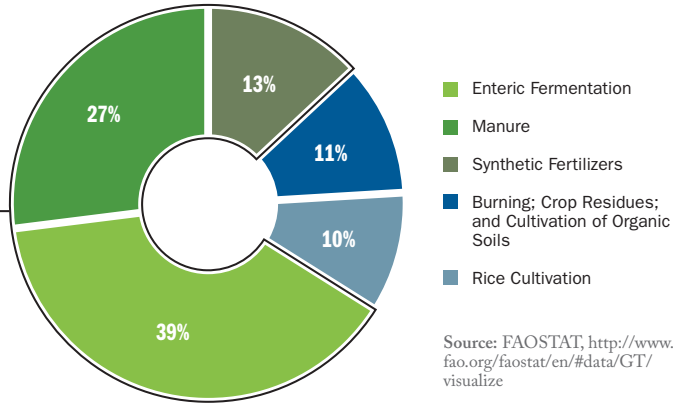
Meat and N Fertilizer-Free Scenario
Agriculture Emissions (Gtons/year)



Source: FAOSTAT, Emission Data for Enteric Fermentation, Manure Management, and Synthetic Nitrogen Fertilizers.

NOTE: FAO 2030 and 2050 projections for ***enteric fermentation***, ***manure management,*** & ***N fertilizer emissions*** reduced by 50% (2030) and 100% (2050). Eliminating these sources would significantly reduce total agriculture emissions.

Global Agriculture Emissions
by Source (2016)



Source: FAOSTAT, http://www.fao.org/faostat/en/#data/GT/visualize

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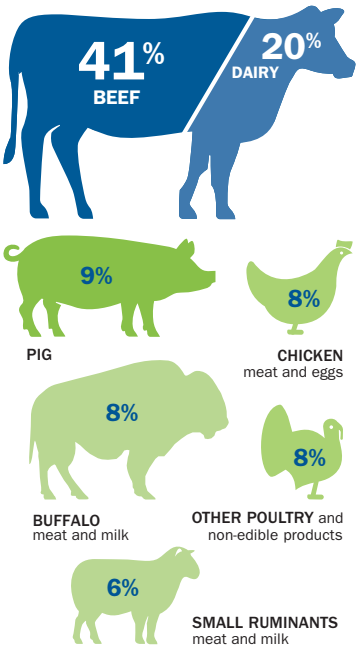
THE NEED FOR SUSTAINABLE GROWTH

Livestock Emission Sources

Source: FAO, By the numbers: GHG emissions by livestock, http://www.fao.org/news/story/en/item/197623/icode/



THE UN FOOD AND AGRICULTURE ORGANIZATION (FAO)[2] estimates that by 2050, 49% more food will need to be produced worldwide to feed the global population.[3] Historically GHG emissions have risen steadily with food production. Methane and nitrous oxide gases, which account for more than 80% of total agriculture GHG emissions,[4] could increase by as much as 60% by 2030[5] without mitigation. What are the low-carbon solutions that hold promise for decoupling food production and emissions growth?

LIVESTOCK FARMING

Cattle raised for dairy and meat production represent the largest share of livestock methane emissions, at 60%. Enteric fermentation, which results from the digestion of plant material in the ruminant digestive tract (commonly referred to as "cow belching"), and manure management are responsible for more than half of these emissions. Changing cattle diets could greatly reduce the methane emitted from cow belching. Options currently being explored include probiotics and food additives. Seaweed also shows great potential, with early measurements of 60% methane reduction.

Methane also is released as a byproduct of long-term manure storage. Anaerobic digesters, closed systems that introduce microorganisms to break down the waste in the absence of oxygen, can be deployed on-site to capture the gas. Farmers using this technology can sell the gas to local utilities interested in greening their own distribution.

A more radical approach to GHG emissions mitigation is to grow meat in the laboratory. Clean meat, in-vitro meat, cell-based meat, and cultured meat are all names being used for meat products derived from a sample of animal cells replicated in a culture outside of the animal. The impacts of clean meat on emissions would be significant, but consumer acceptance is questionable and commercialization years away.

SOIL MANAGEMENT

Nitrous oxide is naturally released from soils as a result of denitrification (removal of nitrogen) under anaerobic conditions. The addition of nitrogen-rich fertilizers, meant to increase yields, greatly increases nitrous oxide emissions. Applying fertilizers following the 4 Rs—right source, right rate, right time, and right place—can reduce the amount of excess nitrogen lost to the environment. Digital technologies and drones are helping to provide improved precision in plant and nutrient management.

What if a plant could pull nitrogen from the air? Legumes such as soybeans and peas have a natural ability to fix nitrogen through a symbiotic relationship with rhizobia bacteria. If a similar relationship could be established with commodity crops such as corn and wheat, then the demand for nitrogen fertilizers could be greatly reduced. Soil emissions also could be eliminated through the use of hydroponic (soil-less) indoor vertical farms. These are high-yield, low-carbon farms by design and offer other benefits such as food safety, high nutrition, and low water consumption. Yet these farms face significant cost and scaling challenges.

[1] US Environmental Protection Agency, Global Greenhouse Gas Emissions Data, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data (accessed August 2018). The share provided here represents direct emissions, or those generated on-site to support industrial operations. Electricity generated off-site is covered by the previous report, *Path to 2060: Decarbonizing the Electric Utility Industry*.

[2] FAO is an agency of the United Nations that leads a number of initiatives aimed at reducing worldwide hunger, malnutrition, and poverty. FAO is working with countries to mitigate climate change and strengthen the resilience of agriculture systems around the world.

[3] FAOs Work on Climate Change, UN 2017 Conference (compared to 2012 production).

[4] FAOSTAT, http://www.fao.org/faostat/en/#data/GT/visualize.

LEVERS TO SUPPORT CARBON REDUCED AGRICULTURE

TO DECARBONIZE THE AGRICULTURE industry, it will be necessary to consider several levers of change across the entire food chain: production, distribution and consumption. Farmer education is a critical starting point. According to FAO, 90% of farms worldwide are managed by one person or a family, and these farms produce 80% of agricultural output.[6] In order to meet a 2060 decarbonization goal, this education must be matched with advances in science and technologies, as well as changes in consumer demand.

INCREASE CONSUMER DEMAND FOR SUSTAINABLE ALTERNATIVES

Changes in the agriculture industry are driven by the consumer. We are already seeing a shift in developed countries away from dairy and toward more sustainable alternatives, such as almond, soy and coconut. In the United States, dairy milk consumption declined by 22% between 2000 and 2016, and plant-based alternatives are predicted to represent 40% of total sales by 2021.[7] In addition, higher consumer demand for plant-based meat substitutes, for clean meats, and for sustainably grown crops and forests could help accelerate a transition to low-carbon farming.

REDUCE FOOD LOSS AND WASTE

According to FAO, 1.3 billion tons of the food produced annually for human consumption is lost or wasted. Food waste accounts for 8% of global GHG emissions. In developed countries, this waste occurs at the retail and consumer stages. For developing countries, food is lost because of an inability to store and transport food properly. Strategies for reducing food waste include educating consumers and establishing cold-chain storage and transportation networks.

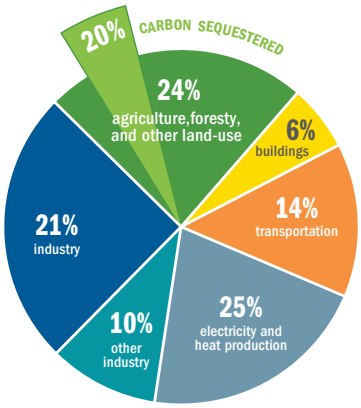
INCREASE PUBLIC SECTOR INVESTMENT AND INCENTIVES

Investments by the federal government can help to accelerate the development and commercialization of new technologies in agriculture. Yet in the United States, public sector investments in agriculture R&D are in decline. Incentives for best practices such as cover crops, crop rotation, advanced grazing management and comprehensive conservation planning are included in the 2018 Farm Bill. Still, the United States is falling behind other economies that are directing significant public funds toward innovation in agriculture.

INFLUENCE SUSTAINABLE PRACTICES IN THE SUPPLY CHAIN

For many large food companies, most carbon emissions result from actions in supply chains that are not entirely under their control, also known as Scope 3 emissions. Tracking emissions down to the level of farming operations can be challenging for a corporation to control and verify. Accounting tools have been published by organizations like CERES to help companies track emissions and identify opportunities for reduction throughout their supply chains. Partnerships are emerging between NGOs, producers, consumer goods companies, retailers, and traders to establish internationally recognized sustainable product standards, putting pressure on suppliers to deliver certified goods.

Carbon Sinks



The agriculture, forestry, and other land-use sector is unique in that it includes processes that not only release GHGs to the atmosphere but also natural resources able to store CO_2. Known as "carbon sinks," these resources currently **offset about 20% of global agriculture emissions**. Improving soil and forest management, planting new-growth forests, and cultivating crops that boost soil carbon could increase the CO_2 stored.

[5] Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, 2007: Agriculture. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter8-1.pdf.

[6] Global Agriculture, "Industrial Agriculture and Small Scale Farming", Agriculture at a Crossroads, https://www.globalagriculture.org/report-topics/industrial-agriculture-and-small-scale-farming.html (accessed May 2019).

[7] Cargill, "The Shifting Global Dairy Market", 2018, https://www.cargill.com/doc/1432126152938/dairy-white-paper-2018.pdf.

This briefing is the fourth in a series of sector-focused reports published by the Batten Institute for Entrepreneurship and Innovation at the University of Virginia Darden School of Business.

Visit **www.darden.virginia.edu/innovation-climate** to listen to a podcast discussing the findings of this report and to learn more about Darden's Business Innovation & Climate Change Initiative.

CREATE INCENTIVES FOR CARBON SINKS

Soils have the potential to store carbon if effectively nurtured and managed. Financial incentives aimed at sustainable land-management practices could encourage farmers to protect these carbon sinks. In California, rice farmers incorporating one or more farming methods provided in the Rice Cultivation Projects Compliance Offset Protocol, as part of the state's carbon emissions trading program, can generate offsets that are then sold to corporations looking to reduce their own carbon footprints. As the first of its kind, the rice protocol opens the door to other agriculture cap-and-trade protocols.

THE URGENT NEED FOR DECARBONIZATION

NO OTHER INDUSTRY is more tightly intertwined with climate than agriculture. Food production is a significant driver of GHG emissions and is the most vulnerable to a changing climate. There is widespread motivation to mitigate climate change, but these efforts are challenged by the diverse and distributed nature of farming operations across the globe.

Exciting new digital technologies and science-based solutions have the potential to drastically cut GHG emissions and boost production. Adoption of these novel approaches will require a worldwide effort led by individual nation-states to create significant incentives and programs to dramatically change agricultural practices at the local level. Carbon sequestration through more effective land management will go a long way toward balancing out the more carbon-intensive agricultural activities. Companies can assist with the transition to low-carbon farming by taking steps to better understand and influence their own supply chains. Consumers will accelerate this shift by demanding more sustainable products.

The amount of innovative activity taking place today in sustainable food production is encouraging, but decarbonization of global agriculture by 2060 seems unlikely. Unlike other industries in which a single disruptive technology can shift entire markets—such as electric vehicles—agriculture is more complex and will likely require a mix of technologies, best practices, and policies that speak to both multinational organizations and the small farmer.