Science Societies

Beyond yield: ARPA-E changes what's possible for biofuel feedstock production

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April 22, 2020

TerraSentia robot, from the University of Illinois at Urbana-Champaign, navigating under the crop canopy to collect plant phenotypic data to assess plant health and traits for breeding decisions. Photo courtesy of Claire Benjamin, University of Illinois.

> ARPA-E is accepting full applications to Phase 2 of the SMARTFARM program, and this solicitation is open to all. For more information, please visit **https://arpa-e-foa.energy.gov** and search for the SMARTFARM program.

The Department of Energy's (DOE) Advanced Research Projects Agency–Energy (ARPA-E) advances high-potential, high-impact technologies capable of transforming the ways we generate, store, and use energy with grants for $20 to $40 million each. As a producer and consumer of energy, the agricultural sector has been an important ally in the development, launch, and performance of programs. Recent examples are TERRA (**https://bit.ly/2Xg6Gzc**) and ROOTS (**https://bit.ly/3e6fY6O**), which commissioned multidisciplinary teams to combine advanced sensing, robotics, and analytics to create new possibilities in plant breeding and precision agriculture.

ARPA-E identifies technical challenges that are too risky for the private sector to attempt but have potential to transform the agricultural landscape. Additionally, producers need to be assured of the value of the science, at scale, before it can succeed in a commercial environment. One such challenge is the production of commercial-scale data sets in agriculture that are relevant, accurate, reliable, accessible, *and* cost effective. A 2018 workshop on the topic (**https://bit.ly/2UOmgjY**) sought to identify bottlenecks in the development of advanced sensing systems for energy-smart agriculture.

ARPA-E workshops are one-of-a-kind opportunities for interdisciplinary discussions about great technical challenges. As a result of this workshop on energy-smart agriculture, ARPA-E received several proposals, leading to the formation of a family of projects called the OPEN+ Sensors for Bioenergy and Agriculture Cohort (**https://bit.ly/2JNHici**). These projects include the development of biodegradable sensors, “wake up” sensors that power off until an analyte of interest is detected to conserve power, and micro-sensors for continuous soil monitoring. Such developments have transformational potential both in commercial agriculture and in the R&D community, offering insights into soil and plant health that would otherwise remain elusive.

A microneedle-based nitrate sensor capable of real-time, in planta measurements in the field. Photo courtesy of Liang Dong, Iowa State University.

The initial workshop exposed a wealth of exciting work toward improving crop yields, nitrogen efficiency, and pest resistance that would absolutely benefit the agricultural sector, including biofuel feedstock production—the primary focus of ARPA-E as a Department of Energy agency. Conversations with industry researchers, investors, and executives also highlighted a significant gap in understanding how these strategies would impact the emissions profile of biofuel feedstock production and whether that impact can be quantified with enough certainty to recruit feedstock producers into existing and emerging carbon markets.

With this knowledge gap in mind, ARPA-E recently launched the SMARTFARM program (**https://bit.ly/2V3XrPS**) to develop new sensor technologies, data analytics systems, and field-level management tools to inexpensively connect biofuel feedstock production practices to established fuel carbon markets. Accurate quantification of the emissions associated with feedstock production offers a pathway toward supply-chain-wide lifecycle accounting, allowing each stage in the supply chain to set its baseline and track improvements toward more sustainable and more valuable low-carbon fuels.

This will also benefit producers since growing feedstocks for biofuels is not easy, and the margins are small. But farmers could theoretically increase the value of their crop by implementing technologies and strategies that decrease the crop's carbon intensity, a metric for describing a biofuel feedstock's lifecycle greenhouse gas emissions. Established low-carbon fuel markets can confer nearly $200 per ton of carbon reduced to the product. At this level of carbon pricing, implementing strategies to reduce farm-level carbon intensity by as little as 10 g MJ^{-1} of biofuel energy could provide farmers with an additional $100 per acre, a sizeable new source of additional revenue.

The Texas A&M ROOTS team prepares to deploy its Low-Field MRI system to non-destructively image roots. Photo courtesy of Cody Bagnall, Texas A&M University.

It is important to note that the SMARTFARM program will not seek to develop technologies to *reduce* on-farm carbon intensity. Rather, SMARTFARM technologies that can inexpensively and accurately measure carbon intensity will provide a basis for measuring the impact of more efficient precision agriculture, and for the first time, would enable farmers to consider optimization strategies beyond yield. These strategies would complement existing incentives for improving yield by enabling farmers to evaluate the economic and environmental impacts of their decision making in a reliable and quantitative manner.

The first phase of the SMARTFARM program is under way. Phase 1 teams will build a network of ground-truth sites at commercial feedstock production farms growing a variety of crops to measure greenhouse gas fluxes and soil characteristics over the entire field. These “gold-standard” data sets will be made publicly available for farm-level carbon intensity quantification. The second phase will fund advanced research to develop low-cost greenhouse gas and soil carbon measurement systems to allow for broad adoption of carbon intensity quantification infrastructure on commercial farms. These Phase 2 systems will be deployed at the Phase 1 sites to demonstrate their accuracy and operational viability. Finally, a potential capstone for the SMARTFARM program would take the form of a grand challenge in which performing teams will compete to develop and demonstrate systems solutions capable of low-cost on-farm

carbon intensity quantification and optimization decision support.

As the SMARTFARM program picks up speed, ARPA-E remains enthusiastic about continued engagement with industry and R&D stakeholders. Whether it's acting as a reviewer for proposals, attending the ARPA-E Summit or workshops, or applying to be the next ARPA-E Program Director or Tech-to-Market Adviser (**https://arpa-e.energy.gov/?q** = jobs), ARPA-E welcomes your feedback on current programs, thoughts on future programs, and ideas for how the technologies funded by ARPA-E make their way to the market. ARPA-E is in the process of planning its annual meeting for the TERRA, ROOTS, and SMARTFARM programs this winter, where we will be exploring the future of agriculture to identify new program areas and to catalyze new networks across and beyond the current ARPA-E portfolio. Keynote speakers and breakout panels will focus on emerging themes such as soil carbon and ecosystem service markets, the potential of indoor agriculture, feedstock production for the growing bioeconomy, and more. As always, we welcome the opportunity to hear from you.

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