cenusa bioenergy

Closing Statements: Views from the CenUSA Leadership Team

Tyler Worsham and Anne Kinzel, July 2019

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Acknowledgement

We wish to acknowledge the efforts of CenUSA Communications Intern and Iowa State University Greenlee School of Journalism student Tyler Worsham for his hard work and dedication in interviewing the CenUSA Advisory Board and Executive Leadership Team. Tyler's efforts in drafting these articles was very good, and this publication would not have been successful without his dedication to doing things well and right!

NOTICE

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Introduction

CenUSA Bioenergy or *Agro-ecosystem Approach to Sustainable Biofuels Production via the Pyrolysis-Biochar Platform (AFRI-CAP 2010-05073)* was one of the first seven *AFRI Regional Bioenergy System Coordinated Agricultural Projects* funded by USDA-NIFA. The projects were expected to take on the significant challenge of facilitating "the development of regionally-based industries producing advanced biofuels, industrial chemicals, and other biobased products" across the United States.[1]

CenUSA Bioenergy was funded at the $25 million level to pursue an ambitious agenda between 2011 and 2019:

> Our vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed system will improve the sustainability of existing cropping systems by reducing agricultural runoff of nutrients and soil and increasing carbon sequestration.

This report presents an "**Impact Statement**" outlining CenUSA's core achievements. The Impact Statement was written by Project Director Ken Moore in July 2019.

In addition, CenUSA Communications Intern Tyler Worsham, working with Project COO Anne Kinzel interviewed the CenUSA Advisory Board and the project Executive Leadership Team throughout 2019.[2] We had two goals in mind in interviewing these key project participants. The first was to learn more about how the project progressed toward the vision, the second goal was to document, from the standpoint of these two key constituencies, the experience of participating in an extremely large and complex project.

We want to thank Tom Binder (Chair) and the entire Advisory Board for their commitment as citizen advisors throughout the life of the project, and especially for participating in this final "exit" type interview. The Advisory Board's participation was extremely valuable in providing

[1] Learn more about at the *AFRI Regional Bioenergy System Coordinated Agricultural Projects* at https://nifa.usda.gov/afri-regional-bioenergy-system-coordinated-agricultural-projects

[2] We were unable to interview Advisory Board member LaVon Schiltz. We thank her for her generous commitment of time to the CenUSA project.

insights about how a change as large as that envisioned by CenUSA could take place in the Midwest region.

Our Executive Leadership Team members provided exemplary leadership to their Objective teams. The results of their efforts are documented in the Impact Statement below. The Project Collaborators from the partner universities and their Extension Divisions produced extremely valuable products, both from a public outreach and university research perspective. The information provided in this report will show how well that work was done.

We also want to acknowledge the guidance and support we received from USDA-NIFA Division of Bioenergy National Program Leader Dr. William "Bill Goldner"[3] Dr. Goldner's leadership and insights into the project helped us adapt to a changing bioeconomy landscape.

While the CenUSA project terminated its funded period on July 31, 2019, we have a project website, www.cenusa.iastate.edu where all of the CenUSA resources are available for viewing and downloading. In addition to the website, CenUSA has a YouTube channel with instructional videos and webinars available at https://www.youtube.com/user/CenusaBioenergy.

CenUSA Bioenergy Impact Statement – Dr. Ken Moore

The vision of CenUSA was to create a regional system for producing advanced transportation fuels and other bio-based products from perennial grasses grown on land that was either unsuitable or marginal for row crop production. In addition to producing advanced biofuels, the proposed system would improve the sustainability of existing cropping systems by reducing agricultural runoff of nutrients and soil and increasing carbon sequestration. The project addressed two pressing societal concerns: 1) energy security, and 2) negative impacts of agriculture on soil and water quality. Congress had enacted legislation designed to incentivize the production of biofuels. The Renewable Fuel Standard (RFS) mandated increasing quantities of biofuels be produced with a significant shift to advanced biofuels beginning in 2010 and increasing throughout the duration of the project. The majority of the feedstock for these fuels was projected to be crop residues and dedicated energy crops, such as switchgrass. The question at the time was where were these feedstocks going to come from. There were already serious concerns about the negative impacts that removal of crop residues would have on soil and water quality. At that time, no cultivars of any putative energy crop had been developed and little was known about how to produce, harvest, or transport them. There was also

[3] Learn more about Bill Goldner at https://nifa.usda.gov/office/division-bioenergy.

considerable emphasis being placed on production of biofuels other than ethanol. CenUSA initially focused on thermochemical conversion of cellulosic biomass using pyrolysis. This conversion platform was chosen because it could be deployed in a distributed manner and would therefore be more compatible with the distributed nature of the feedstock than a centralized biorefinery.

The project was initially organized around nine objective areas critical to establishing a biofuel industry based on pyrolysis of perennial biomass crops: 1) develop cultivars and hybrids of perennial grasses optimized for bioenergy production, 2) develop sustainable production systems that optimize perennial biomass yields and ecosystem services, 3) develop flexible, efficient, and sustainable logistics systems, 4) identify and characterize sustainable bioenergy systems to achieve social, economic, and environmental goals and understand socioeconomic and environmental consequences of perennial bioenergy systems, 5) identify germplasm characteristics amenable to pyrolytic conversion and evaluate performance of pyrolytic biofuels, 6) evaluate policy, market, and contract mechanisms to facilitate broad adoption by farmers, 7) develop procedures for managing risks and protecting health for each component of the biofuel production chain, 8) provide interdisciplinary education and engagement opportunities for undergraduate and graduate students, and 9) develop outreach programs for all stakeholders of the bioenergy system. A tenth objective was added in the fourth year that involved exploring commercialization opportunities with industry partners Renmatix and ADM.

1. Feedstock Development

The Feedstock Development team worked on developing new switchgrass varieties and ways to produce more biomass with the goal of doubling switchgrass yields by 2020, primarily through boosting the rate of annual gain. The team's efforts focused on switchgrass, a perennial warm-season grass native to most of North America, because of its potential for high yields on marginal cropland and adaptation to a wide range of habitats and climates.

By employing new methods such as hybridization, delayed flowering, and genomics, the team worked to generate new switchgrass varieties for both bioenergy and forage that are more vigorous and better adapted to marginal lands. They also studied how to better manage switchgrass plants. The team's achievements ranged widely and included:

a. Developed and released 'Liberty', a new switchgrass variety that yields 40% more than other varieties and is widely adapted throughout the Midwest. Plant breeders combined yield traits from southern lowland types with winterhardiness of northern upland types to create Liberty. It was the first cultivar developed specifically for bioenergy production.

b. Developed a system for classifying gene pools of switchgrass that could provide germplasm for improvement of varieties for biofuels and ecosystems services.

c. Identified eight gene pools of switchgrass across the United States that could be a rich source of germplasm to improve commercial switchgrass varieties for biofuel production, and in restoration and conservation work. These gene pools harbor a great deal of genetic variety, providing a potential source of improved germplasm for new varieties that can respond better to climate change. Identification of gene pools gives plant breeders more information, leading to development of a wider range of varieties, adapted to specific regions, for producers to choose from.

d. Identified the origins and the genetic diversity of the two switchgrass ecotypes, upland and lowland, in their native habitats. Because the two ecotypes are adapted to different environments, that identification is important in the classification of gene pools.

e. Identified potential pests of switchgrass. Entomologists found that insects such as aphids could threaten switchgrass production for biofuels. They found that some varieties have resistance to these pests, information important in the development of new varieties.

f. Identified the Panicum mosaic virus as a significant pathogen that could stymie production of switchgrass for biofuels. Geneticists are studying the plant's response to this and other pathogens. Results will help pathologists make recommendations on preventing and managing diseases in switchgrass.

g. Developed a method of NIR calibration to measure more plant properties in switchgrass. This will be valuable in breeding improved bioenergy crop lines and will eventually be used by commercial biorefiners in thermochemical and biochemical conversion processes.

2. Sustainable Feedstock Production Systems

The Sustainable Feedstock Production Systems team conducted comparative analyses of the productivity of several bioenergy crop management strategies, and their potential and environmental impacts using a network of 17 fields strategically located across the Midwestern region. The team worked closely with others to develop production approaches the would fit seamlessly within the projected supply chain in terms of economics and logistics. Significant contributions and impacts included:

a. Developed harvest management strategies for producing feedstock with a composition more amenable to pyrolytic conversion. They discovered that delaying biomass harvest until after senescence dramatically decreases the amount of N contaminants in the final product. In addition, they found that the amount of N in the perennial grass crop is a good predictor of the amount of N in the resulting biofuel.

b. Developed crop budgets for producing switchgrass and other bioenergy crops and identified opportunities for reducing costs associated with establishment and production. This was critical to identifying the gap between cost of producing bioenergy feedstock and the price biofuel refineries were willing to pay for them.

c. Developed and evaluated weed management strategies for producing switchgrass for biofuel. Reducing or eliminating competition from undesirable plant species is critical to protecting yield of the bioenergy crop and maintaining a consistent chemical composition of harvested biomass.

d. Developed and evaluated switchgrass establishment strategies. Rapid establishment of a bioenergy crop is essential for producing an economic return to the land devoted to producing it. Poorly established bioenergy crops do not yield well in the establishment year, do not compete well with weeds, and often take years to reach full production potential.

e. Developed a crop model for assessing the impact of biochar, a coproduct of pyrolysis, on soils and crops. The model enables projections of the long-term impacts of biochar application on soil quality and resulting positive impacts on crop performance.

3. Feedstock Logistics

The Feedstock Logistics team developed innovative systems and strategies for sustainable and economical harvest, transportation, and storage of perennial grasses. Improving the efficiencies of these activities is important because they can account for as much as half of the production cost of biofuel feedstock.

The team focused on the development and evaluation of harvest and logistics systems that are easily adaptable, produce consistent and quality feedstock for conversion, and are economically, energetically, and environmentally efficient and sustainable. The team also investigated novel harvest and transport systems, demonstrated these systems at field scale, and evaluated harvest and supply chain costs. They also evaluated technologies for more efficient feedstock deconstruction and drying. Significant contributions and impacts included:

a. Designed and developed improved equipment for a single-pass, intensive conditioning-tedding process, that saves biomass producers time and money by decreasing the amount of days that it takes to dry switchgrass after harvest.

b. Designed and developed new ways to increase bale density, making storage and transport of switchgrass bales easier and more affordable.

c. Developed new computer models that predict the rate of drying, helping farmers better plan their harvest.

d. Developed models that predict the rate of switchgrass harvest across the Midwest, that will allow biorefineries that harvest their own perennial-grass feedstocks to optimize the size of their harvest fleet.

e. Investigated the possibilities for developing a new, more affordable baler, that provided critical data for designing better equipment in the future.

4. System Performance

The System Performance team focused on providing detailed analyses of feedstock production options. They created simulation models to assist policymakers, farmers, and the bioenergy industry to make informed decisions about which bioenergy feedstocks to grow, where to produce them, what environmental impacts they will have, and how biomass production systems are likely to respond to and contribute to climate change or other environmental impacts.

a. Field studies using a mass balance approach found that surface run-off was low with switchgrass compared to other crops and this resulted in a significant reduction in losses of N and P.

b. System simulations using the SWOT model demonstrated that producing switchgrass on marginal land within the Upper Mississippi River Basin would greatly reduce the flow of nutrients entering surface water and should decrease the extent of hypoxia occurring in the Gulf of Mexico.

c. Using a simulation model, projected that conversion of land to biofuel crop production would, in general, decrease greenhouse gas emissions because there is less carbon and nitrogen returned to the soil.

d. Identified concerns about potential air quality impacts of perennial biomass production associated with N fertilizer management that should be addressed in further developing N management strategies for switchgrass and other perennial biomass crop production.

5. Feedstock Conversion

The Feedstock Conversion and Refining Team initially focused on evaluating the pyrolysis conversion platform and its potential to produce fuel and other valuable coproducts. Later in the project they extended their scope to include other potential bioproducts that could be manufactured from biomass.

One of the team's first objectives was to develop a technoeconomic analysis (TEA) model of the potential for converting perennial grasses used for biofuels and biorefinery co-products into value-added fuels and useful chemicals, through catalytic pyrolysis processing. A TEA uses available data from commercial operations. The model can determine the economics of turning perennial grass feedstocks and their co-products, especially lignin, into marketable, value-added products that can help a biorefinery turn a profit. In the long run, these advances will lead to conversion of grasses into biofuels and such value-added products as bioasphalt, cellulose pulp, fermentable sugars, and carbon fibers. Significant contributions and impacts included:

a. Development of a TEA model for assessing the potential of commercial scale pyrolysis of biomass that would be harvested from perennial grasses grown on marginal land.

b. Found that the composition of biochar and its value as a soil amendment can be manipulated by adjusting operating conditions under which it is pyrolyzed.

c. Determined that the costs associated with converting biomass to fuel through pyrolysis were projected to be too high to be able to compete effectively with fossil fuels. Therefore, alternative uses of bio oil and coproducts of pyrolysis with higher value need to be explored.

d. New thermochemical-process technologies were developed by the team that will help commercial partners (ADM and Renmatix) get more value from the lignin byproducts that they currently generate.

6. Markets and Distribution

The Markets and Distribution team was initially responsible for evaluating farm-level adoption decisions and exploring policy, market, and contract mechanisms that facilitate broad scale adoption of perennials in the landscape. They evaluated potential impacts of an expanded

advanced biofuel system on regional and global food, feed, energy and fiber markets. As the project progressed this objective became aligned with Objectives 2 and 4 and was engaged in producing many of the impacts associated with them. Significant contributions and impacts included:

a. A survey of crop farmers in the North-Central region of the United States found that they would ask for an average of $230 per acre, or about $82 per dry ton, to grow switchgrass for cellulosic biofuel on their marginal crop land. The survey also found that farmers are more willing to use that land to produce switchgrass themselves, rather than lease out the land to another entity for growing switchgrass.

b. Market analyses found that the profitable production of switchgrass for biofuel depends primarily on the price of oil, as well as continuation of the Renewable Fuel Standard (RFS).

c. Research indicated that alternative uses of biomass could be profitable and provide alternative market opportunities while an emerging biofuel market establishes. For example, feedlots could use hay from perennial grasses such as switchgrass as an additional source of roughage in beef rations.

7. Health and Safety

Bioenergy feedstock production will have inherent differences from current agricultural practices. These differences could increase the potential for workforce injury or death if not properly understood and if effective protective counter measures are not in place. The Health and Safety research team evaluated risks associated with feedstock production and increased exposure to dust. Significant contributions and impacts included:

a. Developed a probabilistic risk assessment model to estimate worker injury risk using USDA and Bureau of Labor Statistics (BLS) data of farming operations and worker injuries.

b. Found that injury risk for producing biomass crops would be lower than that associated with producing corn grain.

c. Developed guidelines for the safe handling, application and storing of biochar.

8. Education

The team focused on providing interdisciplinary training and engagement opportunities for undergraduate and graduate students, and developed a shared bioenergy curriculum core for the North Central region of the United States. Significant contributions and impacts included:

a. Developed curriculum materials and learning modules (17) for use in higher education.

b. Hosted an internship program for undergraduates that impacted 69 students.

c. Offered an intensive learning program for graduate students and provided support for 29 graduate students earning research degrees associated with CenUSA research.

d. Provided support and training for three postdoctoral research associates.

9. Extension and Outreach

The Outreach and Extension team delivered science-based knowledge and informal education programs to farmers, the ag industry and to youth programs linked to 4H and FFA. The team produced extensive educational materials which are available in our Resource Library page. Their goals included: developing perennial/biochar/bioenergy materials for ag producers and extension educators; creating awareness of the benefits of perennial and biochar agriculture and horticulture; establishing an Extension Master Gardener "citizen science" program for researching the use of biochar in horticulture; and stimulating adoption of Best Management Practices for perennial grass production, pyrolysis conversion of biomass to biofuels, and utilization of biochar as a soil amendment. Significant contributions and impacts included:

a. Under the direction of professional scientists and their institutions, citizen science projects amplified the impact of the CenUSA program. Farm demonstration sites and garden research plots provided hands-on learning opportunities for participants and produced valuable research data to share with the public.

b. Extension and outreach professionals and farmers in Indiana, Iowa, Minnesota, and Nebraska established nine on-farm demonstration sites. Farmers established plots, collected data, and shared information with others at field days. Extension agents provided guidance, organized the field days, tours of plots, and informational meetings, which eventually reached more than 5,000 agricultural producers, consultants, and agricultural industry leaders.

c. University of Minnesota Extension and outreach professionals and Extension Master Gardener volunteers established five citizen science research garden sites studying

biochar as a soil amendment. More than 7,000 people visited the sites and/or participated in educational programs, and exhibits.

d. Two groups of Extension collaborators focused specifically on youth outreach programming. Purdue University Extension and outreach professionals created interactive electronic lessons and established demonstration plots of perennial grasses for STEM (science, technology, engineering, and math) career events, reaching more than 900 high school students.

e. Faculty and student interns at Iowa State University combined forces to create C6 BioFarm, a robust suite of STEM materials, for middle-school-aged youth. C6BioFarm includes an iPad app, supporting curricula and an iBook. These materials are available online to teachers and other youth mentors, such as 4-H and FFA leaders. C6BioFarm underwent two pilot tests, reaching 350 and 330 youth and adults, respectively. The C6 program has been used by more than 2000 people.

10. Commercialization

Commercialization efforts were focused on creating market opportunities for biomass to be used in commercial processes in advanced stages of development. Archer Daniels Midland Company (ADM) and Renmatix were industry partners involved in this effort to create markets perennial grasses. This objective was active during the last two years of the project and produced the following impacts:

a. Evaluated feedstocks in ADM Acetosolv® process and determined that switchgrass could be used in this industrial process.

b. Evaluated feedstocks in Renmatix Plantrose® process and determine that switchgrass would be an acceptable substrate.

CenUSA Advisory Board and Executive Leadership Team Interviews

All of the words and ideas expressed in the following articles fairly and accurately represent the speakers. Some quotes may be paraphrased for brevity and clarity.

Thomas “Tom” Binder, Advisory Board Chair and Commercialization Co-Project Director

Tom Binder[4], CenUSA Advisory Board Chair and retired senior vice-president of research and development at ADM spoke with CenUSA Communications Intern Tyler Worsham in April 2019 about his work and involvement with CenUSA. Binder served as the Advisory Board Chair and as a co-project director for the Commercialization objective. As a part of his role with CenUSA, Binder determined the feasibility of using the Acetosolv chemical process on switchgrass and other perennial grasses.

How did you initially get involved with CenUSA?

"ADM (Archer-Daniels Midland) had several research projects and was involved in some other ongoing programs at Iowa State University. Jill Euken (Extension and Outreach Co-Project Director) and Robert Brown (Feedstock Conversion/Refining Co-Project Director) asked researchers from ConocoPhillips and I to help them with their presentation of the CenUSA program for the USDA, so we got involved early on in the project."

What was your position at ADM when you got involved?

"I was the senior vice-president of research and development."

Could you briefly describe why you were interested in working with CenUSA?

"At the time when the CenUSA project started, there was a huge interest in looking at biomass for fuel applications, as well as using crops like switchgrass to control some of the pollution runoff problems associated with row-crop agriculture. ADM was interested in developing those areas so that corn could be more sustainable."

What new ideas and disciplines were you exposed to as a part of your CenUSA experience?

"I learned about a lot of the plant breeding that was involved in developing new strains of

switchgrass, as well as some of the more theoretical environmental research on how planting different crops on different areas would affect sustainability in agriculture."

Have you been involved in any other government-funded research projects other than CenUSA, whether as a participant or in an advisory capacity?

"I was on the Biomass Research and Development initiative. I've also been involved with the

[4]Learn more about Tom Binder at https://www.prairiefood.com/news/tom-binder-joins-the-prairiechar-advisory-board.

National Petroleum Council in developing the energy outlooks for the United States. I've also been involved in several projects funded by the USDA through ADM."

How was CenUSA different form these other government-funded projects?

"The CenUSA project was very large as far as the amount of funding is concerned. It involved multiple universities and multiple disciplines, so after getting all of those things together, it was nice to see that it actually happened."

You became a co-project leader in the third year of the project when CenUSA really started looking at the commercial side of things. Was there a specific area of research that you wanted to see advance?

"At that point, the USDA was pushing CenUSA to expand into the commercialization of switchgrass, so two different programs started that went beyond pyrolysis. We at ADM already had a project looking at corn stover as a feedstock for the Acetosolv chemical process for isolating cellulose, hemicellulose and lignin. What we proposed to do is look at the energy crops as well, including switchgrass and miscanthus, to see if those would work as well as corn stover."

What were some noteworthy successes that you achieved in your role as a CenUSA commercialization co-project director?

"Both the switchgrass and miscanthus worked well in that Acetosolv process we were looking at. The most interesting thing was that miscanthus had a very high lignin content compared to other grasses, so if you are after lignin, miscanthus would be a good source for processing for that product.

I think that the biggest problem with bioenergy crops right now is that there's no developed market for energy crops that can be commercialized, so I don't know that there are any major discoveries. I do think that in the long-term, the energy crops could provide a lot of the fiber needs of the world, but until that is expanded beyond what we currently have available, the market's just not there."

What do you think it would take to create those markets?

"Your guess is as good as mine."

Did you and your team encounter any unforeseen obstacles in your research?

"No, not really, since switchgrass and miscanthus fit pretty well into our process. That worked well."

Were there any challenges that you expected to have going into your work?

"No, I assumed that they would act similarly to corn stover, and they did. The major thing that we found was that if I wanted to produce lignin as my major product, miscanthus would be a better crop than corn stover and switchgrass."

There are niche markets that are slowly starting to develop for perennials, but there is little demand for producers to invest in producing for them. In your opinion, what is the potential tipping point that will get producers to plant more switchgrass acreage?

"The market has to be large enough before someone will invest in a processing plant that can take significant acreage of switchgrass. The market's just not there. It's just not large enough. Someone has to find a really efficient way to convert it into a fuel or a chemical feedstock in order to get someone to invest in a large processing plant."

So You don't know exactly what it would take to make them competitive in the biofeedstock market?

"I do think CenUSA helped develop a lot of the tools so that when someone does come up with an idea for an application, those can be put into place, but we just haven't found the markets with high enough value to get anyone to invest in this industry."

What might some of those tools be?

"I refer to the breeding tools for if you want to change the cellulose, hemicellulose or lignin content, maybe to change what organic molecules are in the lignin."

In what new directions do you hope to see perennial biofeedstocks go moving forward?

"I would like to see a regrowth in the U.S. cellulose market. Most of the pulp used for paper and other applications like that has moved to Canada. Even a measured portion of that has moved to Brazil and Asia. I'd like to see a revitalization of paper and pulp industry in the United States. I do think that some perennial crops could be feeding into that."

In what ways did your participation in the project challenge and broaden your professional knowledge and skillset?

"There were a large number of teams that were working on this project from plant breeding to Extension and safety which really put into perspective that if you're going to develop something new, you not only have to be developing that new product, but you have to get the public to accept it. You have to have safe operations and so on. A very broad team is needed to bring a new product along."

What is the most important or most interesting facet of your work with CenUSA that you would like for the interested members of the general public to know and understand?

"The public should know that the universities and the federal research groups are really working to have things in place so that when the need for them is there, they're ready to go. They're looking to the future rather than simply solving today's problems. There's a huge amount of information that Iowa State University and the other universities have put together so that when we do need it, it will be available."

* * * *

Kenneth "Ken" Moore, Project Director

Ken Moore, Charles F. Curtiss Distinguished Professor in Agriculture and Life Sciences and Pioneer Hi-Bred Agronomy Professor in Agronomy,[5] has been the CenUSA Bioenergy Project Director since the project's inception in August 2011. In July 2019, Dr. Moore spoke about his work and involvement with CenUSA in the areas of feedstock development and sustainable feedstock production systems with CenUSA Communications Intern Tyler Worsham.

Moore was approached to be the CenUSA Bioenergy Project Director due to his background in agronomy and his previous administrative experiences with various scientific research projects and professional societies. Much of the nature of his leadership role and the responsibilities of his position revolved around communicating the needs and requests of the USDA to the co-project leaders and advisory board members. He served as a liaison between the various elements of the project to ensure that CenUSA faithfully followed USDA-NIFA's vision for the project.

In spite of various complications, Moore believes that CenUSA was able to accomplish a lot over the years. The project proved the economic feasibility of growing switchgrass on marginal soils, found new ways to utilize bioproducts, made advancements in the field of plant breeding and so on. Moore holds that the successes of the project are a foundation upon which to expand further research and from which this country will know how to successfully use switchgrass and other perennial grasses as an alternative transportation biofuel when the time comes.

How did you get involved with the CenUSA project?

"CenUSA was the result of two independent teams merging their efforts. I had been asked to participate in both projects, so I was aware of what both teams were preparing to do. It

[5] Learn more about Dr. Moore at https://www.agron.iastate.edu/people/kenneth-moore

occurred to me that neither project addressed all of the goals expressed in the Request for Application, but they could be a formidable project together. I brought this to the attention to the leaders of both teams, Ken Vogel in Nebraska, who was focusing more on the feedstock side, and Robert Brown in Iowa, who was focused on the conversion side.

That eventually led them to ask me to assume a leadership role. At the time I was asked, I misunderstood the question. I thought they were just asking me to lead a part of CenUSA related to agronomy. As it turned out, I became the project director and assumed that leadership role for the entire project."

What about you and your professional background made you the best choice for the role of the CenUSA project director?

"I would say that I was a 'good' choice given the circumstances. I had served as the president of two different scientific societies and had a lot of experience working with people from different audiences and backgrounds. The project needed someone to promote its vision and to take care of their administrative needs. I knew a lot of the people involved because I had previously worked with many of them. We had the mutual trust that we needed to work together in a large team."

Could you go into further detail about your professional background? If you worked on any other projects as the project director or otherwise, what did you do, and how did it differ from CenUSA?

“Well, I have a lot of experience leading research projects in my career, but nothing of the size and scale of CenUSA. I have, however, been the research leader for a number of smaller projects. With respect to this project, the leadership skills that I needed were not necessarily related to research, but rather in administration. I have been involved in professional societies, served on the board of directors and have been the president of two societies, so I have this experience working with people across a broad array of disciplines, backgrounds and experiences. I was able to work with all of them to achieve a common goal, so I think that was what was needed in a director for CenUSA. I think that’s what I brought to the table.”

What were some of the unique experiences and responsibilities of being Project Director that perhaps the co-project directors, the advisory board members and others involved with the project didn’t have?

“As the director, I worked directly with both CenUSA personnel and our advisory board, and it was my responsibility to manage these relationships. Working with the sponsor was

extremely challenging and rewarding. There were so many occasions where we had to respond to unanticipated requests.

We developed four budgets over five years, each one resulting in a reduction of funds available to each co-PD. As you can imagine, some were quite reluctant to engage in this process, but on the whole, most were extremely gracious and helpful as we scrambled to meet yet another request from USDA. Working with the advisory board turned out to be the most rewarding aspect of my experience with USDA. We had so many excellent people serving on the board who were committed to helping us succeed. They critiqued our work in the most positive way and helped keep our activities aligned with the vision of the project."

What were some of the anticipated and unforeseen obstacles that were unique to your role as Project Director?

"When we began the project, it was an entirely different economic environment than the one under which we operated for most of the time that we worked on the project. We proposed a system that made a lot of sense when corn prices were extremely high. There was a lot of potential for developing fuels from cellulosic biomass, but then the bottom fell out of the corn market. You could make ethanol with corn very inexpensively compared to what we were proposing, so it sort of took the wind out of our sails."

How did the project broaden and challenge your professional knowledge and skill set?

"I think that to be successful, we all needed to be flexible and willing to adapt in response to changes that were imposed on us by the sponsor and by the economic environment. The basic principles and operating parameters under which we started changed. Even though some of our goals remained important and fixed relating to environmental services, we really had to scramble to deal with the economic side. Had the corn market stayed the way it was in terms of cost of producing ethanol, we would have likely achieved much greater success at penetrating the market with cellulosic biofuels. Given that this didn't happen, a lot of the work that we did is going to be dormant until the price of corn increases again.

I also had some experience working with people from different disciplines and had to learn some of the different language that they use, so it was interesting to try to bring those people together and try to help them understand each other. I think that was challenging. In a way, it was kind of like being an interpreter. We had to develop a common language in order to interact with each other."

Language has different meanings depending on your background.

"Exactly. Fortunately, I had experience with that. Once we overcame those obstacles, the team really worked well together across disciplines. It was quite extraordinary."

What were some of the unique experiences and responsibilities of being Project Director that perhaps the co-project directors, the advisory board members and others involved with the project didn't have?

"As the director, I directly interfaced with both USDA-NIFA and our advisory board, and it was my responsibility to manage these relationships. My responsibility to the project was administrative in nature. My job was to make each team member's job easier, so I was responsible for dealing with the granting agency USDA-NIFA, and I was also the direct liaison with the advisory board. I spent a lot of time on those activities, and as it turned out, dealing with the administrative requests from USDA was almost a full-time job.

In my previous experience, you wrote a grant proposal, it was funded, and the budget was largely set. Nobody involved would be tinkering with your objectives and trying to direct your outcomes. That was not the case with this project. USDA-NIFA was pretty demanding in how they redirected our goals as we went along. Of course, whenever you do that, you have to adjust the budgets that follow. There were so many occasions when we had to respond to unanticipated requests. We developed four budgets over five years, each one resulting in a reduction of funds available to each co-project director. They wanted us to do different things, but they couldn't give us the extra funding to do those things. This forced us to re-budget.

As you can imagine, some team leaders were quite reluctant to engage in this process, but on the whole, most were extremely gracious and helpful as we scrambled to meet more requests from USDA. That took a lot of time and effort. I had to work with people who had to give up funds to make that possible. That was challenging, but it was also rewarding in the sense that we had a much better project for having made those changes.

Working with the advisory board turned out to be the most rewarding aspect of my experience with CenUSA. We had so many excellent people serving on the board who were committed to helping us succeed. They critiqued our work in the most positive way and helped keep our activities aligned with the vision of the project.

We had a lot of interaction with Bill Goldner and others at NIFA who really tried to keep us relevant to the changing situation in the world. It was very challenging, but also very rewarding. The advisory board was a gift. We had a great team that really engaged with us and provided great insights and critiques of our work that helped us achieve more than what we would have without their advice and assistance. Some of them actually provided

material assistance as well. I didn't anticipate that going in, and that was extremely rewarding for me."

I got the impression from the advisory board members that they kept the perspectives of the researchers grounded.

"Yes, they did. They asked the hard questions, and I think that was absolutely essential. They provided the grounding for the project, and they did that in a very constructive and friendly way. There was the potential for contention not only between the board members themselves, given that they were all from different areas, but also with the researchers and educators, and very little of that happened. I don't know how else to describe it in any other way."

You mentioned your experience working with people from USDA, with the advisory board members and the co-project directors. I'm aware that there are others with whom you also worked closely on the project. Could you elaborate on the capacity to which you worked with those who were not among the co-project directors and advisory board members?

Thank you for asking this question. There were so many people working behind the scenes to make the project successful. Anne Kinzel became the associate director soon after the project was funded and stayed with it throughout. She played a key role in keeping the project on track and also in managing our relationships with USDA and the Advisory Board. She was so essential to the project's success that I can honestly say that it would not have been possible to manage without her.

There were others on the administrative team whose contributions need to be acknowledged as well. Diane Meyer was the grant coordinator at the Bioeconomy Institute who assisted us with the original grant application. There would have never been a project without her extraordinary effort in pulling together all of the documents and budgets required for the application. She even pulled an 'all-nighter' in order to get the application done.

Becky Staedtler oversaw the budget for most of the project. It was a huge job in that we were undergoing perpetual re-budgeting. Valerie Evans became our budget manager and did an extraordinary job managing the transactions and attending to the details involved. When she moved to another position, Jill Cornelius replaced her and likewise did a fantastic job. When Becky retired, Mary Scott-Hall became the budget director for BEI and oversaw the closeout of the project financials. I am truly grateful to have been able to work with all

of these people and I am greatly pleased to acknowledge their contributions to CenUSA's success."

What is the most noteworthy or most interesting facet of your work that you would like the interested members of the general public to understand?

"I would like for people to understand that the project was led by a lot of people. Just because I was Project Director doesn't mean that leading the project wasn't a team effort. There were a lot of people involved in that. The co-project directors who led the objective areas really deserve credit for leading their teams and for the successes that those teams achieved. My role was to help them be successful at leading their teams.

I don't think people understand how large and complex these projects are and how many people they involve. We had well over 100 people, so partitioning the success was difficult because it really depends on so many people being willing to work together and help each other to do so many different things to achieve our goals. I don't think people have any idea how complicated it is."

What do you currently hope will happen as a result of what CenUSA has been able to accomplish?

"Well, I think that a lot of good things have come out of CenUSA. Certainly there are all of the deliverables that you anticipate, all of the journal articles, popular press articles, Extension bulletins, the videos and educational products. All of that stuff is and will continue to have a strong impact. I think that we demonstrated that it is feasible to produce bioenergy feedstocks from native perennial grasses that are grown on land that isn't particularly productive for growing row crops like corn or soybeans. We closed the gap, but we still didn't quite achieve economic success. We closed the gap to around $20-to-$25, so that is the next frontier, but it really isn't that much of a change in commodity prices to make cellulosic biofuels more attractive. When that happens, or if we can close that gap with more research, everything we did in our research is going to pay off significantly.

We also had a lot of successes within each of the individual disciplines. I'm sure that the objective area leaders talked to you about what they accomplished. Rob Mitchell told me that they advanced the science of switchgrass production by 25 years. That's a huge statement. Mike Casler in plant breeding was able to accomplish so much with the resources available to his team. He accomplished a lot of incredible things. 'Liberty,' a switchgrass variety for bioenergy, was finally released under CenUSA. All of the teams made scientific advances that will stand for a long time."

In what new directions do you hope to take your own work after CenUSA?

"I'm currently focused on things that are tangentially related. We want to expand into new directions in perennial groundcover systems for corn and soybean production. We want to increase the land area under perennial groundcover, and one way to do that is with the approach we took with CenUSA by putting marginal land into perennial energy crops. The next steps are to focus on land that isn't marginal that would otherwise be used for corn and soybean production and to find ways to farm it more sustainably. One of the ways to do that is to increase the amount of cover throughout the year that is present on the land, so we will continue to work with perennial groundcovers in order to do that. We've been reasonably successful and will continue to expand our efforts to develop that system."

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CenUSA Bioenergy Advisory Board

Albert "Bert" Bennett, CenUSA Advisory Board

Albert Bennett[6] spoke in May 2019 with CenUSA Communications Intern Tyler Worsham about his experience on the CenUSA Advisory Board, where Bennett utilized his familiarity with thermal conversion technologies and industrial-scale biochar production to assist in the direction of the project.

How and why did you join the CenUSA Advisory Board?

"I'm an alumnus at ISU (Iowa State University) and did my Ph.D. work in agriculture engineering and biorenewable resources and technology. After completing that academic work, I went to work in industry at a company called ICM, Inc., located in Colwich, Kansas. ICM is a leading engineering and manufacturing firm that helped develop the majority of first-generation ethanol production facilities here in the United States.

One of my tasks at ICM was to look at new and developing thermal conversion technologies and look at how they might be integrated into existing first-generation ethanol production facilities. Those early efforts led to my helping develop, design, and build a commercial-scale biomass gasification facility, which we used to demonstrate the technology. One of the benefits of operating that demonstration facility was that we were also able to produce large volumes of biochar. Much of that biochar was supplied to local farmers and major research institutions, including ISU (Iowa State University). I assume the reason why

[6] Learn more about Bert Bennett at https://www.linkedin.com/in/albert-bert-bennett-86b08226/

CenUSA asked me to join the advisory board was because of my expertise with thermal conversion technology and industrial-scale biochar production."

Could you go into more detail about your professional background as it relates to your role with the advisory board?

"When I was completing my academic studies at Iowa State, a lot of what I was looking at involved modeling logistics and conversion of biomass fuels into energy for a first-generation or modified first-generation ethanol facilities. That academic experience and my knowledge of how to integrate biomass utilization into an industrial process is one area where I feel that my expertise had some value to the advisory board. Also of value was my actual engineering and manufacturing experience with thermal conversion systems and their integration into larger industrial applications, as well as the utilization of these systems for the production of biochar. Those are the areas, I believe, where my expertise was of most benefit to CenUSA."

What were some of the most important inputs you personally provided to the CenUSA leadership team?

"I like to think that some of my insight on biomass logistics was of value to the CenUSA logistics team. I was very impressed with the team that CenUSA put together. In addition to logistics, the area where I like to think I had the most benefit was sharing my experiences with the feedstock conversion team. One of my suggestions, which was also shared by others on the team, included recommending that the team consider integrating fast pyrolysis technologies and other feedstock thermal conversion technologies into first-generation ethanol production facilities and other industries as a potential market for the large volumes of future biomass produced in the CenUSA region, as well as a platform to demonstrate the value of these new and existing conversion technologies."

Could you provide any specific examples of how you applied that knowledge to your advisory role on the board?

"When attempting to commercially deploy a new technology, it is usually very challenging to accurately estimate the actual investment costs needed to scale up from successful laboratory or pilot scale demonstrations. Speaking from my own personal academic experiences, it is typically very difficult to obtain real-world cost information that can be used in developing a representative Techno-Economic Analysis (TEA) for new biomass conversion technologies, such as fast pyrolysis. Developing a realistic TEA is especially challenging when the new technology is coming from small startup companies or from academia.

The inventors and researchers typically do not have the engineering and construction experiences needed to scale up from lab and pilot scales to commercially viable, large-scale industrial processes. Much of the real-world cost information needed to describe a new technology at industrial scale is also usually tied up as trade secrets or proprietary information; or it requires allocation of limited and costly 3rd party engineering and construction management resources. In addition to difficulties in estimating costs of scaling up new technologies, it is also common to encounter unexpected and costly engineering challenges.

As a means to bridge the gap between successful lab and pilot scale demonstrations and a commercially viable, large-scale industrial processes, my suggestion to the team was to consider co-locating new feedstock conversion technologies at an existing ethanol production facility. By co-locating at an existing facility, the new conversion technology can be commercially demonstrated at an intermediate scale and take advantage of the facility's existing infrastructure, experienced operations and maintenance personnel. The existing facility can benefit from commercializing new products, likely recovery and utilization of waste heat energy which can potentially reduce the facility's overall carbon footprint. In turn, the inventors and researchers can benefit by having much of the required investment capital dedicated to engineering, equipment manufacturing and installation of the actual systems needed to demonstrate the commercial viability of the new process.

More specifically, I suggested that we consider demonstrating the conversion of biomass at a scale of 100-to200 tons/day, which is at a scale that can provide a good design basis for scaling to future larger applications. It is also at a scale that can be readily supported by the local collection, transportation and handling of biomass in much of the CenUSA's area of interest."

What specific project objectives do you think directly benefited the most from your knowledge and experience?

"I think that the thermal conversion team benefited most from my experience, as well as the feedstock logistics team to a lesser extent. Regarding the other areas, I was appreciative of the opportunity to learn from their expertise."

How was the advisory board as a whole able to exert influence on the direction of the project?

"The advisory board's diverse makeup and combination of experienced producers, equipment manufacturers, industry representatives and state government agricultural representatives provided what I believe to be a lot of valuable guidance and insight to

CenUSA's research teams. I was especially impressed with input from actual producers and state government representatives. I'd like to think that hearing directly from producers and their state agricultural representatives helped the CenUSA teams to focus on efforts that would ultimately help local producers and the environment."

What is the most important contribution that the overall advisory board has made to the CenUSA project?

"In my view, it was a combination of all of the diverse feedback we gave. We had a lot of really talented individuals on the advisory board, and I personally learned a lot from listening to the other advisors. Hopefully, the board's comments and interaction with the research teams provided guidance that will ultimately benefit the producers and the environment."

How do you think your experience with the CenUSA advisory board will influence your future work?

"There are many of us in industry, myself included, who are interested in deploying renewable biomass resources and energy systems into our respective industries. By listening to CenUSA researchers and fellow advisory board members, I now have a greater understanding and appreciation for what it would take to produce, handle and utilize large volumes of renewable sources of biomass for industrial applications. In fact, my company is now actually building a large thermal conversion system dedicated to providing a new ethanol production facility with combined heat and power from locally collected biomass."

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Denny Harding, CenUSA Advisory Board

Denny Harding[7], Bio-Economy Manager (Ret.) for the Iowa Farm Bureau and a CenUSA Advisory Board member, spoke about his experience on the project with CenUSA Communications Intern Tyler Worsham in June 2019. Harding spoke about how he provided CenUSA with the input and perspective of an Iowa farmer and Farm Bureau professional.

How and why did you come to join the CenUSA advisory board?

"When it was first being put together, I believe CenUSA approached the (Iowa) Farm Bureau so they could have a representative of Iowa's farming community. The Iowa Farm Bureau is

[7] Learn more about Denny Harding at https://www.linkedin.com/in/denny-harding-6a39b35/

the largest general farm association in Iowa, so I was asked to join the advisory board to bring the perspective of farmers."

Could you give a brief description of your professional background?

"After graduating from Iowa State University, I taught vocational agriculture for four years. After that, I worked for what at that time was called the Iowa Development Commission where I worked on economic development projects. I returned to the farm in 1985 where I farmed for 15 years. In 1999, I got out of active farming and leased the farmland to a young farmer. This allowed me to work for the Iowa Farm Bureau in the Research and Commodity Services division.

I worked with our farmer members on developing projects that add value for farmers. The biggest involvement was probably working with farmers on the development of the ethanol industry in Iowa, specifically farmer-owned ethanol plants. We later got involved in farmer-owned bio-diesel plants, farmer-owned wind farms and other energy related projects."

Have you advised for any other research projects, and if so, what did you do?

"Well, I was on the advisory committee for MASBI, the Midwest Aviation Sustainable Biofuel Initiative. That project was put together in part by USDA, but also the Navy, United Airlines, Boeing Corps. and others to look into the development of sustainable biofuels for air-transportation. I also served as an advisor to the Iowa State University Department of Animal Science, as well as to the BioCentury Research Farm at Iowa State."

How did your background and previous advisory experience inform your approach on the CenUSA advisory board?

"Our experiences in the early stages of developing the renewable fuels industry were similar to the challenges facing the CenUSA project. It's interesting doing the research and discovery phase, but the real challenge is bringing things to the table that make sense financially. The main thing is if there is an opportunity for farmers to get involved, have a new commodity that can be sold in a market and can make a profit."

How did the project challenge and broaden your professional knowledge and skill set?

The fact that we were looking at switchgrass as an alternative for producing biofuels sort of broadened my perspective. Looking back at the ethanol industry, it's based on an existing commodity in an existing market with an existing infrastructure. The challenge for CenUSA was coming up with a new infrastructure and uses for products made from switchgrass. It (switchgrass) didn't have an existing infrastructure for the fuel and energy industry."

What specific project objectives do you think uniquely benefited most from your knowledge and experience?

"It's been a while since we've had hands-on meetings, but looking back, the other advisory board members and I always brought the perspective of how things can get done. 'What usable energy products can be developed from switchgrass for this market?'"

How did the advisory board as a whole influence the direction of CenUSA and the leadership?

"I think that as a whole, this advisory board was very involved. The advisory board member actively raised questions as the project developed. This board can be proud of its involvement."

What do you think was the most important contribution that the advisory board made to the overall CenUSA project, if you could distill it down to one thing that was most important?

"Collectively, we brought a real-world perspective to the project."

In what way?

"Advisory board members kept asking what is the market potential for the products produced by this project."

What do you hope will come out of CenUSA?

"It's laid a lot of good and positive groundwork. I think there's potential in a new industry being developed that is broadening the scope of opportunities for farmers by using the information we learned through this project. I think new industry potential is probably the biggest thing to come out of it."

How will you take your CenUSA experience and apply it in the future? Alternatively, how do you think the experience of CenUSA might be applied to future research projects independent of your involvement?

"I'm retired now. I think it's kind of like the space program in that back in the 60s, people thought 'we needed to orbit the earth and go to the moon,' but in the process of reaching those long-term goals, there were a lot of things that were discovered along the way that benefited society. I almost look at this in the same way. This experience has laid out some things that may bring benefits to other related industries."

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Jerry Kaiser, CenUSA Advisory Board

Jerry Kaiser[8] spoke in July 2019 about his work and involvement with CenUSA Advisory Board with CenUSA Communications Intern Tyler Worsham. Kaiser detailed his background in plant selection and how he used that specialty to advise the project's development of effective demonstration plots.

How and why did you get involved CenUSA?

"I guess it all got started when I was recommended by Ken Vogel (Former CenUSA Co-Project Director, Ret.) from ARS (Agriculture Research Service) to be on the advisory board. I was the USDA Plant Materials Specialist for Iowa, Illinois and Missouri. Those were the three states that I served."

Could you give a brief description of your professional background?

"My personal background is in plant selection. I've been an agronomist and a USDA field conservationist with the Natural Resources Conservation Service (NRCS) for 38 years, and I was the Plant Materials Specialist at Elsberry Plant Materials Center (PMC) with the USDA NRCS for 22 years. The plant materials center at Elsberry serves three states: Iowa, Illinois and Missouri. I was developing native plant materials, testing and releasing these new products with seed and plant producers to market these new plant releases for our service area. That was my main responsibility."

Have you advised for any other research projects?

"We had ongoing research projects at Elsberry PMC. We released new plants and developed planting guides and technical notes for our NRCS field offices. They are located in each county within our three-state service area. This information directly benefits land owners with whom our field offices are working, so with our new releases, we would do the studies for those and actually do the field testing for in-field performance of the release."

How did your background and advisory experience inform your approach with the CenUSA advisory board?

"It was important to be able to apply the research being conducted by CenUSA, and we wanted to test and implement that on a field scale so it would be practical for land owners

[8] Learn more about Jerry Kaiser at https://www.linkedin.com/in/jerry-kaiser-1b752975/

to accomplish. We really wanted more demonstrations in the field based on the research that was done."

In what ways did the project challenge and broaden your knowledge and skill set?

"The challenge was that so many different research areas were being explored by the teams. To accomplish this, there were various universities throughout the Midwest that were working on these projects. It was enlightening to know all of this information, but sometimes the amount of data being generated was overbearing at times.

The organization was great. They brought the teams together for various annual meetings, and we had the opportunity to interact with the researchers on their projects. They gave reports, and we were able to provide feedback, but how we connected and interacted was the most important part of accomplishing the goal of the project. That was difficult at times with the amount of research involved."

What specific project objectives do you believe directly benefited from your experience?

"With my background as a plant material specialist, I worked with native grasses, targeting major land resource areas for specific plant species and working on highly erodible land areas. We wanted to select the right plant species that would work on those sites, and we would also want the correct management techniques to be used such as weed control and seeding methods. We suggested training ideas like drill calibration and harvesting techniques so that the land owners would have a better opportunity to implement, establish and manage those native grasses that were going to be used for bioenergy. Things like timing of harvesting was important so that nutrients would cycle down and so the biomass could be harvested without having all of the nutrients in the plant material. These techniques were the way they benefited from my knowledge and experience over the past 22 years as a plant materials specialist."

How was the advisory board as a whole able to influence the direction of the project?

"When we started out with our first meeting, each advisory board member was given the opportunity to provide feedback. First, the advisory board comments were given at the end of the annual meetings, and we had to accumulate all of this research that we thought was important. We gave reports, and they made that a part of the study documentation. The study team could summarize our concerns for the project, but as we moved on, we found it was more beneficial to give our feedback immediately after the researchers gave their documentation. We could give our feedback and be part of a discussion that clarified our

concerns with the research groups. This was all being documented so that they could go back later and review our comments as an advisory committee."

What do you think is the most important contribution made by the advisory board?

"Well, the advisory board was made up of industries, agencies, landowners and individuals with special backgrounds that could promote the advancement of bioenergy. The main focus of the guidance and recommendations that the advisory board offered was ensuring a practical, economical product that can be implemented and produced by the rural community. We were always emphasizing that it has to be practical and able to be implemented.

The land owners and operators would produce it, whatever the bioenergy crop, so long as they can make money with it and have it as a marketable and sustainable product in the long-term. That was the most important contribution that we were hoping to emphasize with all of the research that was going on with the broad diversity of the advisory members that represented the board. That was the important thing that we could share to make this move forward."

What do you hope will come of CenUSA?

"My hope was that bioenergy crops would be an industry that would develop from this (CenUSA Bioenergy), that it would be widely accepted and used to protect our natural resources. My hope is that we would use targeted natural grasses and plant material on areas that are sensitive in the environment such as erodible land. It has to be sustainable and profitable for the land owners. That was the ultimate goal for any bioenergy crop. It's has to be usable, functional and marketable."

How do you think others will take the CenUSA project and apply it to future research?

"I'm hoping that all of the data that has been developed and the research that has been done through this project have a future so that this won't have to be done again. The research studies, papers and all the documentation are usable and able to be implemented. Hopefully, it will be practical and marketable.

It seems like we have outside factors that we couldn't control like the price of other fuels such as oil. When the price of oil goes down, bioenergy becomes less profitable. As our fossil fuels are depleted, we have to have other alternatives, but they have to be able to compete in the marketplace and have the opportunity to be available for the consumer to

use them. That's what I hope that CenUSA has done, that this great research pushed us forward to a future in which this can be utilized when we need it."

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Bryan Mellage, CenUSA Advisory Board

Bryan Mellage[9], owner of Mellage Truck and Tractor, a Nebraska farm equipment dealership and tractor repair business, spoke with CenUSA Communications Intern Tyler Worsham in June 2019 about his contributions to the CenUSA Advisory Board from the perspective of someone involved in agriculture from a very young age. Mellage used his business acumen and his experience in farming and equipment maintenance to provide a sense of capitalistic practicality to the research effort.

How and why did you come to join the CenUSA advisory board?

"I know some people at the University of Nebraska. They recommended me and gave that inside connection, I guess. I honestly didn't know about CenUSA until the University of Nebraska contacted me, told me about it and asked me if I wanted to do it."

Could you give a description of what you do in your professional background?

"I kind of grew up in the farming world. My family owns farmland, so I'm very familiar with farming. I grew up in the family business of farm repair, so we work on farm equipment. When I became old enough, I took over the business. I own a farm tractor repair business, so I'm very familiar with farming and very interested in renewable energy. I do a lot of stuff along those lines, so I guess my background is in farming, leaning toward renewable energy."

Have you advised for any other research projects, and if so, what did you do?

"No I have not. This is my first opportunity to do it at this level. I guess I could have always stood on a street corner and stated my opinions, but as far as being on a board on this level and magnitude, no, I have not."

How did your background inform your approach on the CenUSA advisory board?

"I think what I brought to the table that was the most valuable was my business experience. This is a college setting. There were so many colleges that were a part of this, and each of

[9] Learn more about Bryan Mellage at https://www.linkedin.com/in/bryanmellage/.

them had a discipline on which they were working. They were looking at it from the classroom and from the laboratory looking out, and being from the outside, from a capitalist, self-employed business person, I brought the perspective that 'this is all great, but how are we going to make money with it?' I think that my insight from being a business person brought some pretty good thoughts and ideas to people who were trying to make it happen on the scientific side. We still have to survive in the marketplace, and that's where I exist."

How did the project challenge and broaden your professional knowledge and skill set?

"It was very exciting to be rubbing elbows with the professors who not only have the knowledge and intelligence in their background, but also with all of the young people who had so much drive and energy looking at the world they're going to inherit and how we can make things work. It was really exciting to be around people with ideas and the willingness to try to find out what's going to work in this field. It was very exciting for me to see all of that."

What specific project objectives do you think directly benefited most from your knowledge and experience?

"There were 10 or 12 objectives. I can't remember which one it was, but the whole CenUSA idea was to figure out how to make it work and figure out how to transform that into true business ideas in the marketplace. To go back, I think what I brought to it was that business experience. I can't remember which particular project objective it was (Objective 10: Commercialization), but I helped take it to feasible marketplace ideas. That's where I come in."

How was the advisory board as a whole able to influence the direction of the project?

"I would like to think that it was an integral part of the whole effort. I don't think that any one thing was any better than the other. I think it was a quality team effort from the people doing the paperwork to the people in the laboratory, the student interns and the advisory board. I think it was a good mix in the team. Everyone did their part, and I think that the advisory board was just one very solid, integral cog in the wheel that helped give it that holistic view. We needed that.

CenUSA was trying to be this holistic project from chalkboard idea to marketplace setting, and it took everybody's input. I think the board was one of those things that helped give it that worldly view. The advisory board wasn't bigger or more important than anyone else. It was just one of the important things that made it work."

If you could distill it down to one thing, what do you think was the most important contribution that the CenUSA advisory board made to the overall project?

"They helped make a path to the marketplace."

What do you hope will come of CenUSA?

"I think there are a couple things that come to my mind. I hope we've proven that these things work and that there are pathways to the marketplace and business ideas and applications. I think that was the goal of the whole thing, and we proved it can happen, so what I would like to see would be marketplace ideas that result in a company doing something with this and making money with it. Until some company makes money with it, it's just ideas on a term paper. It's a thesis that makes for nice reading, but unless someone can make money with it, it's not going to survive in the marketplace."

How might you take your experience with CenUSA and apply it to future work?

"I have business ideas on which I would like to work, ideas of which I had no knowledge until I was a part of CenUSA."

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Scott Rempe, CenUSA Advisory Board

Scott Rempe[10], Sr. Project Engineer at Vermeer Corps., spoke in May 2019 about his work and involvement on the CenUSA Advisory Board with CenUSA Communications Intern Tyler Worsham. In the discussion, Rempe emphasized the importance of harvesting logistics and commercial viability in order for biofeedstocks to be successful in the market.

How and why did you join the CenUSA advisory board?

"I believe we were asked to participate because of previous involvement with some other USDA and DOE (Department of Energy) research projects."

Could you briefly describe some of those other projects?

"These other projects were related to biomass harvesting equipment."

How has your professional background and advisory experience informed what you have done with CenUSA?

[10] Learn more about Scott Rempe at https://www.linkedin.com/in/scott-rempe-3a740210/.

"My background is in design and development of hay equipment, balers and mowers, so I guess I relied on that experience to consider different aspects of harvesting."

Could you go into a little more detail on your professional background? What did you do before joining the CenUSA advisory board?

"I was responsible for the round baler design for several years at Vermeer. I'm also currently involved with reviewing technologies as a Patent Agent at Vermeer."

What were some of the most important inputs that you were personally able to provide to the CenUSA leadership team?

"I think it was the practical input on what the appropriate commercialization goals for the project should be."

Allow me to rephrase that. What were you able to bring to the table that was unique to your own experience?

"I was focusing primarily on the harvesting considerations."

How was the advisory board able as a whole to exert influence on the direction of the project?

"I think that we gave a lot of good guidance from a commercialization perspective. If you just look at research alone, you can focus on things that aren't very important for commercialization, so we were able to bring some commercialization considerations to the table."

What do you think was the most important contribution that the advisory board made to the project? Considering everything they did, what was the most important?

"It really was providing incentive to focus on something real and deliverable, something more than just the research. Maybe we got the ball moving forward a little faster than we would have otherwise."

What do you hope will come of the CenUSA project?

"Hopefully, there will be some business to come out of it or some business opportunity for some existing company."

How do you think that will happen? What would it take for that to occur?

"At one time, I was hopeful that the project would actually demonstrate the complete

process of growing crop, harvesting it, processing it and turning it into some kind of specific product on some smaller scale."

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Thomas "Tom" Shannon, CenUSA Advisory Board

In June 2019, Tom Shannon[11], Research Technical Leader at Kimberly-Clark Corps. and a CenUSA Advisory Board member, spoke about his advisory role with CenUSA Communications Intern Tyler Worsham. One of the primary ways in which he advised the project was to point out the need for alternative sources of revenue in addition to bioenergy fuels so that companies can adequately cater to the needs and interests of those who are invested in the success of bioproducts.

How and why did you join the CenUSA advisory board?

"We came to it by a recommendation from Tom Binder at ADM. Tom was on the advisory board. Tom and I had worked on a couple projects over the years. Tom thought that Kimberly-Clark would be a good addition to it (the advisory board) from the standpoint of our interest in sustainability and bio-based materials."

Could you give a brief description of your professional background?

"I was with General Electric out of grad school. I worked with General Electric at their corporate R&D center in New York. I spent four years there and eight years in operations. Now I've been with Kimberly-Clark for about 20 years."

Have you advised for any other research projects, and if so, what did you do?

"I've advised for a lot of internal research projects, both at General Electric and at Kimberly-Clark, as well as for a number of academic endeavors and joint-development agreements that we may have had with different organizations. I think the challenge is trying to get your stakeholders to understand your point of view and what would be in it for them. I am a strong believer that there are three questions that your stakeholders have that you should be ready to answer. What's in it for me (the stakeholder)? Why should I care? How much is it going to cost?"

[11] Learn more about Tom Shannon at https://www.linkedin.com/in/tom-shannon-b522ba23/

How did your background and previous advisory experience inform your approach on the CenUSA advisory board?

"I think that it all comes back to the number of years of experience learning how to talk with your customers, understanding what's in it for them, and why it's important. Coming in to CenUSA, I tried to help people understand that even though everything has been circulating around energy and fuel, a lot of these crops have fiber that is probably more valuable than the fuel."

How did the project challenge and broaden your professional knowledge and skill set?

"This was totally new for me. It's the first time I had ever worked with the agricultural industry, so I think there was just a difference in how we approach our stakeholders, how we influence them to see our point of view and how to help it make sense to them. It was a totally different situation, especially when you look at the cooperatives and working with some of those organizations. I worked with the academic side quite a lot, so I'd say that I have quite a bit of experience with that. I would say that working with the agricultural side of things was something with which I did not have any previous experience."

What specific project objectives do you think directly benefited most from your knowledge and experience?

"They're talking a lot about looking at platform chemicals outside of their focus on energy, so as you start reading some of the CenUSA material, it's starting to look outside of cellulosic ethanol to how else we can use some of these products for things that might be more profitable. I think that's a big part of it, getting them to look in different directions outside of energy."

How was the advisory board as a whole able to influence the direction of the project? Put another way, what do you think came out of CenUSA because of the advisory board that otherwise might not have happened had the advisory board not existed?

"It all comes back to commercialization in my mind. That's the success of these efforts, when you get something that actually goes commercial and produces products of value. I think that's the advisory board representing customers. I think it clearly directed the researchers to not only answer the academic and scientific questions, but the questions about the supply chain, how you create value and how you get people interested in that so farmers will want to grow this. I think a big part of the advisory role was to ask honestly about the interest of the customer and how we address issues surrounding cost and risk. Those are big questions that often get overlooked in academic exercises for the sake of the science."

If you could distill it down to one thing, what do you think was the most important contribution that the CenUSA advisory board made to the overall project?

"I would say it's providing the voice of the customer, the commercialization and making it a reality."

What do you hope will come of CenUSA?

"I would hope that what comes out of this is that we do start to see a conversion of a lot of this biomass that is grown in the United States and throughout the world into useful products so that we can reduce our dependence on petroleum. We are going to eventually run out of petroleum. I don't think anyone disagrees with that. The question is when. That's the bigger question. I hope we start to see some actual commercial operations using biomass to create products that are successful from an economic standpoint."

How might you take your experience with CenUSA and apply it to future work?

"We need to understand how to work with different people, people from agriculture, for example. We had no experience with that. Kimberly-Clark is constantly looking for new sources of raw materials, and perhaps those raw materials could come from agricultural resources. I think we will find many more material solutions in agriculture as we start to shift towards a bio-based economy. From my own personal perspective, I think it really helped to learn how to interact with agricultural interests that are necessary to develop supply chains for bio-based products."

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David Stock, CenUSA Advisory Board

David Stock[12], owner of Stock Seed Farm Inc., a native grass and wildflower production and marketing company, spoke about his work and experience on the CenUSA Advisory Board with CenUSA Communications Tyler Worsham in June 2019. Stock stressed the vital role that those involved in commercialization and production played in shaping the direction of the project and helping it achieving its goals.

How and why did you join the CenUSA advisory board?

"That's a good question. I think I was asked by the USDA-ARS (Agricultural Research Center) leaders at the University of Nebraska. I think it was Ken Vogel who asked me to join. I

[12] Learn more about David Stock at https://www.linkedin.com/in/david-stock-26646624/

already knew several of the university people from different states who were going to be working on the project."

Could you describe your professional background?

"I am the owner of a native grass and wildflower production and marketing company, I gained my education through the University of Nebraska's Institute of Agriculture and Natural Resources, and I started my professional career in 1972, so I've been doing it here in eastern Nebraska since then."

Have you advised for any other research projects, and if so, what did you do?

"We have research going on in our operation all the time. We're close enough to University of Nebraska, between the university and their research farms, so we have a lot of research that's taking place in our operation. I've been involved in a lot of research projects on my own, and I've been helping students in cooperation with other projects."

How did your background and experience inform how you handled the CenUSA advisory board?

"I had experience on the production side. As you've found out, this project has a lot of moving parts to it, and one of those parts was the production side of the biomass itself. We're talking about a product that I've been handling throughout all of my professional career. I'm thinking that my long experience working with this material for all of these years, knowing what works, what doesn't work and what we need to make it work were probably my greatest contributions."

How did the project challenge and broaden your professional knowledge and skill set?

"I found it very interesting to visit with the other advisors and with the other aspects of this whole project. It was very comprehensive. That's what was very interesting to me. The team leaders thought it through enough to see that a lot of things had to come together to make this successful for a future using biomass as a fuel. It was very educational for me to see all of the different challenges in all of the different areas that I had never considered before then. I thought that was very enlightening."

What specific project objectives do you think directly benefited from your knowledge and experience?

"I would think that the production side benefitted, as well as the adaptability of the future producers given that I have worked with farmers all of my life. I know the kind of challenges

they face and what it takes for them to succeed. I'd say I have a lot of experience with all of that, so that's where I probably contributed the most."

How was the advisory board as a whole able to influence the direction of the project?

"I think that there are several areas in which the advisory board was able to bring up situations from their own personal experience that needed to be addressed by the actual research team as the project went along. I think we also brought in more of the commercial side. The people who were involved in the commercial side of producing the biomass and people like ourselves who are actually growing the biomass for the seed production were able to exert the most influence on the direction of the whole project."

If you could distill it down to one thing, what was the most important contribution that the advisory board made? Is there a particular example of something that was essential to the way the project turned out in a way that it wouldn't have had the advisory board not existed to advise the project?

"It's not necessarily in the area in which I was involved, but I think the advisers who were on the commercial side of the end-product were probably the ones to contribute the most to the whole project. I think that those on the production and breeding side understood, but I think that maybe the biggest challenges of the final product were probably in the areas with the most input and influence in that there's more than one product that can come out of this biomass. Take the biochar and some of these other bioproducts, for example. I guess that's the only way that I can see what the advisory board was able to contribute from my perspective."

What do you think will come out of CenUSA?

"Well, I would hope that when the day comes when we really need to use biomass for renewable fuel in this country, this research will be a base platform for moving us toward a feasible economic product."

How might you take your experience with CenUSA and apply it in the future?

"I think it (CenUSA) has probably opened my eyes to different areas that I haven't thought of before that need to be addressed. I've been raising biomass all by myself for my entire life. Again, that's for seed, not the dry product, so that part I understand. What I probably didn't understand as much was the challenges that are faced by the people who are actually processing that product to turn it into an economical fuel."

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Jay Van Roekel, CenUSA Advisory Board

Jay Van Roekel[13], Corporate Accounts Manager for Biomass, Recycling and Forestry at Vermeer Corps. and a CenUSA advisory board member, spoke with CenUSA Communications Intern Tyler Worsham in June 2019 about his experience with the project in which he advised the researchers in understanding harvesting logistics best practices.

Why and how did you come to join the CenUSA advisory board?

"Through previous relationships that we had with Iowa State University: Stuart Birrell, Jill Euken and others with whom we worked on other projects. Vermeer and Iowa State are only about an hour apart, so we have a lot of alumni working here. There was a relationship between Vermeer and Iowa State, and with my work in biomass, it was a nice fit, so I was called and asked to serve on the board."

Could you go into further detail about your professional background?

"I've been with Vermeer for 32 years. I started my career in our agriculture division, or 'forage group' as we call it here, baling hay, working with dealers around the globe baling all sorts of crops. As biomass began to generate some interest, I started to focus more on what our opportunities were in biomass, ag-residues and energy feedstocks we could harvest. Then I was asked to lead our biomass relationships here at Vermeer, so I was not only on the harvest side of things, but also representing our grinders which can grind up bales or wood. We have a natural fit with the biomass supply chain here at Vermeer. I was asked to lead those relationships, and I continue to do that to this day."

Have you advised for other research projects, and if so, what did you do?

"Any customer considering a biomass project needs someone to advise them on the best way to collect and pre-process biomass material – so this role has a consulting flair to it. I was a member of an advisory board for the Biomass Thermal Energy Council. It was an association group. That's the only other board on which I have served. I also lead Vermeer's participation in a DOE grant to improve biomass supply chain which involved both harvesting and pre-processing biomass."

How did your background and previous advisory experience inform your actions on the CenUSA advisory board?

[13] Lean more about Jay Van Roekel at https://www.linkedin.com/in/jay-van-roekel-34916622/.

"I think it offered real-world, practical experience. When you are working with a farmer baling switchgrass, corn stalks or forage, you understand that quality and profit are important. I think that the practical experience of working with our customers can help advise a research group like CenUSA or a university research project. What our customers have to deal with is more based in reality in order for them to be profitable and able to run their business."

How did the project challenge and broaden your professional knowledge and skill set?

"I really didn't know much about developing hybrids or varieties from (CenUSA) Objective 1, Feedstock Development. It was interesting to learn about those things, how they cross-bred different plants and picked the strongest survivors out of a test plot. How do you take on the challenge of moving a crop to a different climate? What impacts moisture, whether it's drought, too much rain, insects or soil types?

It was also fun for me to learn how they were going to educate farmers and the public, that being a part of Objectives 8 and 9, Education and Extension & Outreach. That is a really important part. I can see part of the resistance of someone maybe not wanting to set aside some ground to grow switchgrass for seven-to-eight years. How do you educate them to know that this could be a smart move that will be good for their income stream, soil and the environment? Education is so important, especially in schools with younger generations to get them to be more comfortable with it now instead of trying to convert someone who already has their own opinions and methods."

What was the most important input that you were personally able to provide to the leadership team?

"Well, my roles here at Vermeer are in the feedstock logistics group which lined up with Objective 3, harvest storage and transport pre-processing. That's what we do here, and that's what I'm experienced at. I was able to challenge them to look at some different ideas or wonder why they're going down a particular path in the area of feedstock logistics."

How was the advisory board as a whole able to exert influence on the direction of the project?

"I think it was a pretty interesting group. I knew a few of them before and got to know a few a bit more. I think they're all based in a for-profit industry. We had a couple farmer-land owners in there, some ADM conversion-type people, some equipment manufacturers like me. We were able to think about what the team was proposing or what their ideas were,

and we were able to give a little feedback. 'Does that make sense?' 'Will it work?' 'Can it work?'"

If you could distill it down to one thing, what was the single most important contribution that the board made to the overall project?

"I think we challenged them to deliver practical, real-world solutions and attainable results. I think that was important."

What do you hope will come out of CenUSA?

"We need a successful model. Having been involved with different projects, it seems to me that they start with great excitement, only to stall out or take 10-to-12 years to develop. We need some successful examples or models off of which we can build, and I hope that CenUSA will lead to a practical solution that can stand alone with current energy sources, as well as add all of the benefits to the environment. Renewable energy needs to be competitive with what's out there today. Your extra bonuses for the environment should be the gravy. We've got to stand alone and stand up to current models, and I hope and believe that CenUSA was on the right path."

What do you think it would take to actually achieve that?

"It would take some commercial projects that utilize switchgrass or energy crops. That seems to be the main focus. I think that the challenge is going to be to your traditional commodities that are grown on those acres. How do you fit in a standing crop during corn harvest? It's not like a grass waterway you can drive across. How can you use the highly erodible acres where it wouldn't make sense to grow corn or soybeans? Let's convert those to switchgrass and use your best acres to grow the commodity crops. Then provide some local energy with our tough acres. In the USA, we tend to look at large commercial sized projects, perhaps smaller local projects first, then grow in scale after success."

How might you take your CenUSA experience and apply it to the future?

"It was probably one of the neatest things that I witnessed. I can't remember the number of universities that worked together between Iowa State, Nebraska, Minnesota, Purdue, Wisconsin and so on. Seeing members from each of those big universities and people from different industries, all being experts in their own way, came together, shared experiences and ideas and stayed excited and on task to try new things. Having seen that synergy that the team had, I think that we need to do a better job in our local communities and businesses to listen to one another and stay open-minded with a long-term goal to work towards. It was great. It was just cool to see all of those different players come together to

have good, open and frank discussions and challenging ideas without taking it personally. These are all good things that we need to learn how to do in our own personal lives and in business."

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John Weiss, CenUSA Advisory Board

John Weiss spoke about his work and involvement on the CenUSA Advisory Board with CenUSA Communications Tyler Worsham in July 2019. A primary focus of discussion was on how Weiss used his outside perspective as a farmer/"civilian" to help inform the decision-making processes of the project and to highlight the utmost importance of profitability.

Why and how did you come to join the CenUSA advisory board?

"I'll make this as short as possible. My daughter made contact with one of the professors on the board to help her with her science fair project. She was doing an agronomy soil modification project instead, and I could only do so much to help her, so she reached out to various people from universities. He (the advisory board member) couldn't help her, either, he got to know us because of that. He was already on the board, and they needed a civilian. I ended up being that civilian. They nominated me, so I accepted. CenUSA eventually ended up renting a few acres from me for one of their demonstration plots. Would you like for me to explain it?"

Yes. That leads into the second question. Could you go into further detail about your professional background and how it might have played into your role on the advisory board?

"Well, I grew up on a farm and farmed for many years as an adult, and I've worked in horticulture for the rest of my working career, so I'm very familiar with cover crops and general agricultural practices even though I'm a civilian who isn't connected to a university. They thought I could bring a farmer's perspective, and that's what I tried to do."

Have you advised for other research projects, and if so, what did you do?

"No, I haven't advised other research projects."

How did the project challenge and broaden your professional knowledge and skill set?

"I learned a whole lot more about their involvement in what they're doing. I have a lot of native grasses planted around here, so I've learned about how to manage those. I learned about the problems facing corporations to turn these native grasses into a usable product,

whether it be oil, chemicals, sugars or whatever else they're trying to make, as well as how they can make a profit doing it. There's the logistics of the whole thing, getting the raw material to a processing facility and everything that this entails. I learned a lot, and I tried to bring a producer's perspective to what they were talking about doing."

What was the most important input that you were personally able to provide to the leadership team?

"I have no idea beyond that I tried to bring a producer's perspective. I don't think it was any one thing in particular. We had one member of the board who tried to explain that it's not all about return on investment. I said, 'It sure is about return on investment! If I can't make money doing this, I'm not going to do it. Do you do things on which you don't make any money? Does your company make machines that don't make any money? No? Well, as a farmer, I'm not going to do something that doesn't make money. That's why we're doing it.'

There are a bunch of academics, and then they had a bunch of equipment people there. They're kind of in their own little world. The equipment guys know their equipment and know how to build a machine to do anything as long as we don't care about the cost. The scientists are there who can do anything to get a product as long as we don't care how well it sells and how much it costs to produce. I think that they finally got the point and were able to come up with a thing that would make money for everyone involved, but you had to steer them in that direction once in a while."

There's more theory than practicality.

"Well, yes, it was in the beginning."

Let's reframe the question, then. How do you think that farmer's perspective changed the way they approached the project?

"I hope it was effective, and I think it made them more aware of the farmers' production problems. Most land is rented or leased now-a-days. Very few producers have five-year leases, and you need to grow these grasses for five years. Getting the renter and their landlord to come to a five-year agreement is tough, especially with a fluctuating market. It's just tough without a worthwhile return on their investment."

How was the advisory board as a whole able to exert influence on the direction of the project?

"I think the people on the board were excellent. They really helped the various parts of the study to focus on what the board thought needed to be done. Sometimes, parts of the

study would go off to do their own thing. 'No, we really want you to do this instead to coordinate with everyone else,' we'd say, so they went off and did that and would come back with excellent data.

The advisory board was a way to bring together all of these different factions in order to work towards a common goal, and that's a difficult thing to do in any situation. I thought they did an excellent job of that. There were so many parts that had to be studied, everything from health and safety to production, marketing and transportation. They tried to put together a whole package of how to do this, to get everyone working towards a common goal at the same time. That's always hard with a large group. Having been in a lot of groups, I can tell you it's very hard. Parts tend to go off on their own unless you really steer them in the right direction."

If you could distill it down to one thing, what was the single most important contribution that the board made to the overall project?

"We kept it all on track and came up with a plan to make this system work. We came up with answers to all of the possible questions that both the producers and manufacturers will have about this kind of process. I think they did come up with a plan to make the system work, but you need buy-in from corporations and others. We had one board member from ADM who presented to ADM what the board was doing, and ADM figured that they could make money doing it by turning it into chemicals, sugars and whatnot, but they declined to do it for whatever reason. Putting together this whole system and showing that it has the potential to make money at realistic price-points is probably the most important thing that the board did."

What do you hope will come out of CenUSA?

"I would hope that people will start doing what we were talking about sooner rather than later. That's my big hope. There are all kinds of problems preventing that from happening though. You can get into politics, 'big oil,' big oil subsidies and all kinds of things. They're not going to do it until gas is $5. Then all of a sudden they're going to wonder where else we can get gas, but as long as we continue to subsidize oil and gas production as a nation, it's not going to happen.

If consumers had to pay the real cost of oil and gas, it would happen tomorrow. I've seen studies saying that if we paid the real cost, we'd be looking at what Europe is paying or higher, but because we subsidize this whole system as a nation, having everything from warships in the Persian Gulf to tax credits for fracking, it isn't going to happen."

How might you take your CenUSA experience and apply it to the future?

"I'm retired, but if someone came up to me and said that they could mow my grassland in return for a certain amount of dollars-per-ton, I'd probably sell. I'd sell them grass, but I'm retired, so I'm probably not going to do much personally."

Would you take another advisory role, and if so, how would your experience on the CenUSA advisory board change your approach?

"I would certainly take another role on another advisory board for a project. I thought it was a great experience. When I go to a thing like this, I like to sit in the front row and ask questions. Sometimes that makes people nervous, but I like to ask questions, so I wouldn't change that. I suppose I maybe wouldn't be so blunt. I am a little blunt sometimes. I don't know how much I would change. It was certainly a great experience, and I thought they had a great idea there. Trying to make it happen, however, is another matter."

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Eric Zach, CenUSA Advisory Board

Eric Zach, an agriculture program manager for the Nebraska Game and Parks Commission, spoke with CenUSA Communications Intern Tyler Worsham in May 2019 about his experience on the CenUSA Advisory Board, on which he shared with the researchers his knowledge of land and wildlife management.

How and why did you come to join the CenUSA advisory board?

"In 2011, my predecessor got promoted, and I took his position. He was on the advisory board, and I got onto the board because I took over his position as the state agency wildlife advisor. It was sort of thrust upon me, but I've enjoyed it."

Could you give a brief description of your professional background?

"I have a Bachelor of Science degree in fisheries and wildlife management. I've spent around 17 years or more as a full-time biologist in various positions, mostly with the state of Nebraska's Game and Parks Commission. I've done everything from land management work to agriculture and conservation policy. That's been the majority of my background. One other thing I would add is that there's an association called the Association of Fish and Wildlife Agency. It's the collective voice of all 50 states. I serve as the chair of the group working in bioenergy. Some of what I did with CenUSA was very applicable because I was also the chair of that."

Have you advised any other research projects, and if so, what did you do?

"I haven't done anything on this scale because how big this really is, but we have research projects going on with different entities like the University of Nebraska-Lincoln all the time, so when it applies to my position, we will consult and advise on research methods, asking what we're looking to find, and what questions we are looking to answer, that sort of thing. We mainly do conservation policy research, but also wildlife biology."

How did your work background and previous advisory experience inform your approach on the CenUSA advisory board?

"Well, I admit, I didn't have a lot of background in the bioenergy field before taking this position. I guess that the most applicable background I had was my knowledge of on-the-ground management. Some of what CenUSA was doing was to develop grass species that were best suited for bioenergy and biofuel production, so having some of that background in planting and managing grasslands, warm-season grasses in particular, lent itself to that advisory role."

In what ways has the project challenged or broadened your professional knowledge and skill set?

"I think that because it was such a broad project with a lot of research going on from different angles, getting to see some of those varied projects and research was eye-opening and has led to a better understanding of the bioenergy sector, what goes into all of the planning to get something like this off the ground and how it might relate to a real-world ethanol plant using cellulosic feedstocks for bioenergy. That really helped in other parts of what I do."

What specific objectives do you think benefitted the most from your knowledge and experience?

"I would probably say it was some of the grass development that Rob Mitchell and the Nebraska-based ARS group did. I think that was my strong suit, but there were several other parts of the project that I came to understand and was able to provide some feedback to those researchers and their groups going forward."

How was the advisory board as a whole able to exert influence on the direction of the project?

"The Principle Investigators and leaders of the project as a whole, Anne (Kinzel), Ken (Moore) and the rest, really reached out to the advisory board and took our advice to heart. I think that they developed trust in the advisory board, that what they said was being taken

into consideration. Like I said, we aren't all necessarily experts in every research field that was taking place, but knowing the other board members, I think we brought a lot of that real-world knowledge to the group.

That's not to say that the research didn't have any of that, but there were a lot of advisory board members I got to know who had an interest or business related to bioenergy or carbon sequestration, or who were just forward-thinking producers. I think that group and some of the others who were on the advisory board lent some of that common sense to the work that was being done. I do think that we were able to have a good influence on the project."

If you could distill it down to one thing, what was the most important contribution that the advisory board made to the CenUSA project overall?

"That's tough. I guess we were a sounding board for questions. If there were issues that came up, we were able to provide feedback to keep the project moving forward with the research."

What do you hope will come out of CenUSA?

"Well, the whole point of it was to prove that you could take cellulosic feedstock to economically produce bioenergy in a system that works. The CenUSA project may not have completely proven that, but I think it provides a foundation for someone, perhaps a private entity, who wants to get into this business and move forward with something like this project that would produce biofuel from switchgrass or some other feedstock. This gives them a foundation from which to work so they're not strapped with doing that background research and trying to figure out everything that all of the researchers who were working hard on the CenUSA project already did. They may not have all of the answers, but I think it provides a lot of answers for any private business that might want to start a business like this."

How will you take your CenUSA experience and apply it elsewhere?

"Well, it has definitely built my interest in the realm of bioenergy, and being a part of the conservation policy side of things in my current position definitely helps me as the chair of the bioenergy working group. It has also given me a lot of experience going forward. If bioenergy comes to the forefront, which I think it will, even if it has slipped back in the list of priorities of the current administration, I think that this has given me the experience to either be on another type of advisory board or to partner with a company bringing a project like this to Nebraska."

CenUSA Bioenergy CoProject Directors

Stuart Birrell, Feedstock Logistics

Stuart Birrell[14], Professor of Agricultural and Biosystems Engineering at Iowa State University, spoke with CenUSA Communications Intern Tyler Worsham in February 2019 about his work and experience as a CenUSA co-project director in the area of feedstock harvesting and logistics A primary topic that was emphasized in the discussion was the need for the feedstock supply chain to be made as efficient as possible in order to improve biomass density and the timeliness of operations.

How did you initially get involved with CenUSA?

"I had been doing some work in the harvesting of corn stover products. When the CenUSA project started, I was asked to join them and look at the harvest machinery and harvest logistics."

What made you an ideal candidate for your co-project leadership position?

"I think it was because of my background, my knowledge of agricultural machinery and operations, and the previous work I had done involving the development of stover harvesting systems."

In what ways did the project challenge and broaden your knowledge and skill set?

"I think it was broadened by working in a multidisciplinary group and seeing how there are interactions between all of the different phases in the complete development of a new industry. Some of the challenges exist for many of the same reasons. Everyone brings a different perspective to the problem, and you have to discuss those different perspectives to see how you can make the system as efficient as possible."

Have you worked in any other projects as large or as well funded as CenUSA?

"No. I have worked in some large projects, but none of them were at the funding level of CenUSA as a complete project. For my individual component, yes, I've worked in projects that were funded just as well, if not better, but not as an integrated project."

Could you briefly describe some of those other projects?

[14] Learn more about Stuart Birrell at https://www.abe.iastate.edu/stuart-birrell

"A significant portion of my research has been in the development of machinery systems, and many of these have been industry supported."

In what ways were they different from CenUSA?

"In general, the scope of this research tends to be more targeted than the scope of CenUSA because industry-sponsored research tends to focus on one particular aspect or need. It doesn't have competing criteria and constraints that are common in multidisciplinary integrated projects."

What new ideas and disciplines were you exposed to as a part of your experience with CenUSA?

"CenUSA provided exposure to seed breeding and conversion technologies, as well as the potential for interaction between these technologies and machinery systems. Optimal harvesting operations are influenced by seed genetics and agronomic practices, and in turn, harvest operations, timing and performance can significantly affect the conversion technologies. The optimal biomass supply chain can be significantly affected by the relative interaction between the genetics, agronomic practices, machinery systems and conversion technologies. A decrease in cost in one area might be a small decrease, but it can significantly influence cost in another area. Quality is also a factor. A small change in quality in one area can also have a significant effect on the costs in another area."

Did you and your team encounter any unforeseen obstacles coming into the project that you didn't expect?

"I wouldn't say 'unforeseen.' It is always a challenge when you have a very large project with a number of different disciplines. It's always a challenge to keep all of the disciplines working together on top of having enough focus to get real results in your own specific area."

What were some noteworthy discoveries and successes that you achieved?

"We saw a lot of success in looking at the sustainability of the harvest system and managing and minimizing the variations in the quality of the agricultural residue to improve the processing efficiency."

How might future advancements in harvesting methods and machinery help farmers in the future?

"Particularly in the biomass industry, it really comes down to improving the logistics and the timeliness of operations. That is probably the biggest hurdle to the adoption of the

technology. Timeliness affects the operation of their primary income. In many ways, reducing the number of operations that have to be done through the feedstock chain have significant effects on costs and on the timeliness of operations."

In what ways can harvesting and transportation can be improved in the future?

"It really boils down to improving density, reducing the number of operations required and minimizing both the biological and physical material loss during storage. We need to increase the bulk density and value density of the material as close to the field and production unit as possible. The density increase should occur as close to the production field a possible with distributed biomass pre-processing units so that the pre-processed biomass can then be a transported and sold as a commodity feedstock for the biochemical industry to convert into a range of chemical and energy products."

Could you explain how your work on the harvesting and logistics objective differs from that of Kevin Shinners (the other co-project director in harvesting and logistics)?

"Kevin has a lot of expertise in storage. Outside of that was harvesting, so a lot of what we were doing was looking at ways of maintaining quality during harvesting and moving the increase of density as early as possible. We also looked at sustainability. From that point of view, we have to maintain the organic matter of the soil. If you are harvesting biomass material, you are taking more carbon off the field. Conventional agricultural crop production practices, however, tend to include significant tillage to incorporate agricultural residues which tend to reduce accumulated soil organic matter (soil carbon). As you till the soil, you release a lot of the natural carbon that was stored in the soil. I think there is a significant benefit in harvesting some of the material on the surface while reducing tillage intensity so you can maintain the carbon already stored in the soil. I think the economic benefits and the potential for better sustainable systems of production are significant."

Is resolving the issues of density and so on a matter of throwing more research at the problem, or are there other factors involved?

"There is a need for an increase in research to optimize the feedstock supply chain. At present, most biomass feedstock chains are based on single individual units of biomass, generally large square or round bales. These unit operations significantly increase harvest, transportation and handling costs compared to supply chains based on bulk handling of the material. We only have to look at grain production to see the advantages of bulk supply chains, comparing when grain was harvested and transported in bags to the modern practices where grain is harvested, stored and transported in bulk by trucks, railcars, barges

and ships. Research is needed to develop bulk commodity-based systems for biomass supply chains."

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Robert Brown, Feedstock Conversion/Refining

Robert Brown[15], director of the Iowa State University Bioeconomy Institute and the Anson Marston Distinguished Professor in Engineering, spoke about his work and experience as a CenUSA co-project director focused on feedstock conversion with CenUSA Communications Tyler Worsham in April 2019. Brown described how a cost-efficient fast pyrolysis process is essential in order mainstream viable alternative biofuels.

How did you initially get involved with CenUSA?

"My staff realized that there was an opportunity through the USDA to do a big project. We did some negotiations through some other schools, concluded that Iowa State University would take the lead and that Ken Moore would be the leader."

What made you an ideal candidate for your co-project leadership position with CenUSA?

"These large CAP projects required a systems approach. In other words, we had to do the agronomy, processing, and logistics. I'm a process guy, so I was interested in bringing thermo-chemical processes to the project. That's why I ended up leading that part of the project."

In what ways did the project challenge and broaden your professional knowledge and skill set?

"It was interesting that we went in with a specific technology called fast pyrolysis. We had to see how these herbaceous feedstocks that were being proposed for this CenUSA project would work with that (fast pyrolysis). Most of the previous research in the field suggested that we should be using woody biomass over herbaceous biomass. Of course, it would have been a hard sell to say that wood was a major feedstock for the Midwest, certainly for Iowa, so we spent some of our efforts learning how we could use these herbaceous materials instead."

Have you worked in any other project as large or well-funded as CenUSA?

[15] Learn more about Robert Brown at https://www.me.iastate.edu/directory/faculty/robert-c-brown/

"There were some of comparable scale. One was with the National Science Foundation. It was called an EPSCoR (Established Program to Stimulate Competitive Research) project, and it was a little bit smaller in scale. It was focused on renewable energy: wind, energy efficiency and bioenergy. It was more diffuse than CenUSA.

We also had another large industry project focused on biofuels. It resembles CenUSA in some ways, but it was more focused on the conversion technologies. CenUSA was very much about adding value to agriculture. The other projects tended to be about the technology as opposed to the impact on agriculture, farmers and communities. CenUSA was much more broad, and it had Extension involved in it."

To what new ideas and disciplines were you exposed in your work?

"For a long time, I took pride in getting to meet people from other disciplines. I'm a mechanical engineer by training, so I've mostly dealt with mechanical engineers. It was after I started working in bioenergy that I realized that I had to talk to agronomists, land engineers, chemical engineers, economists, and even the political scientists. This project let me use those skills and practice them a lot, because this most certainly was an interdisciplinary project."

Did you and your team encounter any obstacles in your work, whether expected or unforeseen?

"Absolutely. An obstacle was the drop in the price of gasoline and diesel when we were supposed to be producing alternative fuels. We suddenly had to produce fuels that were much cheaper than anticipated. We spent a lot of our time making decisions. Farmers are trying to produce an inexpensive feedstock while still turning a profit. The conversion system needs to make a profit as well, but maybe technological innovations could reduce the cost. Ultimately, the problem was petroleum. The price stayed too low over the course of our project. We're just now starting to see prices go up and starting to make these other processes look more cost-effective."

How did your research with CenUSA help make the pyrolysis process more effective?

"I alluded to it earlier. Almost everyone in the field has said that pyrolysis was just for wood. You get higher oil yields, and it just works out a lot better, but we were challenged with herbaceous materials like switchgrass that contain more ash than wood does. Ash represents a problem, but it set us to the task of figuring out how we can do better with these high-ash feedstocks. Today, I can say that we know how to process them. In some cases, we can get yields that are comparable to what we can get with wood."

What were some noteworthy discoveries and successes you achieved in your research?

"I would say it was how we learned to pyrolyze high-ash feedstocks and economically produce good oil yields. We think it looks good compared to other approaches of turning these biofeedstocks into biofuels and products."

What were the most significant obstacles to the commercialization of the biomass-fueled pyrolysis process?

"In terms of commercialization, of course there is the issue of the ultimate cost compared to gasoline and diesel. Another obstacle to commercialization of all bioenergy systems is the capital cost, so going into this program, the estimates were that you would spend a half-billion dollars to build a system that would convert biomass into biofuels. That's five times higher than what an ethanol plant would cost, so our strategy was not only to intensify the process to reduce those capital costs, but also to go to smaller-scale systems instead of what had typically been said about what bioenergy should be. We scale that down by about a factor of 10 to what we think is the appropriate size. Now you're talking about a fraction of the capital cost that people envisioned. It suddenly becomes possible for investors to say that they're not risking a half-billion dollars, we're risking $50 million instead."

When do you think is the earliest that we could see the commercialization of the biomass-fueled pyrolysis process?

"The first thing that has to happen is that we take pilot-scale work, demonstrate it at a scale that is about 50 tons per day. Right now, we are working on the order of a half-ton per day. We want to scale that to 50 tons per day. That will give us the data necessary to scale up to the range of 200 or 250 tons per day. By December 2020, we will have a demonstration project at 50 tons per day set up here in Iowa. We've also got a demonstration project set up for Florida. They want us to use wood which also advances this.

We're also talking with other potential commercial partners about other applications in other parts of the United States and North America in general. With those kinds of demonstration projects in the next couple of years, it's a very viable notion that we could go commercial in the next five years if the markets allow it. Then we'd be looking at if there are going to be carbon taxes and if there are going to be increases in petroleum costs that would make this (carbon taxes) feasible."

Could you go into more detail about these demonstration projects?

"One of these projects is being financed by Harry Stine who has money in corn and soybean seeds. He's interested in herbaceous material, but it's called corn stover instead of

switchgrass. Switchgrass is a more challenging feedstock because of the ash content. His interest started in the production of biochar which is a byproduct (of switchgrass in the pyrolysis process). If biochar can be applied back onto the soil, it brings back the nutrients that you took off by removing the biomass. It can also improve soil quality in that biochar acts very much like a soil-carbon. That was his primary interest, but he also realized that to make it commercially viable, you have to get higher-value energy products.

While he's providing the finances to fund this first demonstration unit, we've contracted with a company located here in Ames called Frontline Bioenergy, an engineering firm doing the design and construction. The California project is being funded by the California Energy Commission. This is a project being led by the Lawrence Livermore National Laboratory, but the technology exclusively comes from Iowa State University. We are actually going to be borrowing what we call the Stine pyrolizer. It's a modular system that we can take apart, take it over to California, evaluate it for several weeks, and then bring it back to Iowa."

What is the most interesting or most important facet of your work that you want the general public to understand about your work?

"I've always been fascinated by biochar ever since I learned about its properties. I would say that the most interesting facet is the notion that we can perform a process that not only produces an energy product, but that also produces a material that will actually improve the productivity of agriculture and can sequester a charcoal product into the soils for hundreds or thousands of years. We envision what we call a carbon-negative energy system. Instead of thinking of a process that emits a net-negative carbon output into the atmosphere through photosynthesis, we can pull carbon out of the atmosphere and sequester some of it as biochar in agricultural lands where it has a good and useful purpose."

How will you take your experience with CenUSA and put it to use in future research projects?

"Well, we are already doing that. These two demonstration projects came after CenUSA. We are certainly using what we learned about herbaceous materials with the Stine pyrolizer, but it has also allowed us to develop improved pyrolysis systems that are improved through the simplicity of how they operate. One of the problems with technologies that convert biomass into energy products is that they can be very complicated, so we had a dramatic simplification of this technology that we are using for these new projects."

In what new directions do you hope to take your own work in the future?

"I'm advocating for something we call 'agriculture-based carbon dioxide removal and reliable sequestration.' We call that Ag-CDRRS, but to put it more simply, it's a carbon removal concept. Let's look at ways that agriculture can contribute to reducing the amount of carbon in the atmosphere. You will often see agriculture blamed for increased emissions of carbon in the atmosphere. We want to turn this on its head and show that agriculture can actually contribute to reducing that. This is the spirit of the whole CenUSA project."

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Sorrel Brown, Extension and Outreach

In May 2019, Sorrel Brown[16], retired Iowa State University Agriculture and Natural Resources Extension Program Evaluator, spoke about her work and experience as a CenUSA co-project director focused on Extension and Outreach with CenUSA Communications Intern Tyler Worsham, to whom she explained how the Extension and Outreach Objective sought to educate the public on the efforts and accomplishments of the project.

How did you initially get involved with CenUSA?

"I knew some of the people who were instrumental in getting the grant, and one of the grant requirements was to have solid evaluation data. I am a program evaluator for Extension agriculture and natural resources, so because they knew that, they came to me and asked me if I would be a part of the CenUSA team."

What made you an ideal candidate for your position as a co-project leader with CenUSA?

"Because I had been involved in other grants before, I was familiar with Extension and its goals and purpose. I was also a program evaluator for agriculture and natural resources, so it was a natural fit. "

What were some of these other projects?

"I'd have to strain my memory to recall some specifics, but they (different projects) would be about different approaches to evaluating different Extension-type activities. They could have been in sustainable agriculture, crop production, or effective communications with public audiences. These were the kind of things I've done in my involvement with other groups and teams."

[16] Learn more about Sorrel Brown in "Sorrel Brown: Women in Agriculture – Taking the Knife and Living the Dream https://blades-newsletter.blogspot.com/2016/04/sorrel-brown-women-in-agriculture.html

In what ways did the project broaden your professional knowledge and skill set?

"Well, it [CenUSA] was quite large. There were about six or seven land-grant universities involved in it, so I didn't know a lot of the personnel involved. That (working with new personnel, new universities and with new fields of research) certainly broadened my exposure to other researchers and other Extension specialists in other land-grant universities."

To what new ideas and disciplines were you exposed as a part of your work with CenUSA?

"When you look at all of the fields that CenUSA covered, they varied considerably in areas in which I had very little expertise. There's marketing distribution, commercialization, feedstock development, sustainable feedstock production systems. A lot of that was out of my purview in terms of technical background. I'm an agronomist by technical profession, so I was much more tuned-in to crop production as opposed to livestock."

How many people participated in Outreach and Extension for this project?

"We worked with individuals from each of the land-grant universities who were responsible for providing information, knowledge and research results to the public, but it would have covered many of these different types of teams that were on CenUSA. That would have been the scope of Extension working with those people and audiences."

Did you and your team encounter any obstacles in your Extension work?

"Yes, because of the different nature of the evaluations that we had to do, we ran into situations in which much of the education and distribution of research results was done on field days when people gathered at the field plots. That's not a very controlled environment in terms of applying a standard survey instrument the way you would in an inside environment. We had to devise methods and approaches that would still help us gather Extension data so we could evaluate what these audiences attending the field plots had learned, whether or not they applied any of what they learned, how they felt about it and whether or not they felt like there were possibilities for future applications in their own operations. It was a very fluid situation from which we had to gather data. It was not a very controlled environment."

What were some of those methods that you used?

"We devised introductions for when the person who was providing the training would alert the audience to what we were going to try to capture in terms of their knowledge. They [the audience] were prepared and were made aware of us coming back with questions that

would get at their response to the field trial and the tour they experienced. That would be one way. I set up different evaluation protocols that depended on the nature of the education or the Extension event. For example, we did things at the Iowa State Fair. Well, that's a very difficult environment to get evaluation responses, so we had to come up with some very simple, quick and straightforward ways to gather information."

What were some noteworthy successes that you and your team achieved in your work with CenUSA?

"We were able to get some significant data from evaluating some of these audiences that were not quite conventional in the way that we tested them. We worked together within the Extension team to devise different ways to capture the audience's responses and the degree of knowledge that they gained from the various tours and educational experiences that they had. I came up with a set of questions for an unstructured group interview to get feedback on their thoughts on things like biochar, one of the products that CenUSA was exploring. That's basically what we did. We learned how to approach the various audiences in the unconventional places in which we found them."

What were your primary means of sharing the knowledge developed by the CenUSA project?

"I wrote one-page fact sheets that were very straightforward and did not use much scientific jargon. Having been in Extension for 35 years, I was certainly experienced in addressing non-scientific lay audiences in the kind of language that would be clear to them and would help them understand the implications of whatever results that the research teams were finding that could apply to the general public."

What is most likely to convince producers to apply and adapt to new skills and information from a project like CenUSA?

"The audiences that came to view our research results in the field plots probably had different reasons for why they were there. Obviously, some of them were probably looking at profitability. Others are concerned with the sustainability of ag practices and the sustainability of environmental conditions, so that's the kind of diverse backgrounds of the people who came, and obviously had different reasons for why they came to learn about what was being done. Others probably just came out of curiosity about what we were doing and what we were finding out. All of those different reasons apply to the audiences with whom we interacted."

Is there anything you and your team learned as a part of your outreach efforts that would change how outreach is done in the future?

"Since I was at the point of retirement by the end of the CenUSA grant period, I wasn't really thinking in terms of using it myself, but I wrote a lot of fact sheets about how I went about developing the evaluation tools that we used and posted them in the web space that ISU (Iowa State University) used so that they would be available. I believe that they were posted in the CenUSA library as well. That information is still available to people who know to look there and would like to see some of the evaluation tools, protocols, and results that we came up with during the term of CenUSA.

How do you hope that outreach could be changed by others in the future?

"I think that we effectively showed that even though you have unconventional environments for providing research data and results that there are ways that we can tap into audience feedback so that you can gather significant evaluation data on whether or not those audiences learned and planned to use something or planned to pass that information on to their friends and fellow farmers. I think that one of the unintended consequences of what we developed was ways to show the unconventional environments that could be tested."

Are there new tools, programs or resources that could be developed to help those who need them? Is there anything that could be done that hasn't been done before?

"I'm sure there are. We haven't thought of everything, and I'm sure that some of the things that we developed can be tweaked for future experiences that may deviate from what we have done while still using many of the protocols that we made. I can't specifically say since I've not been involved in it for three years since (my participation) ended."

What is the most noteworthy or most interesting facet of your work with CenUSA that you would like the interested members of the general public to know and understand about your work?

"Probably the most important aspect is that there are ways of evaluating the application of research data in a way that is practical for a farmer to use. We showed that some of what the researchers found through their fieldwork could be translated into something a farmer could do for themselves.

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Michael "Mike" Casler, Feedstock Development

USDA Research Geneticist Michael Casler[17] was willing to elaborate on this process and his involvement as a CenUSA co-project director with the project. Dr. Casler spoke about his work and involvement with CenUSA in the areas of feedstock development and sustainable feedstock production systems with CenUSA Communications Tyler Worsham in November 2018. Casler detailed the challenges of plant breeding and trial establishment in the field.

How did you initially get involved with CenUSA?

"I was invited from the beginning to be one of the original principle investigators on the project to participate in the planning stages and development of the grant proposal. The group decided right away that it was going to be a multi-state project in the north-central region with a focus on perennial grasses. I've been working on perennial warm season grasses for bioenergy for about 20 years, so I guess I was a logical choice."

Have you worked on any other projects of a similar size or funding?

"Oh no, of all the grants and projects that I've had, this was clearly the highest level of funding and the most extensive project in which I've participated."

What made you the ideal candidate for a feedstock development leadership position?

"There were two of us who were leaders in feedstock development, Ken Vogel and I. Before he retired, we were both actively breeding switchgrass and bluestem for bioenergy. We have the largest programs in the Midwest area, and we've been doing it for a long time, so it just seemed logical for the two of us to be the leaders of that activity. I think you'd have to call us co-leaders. It wasn't just me."

Describe your specific role in feedstock development research for the project.

"My specific role involved two things. We were funded for the six- year period to be able to continue the breeding work we've been doing, and to also set up a new multi-location testing system for candidate varieties. We established trials at thirteen locations with switchgrass and bluestem, and we essentially ran those trials for that six-year period, testing all of these candidate varieties so that now we have this huge database to use for the release of new varieties. We haven't made those decisions yet, but we're in the process of doing that right now. That's pretty much it, conducting the multi-regional trials and continuing the breeding program developing new populations."

[17] Learn more about Mike Casler at https://www.ars.usda.gov/midwest-area/madison-wi/us-dairy-forage-research-center/dairy-forage-research/people/michael-d-casler/

How did the project challenge or broaden your knowledge and skill set?

"The biggest challenge was not science; it was organizing everything from people to all of these trials across all of these states and getting people to do everything the same way. Our goal was to set up uniform trials that are conducted the same way at every location. I must say, that was a challenge, but people were really cooperative.

For the most part, everything went pretty well, but it didn't just happen by happenstance. It required a lot of coordination and a lot of oversight on the part of my technician and myself. It wasn't the science. It was dealing with people."

What was the need for this project? Was it a lack of communication or lack of feedback between projects throughout the country?

"No, you see, Ken Vogel and I had been working together for years. We would test each other's breeding materials and collaborated together very well, but one thing that's really important with these perennial warm season grasses for energy is that the varieties we develop are narrowly adapted geographically. Any one variety is usually adaptive to only two or three hardiness zones. Ken Vogel would adapt varieties to Kansas, Nebraska and South Dakota, and I would be developing varieties that are adaptive to Wisconsin and maybe northern Illinois, northern Iowa, Minnesota and Michigan.

What we needed was a bigger testing region. We needed broader testing, more collaborators to test these varieties in order to get a really good idea of which candidate varieties are best adapted to which regions. That's what CenUSA did for us. It gave us the platform to be able to do that. The platform essentially helped us to get collaborators in multiple states. I think we had nine-or-so states involved with funding to support those field trials. What they were doing for those five or six years of the CenUSA project was testing the varieties Ken (Vogel) and I had been developing for the last 20 years, as well as other varieties from other breeding programs."

What are the most promising approaches to increasing switchgrass yields in the *Midwest?*

"What we're trying to do is develop late flowering varieties. The reason we want later flowering is because we want to be able to utilize the entire growing season. Locally adapted varieties and traditional varieties that we've collected from around here in prairie and savannah sites are early flowering, and they're really wasting six to eight weeks of the growing season. We're trying to develop late flowering types that have sufficient winter hardiness so that they'll survive here and provide sustainable production. We basically want

them to grow all the way up to killing frost. That's our goal so that we're accumulating biomass during the entire growing season."

Could you describe the process that geneticists use to produce higher yields of grass like 'Liberty', for example?

"For 'Liberty', that was a 20-year process. Ken Vogel made hybrids between what we call upland and lowland types of switchgrass. The upland type is a northern type with good winter hardiness but very early flowering, and the lowland type is a southern type that's very late flowering but doesn't have much winter hardiness. He made those crosses in the greenhouse, planting thousands upon thousands of progenies in the field and went through two generations of selection for late flowering, winter survival and biomass. He and I then tested those candidate varieties. There were five of them, and he decided that one of those was going to be released as the variety called 'Liberty'. 'Liberty' is essentially a hybrid. It combines late flowering from the south and winter hardiness from the north into a population that is actually very winter hardy and very late flowering."

Did you have any involvement in the development of 'Liberty'?

"I wasn't involved in development, only the testing."

Where do you hope to take your CenUSA research from here?

"Some of the breeding work that we did during the CenUSA period has yet to be tested because the project has only been completed for a few months. Many of those populations will be going into multiple-location trials over the next few years, so CenUSA is actually going to have a legacy that's going to take us a little bit of time to establish. It's going to take us a few years before we know exactly what that legacy is, but that's probably going to be a legacy of some additional new varieties that will be developed as a result of some of the work we did during CenUSA."

How have advancements in genome research made developing switchgrass varieties easier?

"No, it hasn't been easier. It has been quite the opposite! It's more complicated because we've had to learn genomic techniques. CenUSA helped us develop what we call a genomic selection platform for switchgrass. We went through about five years of developing and implementing that, and now in 2019, we'll be starting to put those materials in the field to test them and determine whether it worked.

I won't know whether or not it worked or how well it worked for another four years, but it was a challenge and a lot of work. It was a struggle to learn some of those techniques and develop the right genotyping platform to support that. We feel pretty good about it. We feel like we've got it moving along and that we developed it. We're hoping that it worked."

Are there any other high biomass cultivars besides 'Liberty' that are being developed?

"Yeah, there are a lot of them that are being developed. There are at least 10 different switchgrass breeding programs in North America, one in Canada and nine or 10 in the United States depending on how you want to define them.

All of those breeding programs are working on developing new bioenergy varieties. The Nebraska program and my program in Wisconsin are just two of those 10. The others are working on similar or slightly different objectives if they're in a different geographic area like the program in Georgia. They might have some different specific research objectives, but their ultimate goal is similar to mine, higher biomass."

I've been told that one of the goals is to achieve 10 tons/acre. How close are you to achieving that amount if it hasn't been already?

"We're about halfway there in the north-central regions. In terms of where we were 20 years ago, I think we've made it halfway there. Maybe it will be another 20 years to get there. I hope not, but it might be."

Were there any new disciplines that you were exposed to that you were involved with directly or that you saw from other people?

"Yeah, I would probably say developing genomic tools to use in plant breeding. That was fairly new for me, and CenUSA was very helpful in being able to do that."

What were the challenges of having to learn those new disciplines and new ideas?

"Well, mainly it's just new technologies. The technology is changing rapidly, so once we learn something new, somebody's telling me, 'you have to learn this new thing!' The fact that it's changing so rapidly means you can't just sit back on your laurels and say, 'Okay, I've got it figured out.' All of a sudden, the technology changes, and you have to adapt to those changes.

Otherwise, they're cookbook procedures, so it's just a matter of figuring out how to extract DNA, how to process the DNA and how to get it sequenced. It's not like rocket science, it's pretty straightforward. It's just constantly changing."

So how do you keep up with those changes?

"I rely a lot on my colleagues, a lot on the people who are more involved in the development of those changes, on the people who are more basic geneticists, genomics people and bioinformatics people. I rely a lot on them for advice."

What were some of your noteworthy developments, discoveries, and different opportunities that you didn't expect?

"I think we got what we expected out of the project. What we expected was that we would be able to continue the breeding programs, continue making improvements, continue making new candidate varieties and also set up this multi-locational regional resting system at these thirteen locations. Those were our goals and we feel we satisfactorily completed those goals."

What do you think is the most interesting facet of your research that you would like the average interested public to know?

"I don't know. The most interesting thing to me is that we have already developed new varieties that are higher in biomass yield and are actually able to produce sustainable biomass that the economists say is at a yield level that is economically sustainable year-in and year-out. In other words, the models that we have and the economic analyses that we've done say that farmers can grow these things and produce economically sustainable biomass.

The only problem is that we don't have markets for it yet. I think that's the most interesting thing we've done. We've gotten at least one variety out there. We have several others coming down the pipeline that have addressed these issues, but there are no markets in order to take off with it yet."

Where do you see switchgrass breeding 20 years from now?

"I would hope that it (research) continues. DOE (Department of Energy) is still funding switchgrass and USDA-NIFA is still funding the development of bioenergy systems, so I hope it continues. I hope people figure out a way to develop markets for this. I'd like to see perennial bioenergy crops be a viable alternative to fossil fuels.

One of the great things about them is that these are crops that can be grown on marginal lands, especially marginal lands for which there are problems like erosion and nutrient loading. These bioenergy systems we're proposing can really have a dual purpose. One is to produce energy, and the other is to solve environmental problems that we have. So yeah,

my hope is that the markets develop and that the mechanisms stay in place to strengthen these markets so that this can become a reality."

You mentioned where research is going. Where do you hope to use and apply your own area of research in the future?

"I'm just going to continue to develop new varieties and continue toward that 10 ton per-acre goal. Like I said, I feel that the data suggests we're only halfway there. I just want to get as close as I can while I still have money to do it."

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Jill Euken, Extension and Outreach

Jill Euken[18], retiring deputy director of the Bioeconomy Institute, spoke in April 2019 about her work and experience as a CenUSA co-project director focused on outreach and Extension with CenUSA Communications Tyler Worsham on. Euken elaborated on her integral role in the early formation of the project and how Extension worked with farmers and the public to communicate the CenUSA vision.

How did you initially get involved with CenUSA?

"Way back before the request for proposal (RFP) was ever released, we heard through the grapevine that the USDA would be releasing requests for large coordinated projects targeting integrated projects around the production of biofuels, so we formed a team. The team was looking at corn stover as the feedstock for the supply chain to make biofuels. I was part of the BEI (Bioeconomy Institute) at the time and helped pull the team together in order to write a working draft for what we thought we would propose.

When the RFP came out, corn and corn stover were not eligible feedstocks, so we had to regroup. I set up a call with Bill Goldner, who is the USDA-NIFA program manager for the project, and I asked the question whether or not he meant to eliminate the Midwest. He said, 'No, we didn't mean to eliminate the Midwest as a candidate, but I can guarantee that if you send a proposal with the word corn in it, it will be eliminated.'

We thought about what we could do that would be helpful to the Midwestern economy and what would be helpful to the Midwest's agricultural-environmental footprint, and we came up with the concept of using perennial grasses as a feedstock for biofuels that would be

[18] Learn more about Jill Euken at https://www.engineering.iastate.edu/research/eri/initiatives/strategies/icne/icne-members/jill-euken/

strategically placed on the landscape to provide not only feedstocks for biofuels and bioproducts, but also environmental benefits as well. At about the same time, we learned that the University of Nebraska and the ARS were going to promote that same kind of concept, so I organized what my husband referred to as the Geneva Convention for the CenUSA project.

We set up a meeting between the ISU team and the Nebraska-ARS team at our family farm which is located about two hours from each university. Each group shared their vision for what they thought we should do. At the end of the day, we arrived at a joint project idea which is what CenUSA turned out to be. We also selected the leader for that project, Ken Moore, who was not at the meeting. He was somebody whose name surfaced throughout the discussion about who would be the logical leader, so we came back to Iowa State and talked to Ken, and he agreed to lead the project.

We started studying the RFP in more detail, and of course, it called for all of the different areas of feedstock breeding, agronomic production and economic and environmental footprint, but of course, two other components were education and Extension outreach. I was asked if I could pull together a team to lead the Extension and Outreach component. I was excited to do that, so I started making calls to Extension colleagues in the target states of Minnesota, Indiana, Nebraska, and South Dakota, which we had as a part of the project at the time. I had the whole team lined up, and we came up with the program which we submitted.

The budget that we had for the project at the time was $45 million, but when our project was selected, it was provided with only $25 million which meant that all of the platforms, the breeding and everything, had to be cut back. We said there were parts of the Extension budget that could be eliminated, so South Dakota was removed from our Extension budget. For the rest of the team, however, we shuffled things around, cut back on hours, cut back on the number of demonstration plots and so on in order to meet the reduced budget requirements. I basically recruited about 25 people to be a part of the Extension effort in those [remaining] states."

Specifically, how did you end up in your position with the project?

"Robert Brown asked if I would lead the Extension component. I had a 25-year history in extension and outreach work, and I was the deputy director for Extension and Outreach with the Bio-Economy Institute, so it fit very well with my responsibilities, experience and skill set."

In what ways did the project broaden and challenge your professional knowledge and skill set?

"I had never been a part of such a large project before, especially coordinating the efforts between so many states where Extension cultures and personalities were very different. I have done a lot of consensus building with teams, and that was probably the most difficult part, especially when you have to cut a lot of money out of your budget. Working on a regional basis and cutting budgets challenged me in that respect."

To what new ideas and disciplines were you exposed in your work?

"Well, I was very familiar with biofuels because I worked here for a lot of years, but I was not as familiar with switchgrass production, breeding and that kind of thing. I was very familiar with CARD (Center for Agricultural and Rural Development See: https://www.card.iastate.edu) and the environmental work they did, so I would say it was the switchgrass, bluestem grass production that I didn't know. I am a farmer, so I am very familiar with agriculture in general, but the switchgrass was the newest for me."

Have you worked in any other projects as large or well-funded as CenUSA?

"I had certainly worked on other projects before, but not $25 million projects. These are almost unheard of in in the history of the USDA, so the short answer is no. I've been a part of some big projects, but more so in the $2-to-$5 million range, not the $25 million range."

How have these other projects differed from CenUSA?

"They're not as comprehensive. The CAP projects were strategically designed to do the full supply chain, and that is indeed a very rare program. Universities tend to work in silos where everyone stays in their own departments, very focused on a very narrow set of problems and solutions."

How many people were involved in Extension?

"There were about 25 of us. It was a big group."

How was that number reached or determined?

"Well, we needed to have a core team in each of the states, so as I mentioned, we had Nebraska, Iowa, Indiana and Minnesota. We had a core group of CenUSA Extension folks in each of those states. We needed to have agronomists, people who could organize all of these demonstration plots who would go for five years, coordinate their maintenance, the spraying, the harvest, the data collection and all of the organized field days. We needed to

have experienced people, so we sort of looked at the skill sets of those who would be the best partners. I took recommendations from people I knew here on campus who knew their colleagues from other states, so that core group was derived from that process."

Did you encounter any obstacles, whether unforeseen or expected, in the process of your work?

"I would say that the number-one problem was that there is no market for these grasses, and as I would remind my ivory-tower colleagues, farmers have mortgages to pay. They have families to support. They can't grow a crop for fun. They have to grow a crop they can sell. Our main objective was not only to help farmers learn about producing these grasses, but to also have them adopt the practice of growing them, but because there was no market, we can't expect farmers to grow them. That was the number-one problem with the project in my estimation.

Another problem that was more subtle. Those of us in the Extension all felt that there is an ongoing problem at land-grant institutions worldwide. Research people don't always value the importance of the skill set required to do good outreach. Some of our team did, but others did not, so Extension was sometimes seen as 'the red-headed step-child.'"

Do you think that is because they are locked into that research phase?

"Of course. Because they are very committed to their experiments and research, they think that their particular area of the supply chain is the most important and deserves more money, so of course."

Were there any noteworthy discoveries or successes achieved in your work with CenUSA?

"In good Extension work, we do evaluation at the end of the work period to get a feel for how we are doing with our outreach programming. We planned Extension publications, fact sheets and videos, and they were all done in collaboration with the research people. When they made a new discovery, our team would meet with them and come up with the publications. One success was a huge amount of publicly available information that was designed for farmers and other people in agricultural businesses. That we have such a body of information for when we do have that market available was a huge success.

In addition to all of the knowledge pieces, we held a lot of workshops and field days where people would come to our CenUSA demonstration plots. We would have surveys where we asked people how much they already knew about some particular production practice -- like best practices for fertilizing switchgrass. We would ask how much they knew before and after the meeting so we could compare their knowledge gain with participants in these

events. We have fact sheets on our evaluation summaries on our website, and you can see that people learned, so that was a success. We certainly have anecdotal evidence that farmers are willing to grow these crops when there is a market. Farmers will grow anything that has a market. They have mortgages and families to support, so they have to grow things they can sell."

Was there anything that you wanted to accomplish but didn't quite achieve that success?

"Absolutely. The overall objective of the whole project was to have people actually growing these crops and making biofuels with them, and that has yet to happen, even for the processing systems that can use those crops. The existing facilities like the POET facility up in Emmetsburg (Iowa) use corn stover. We at the Bioeconomy Institute now have an initiative that can use any kind of biomass. We are building a demonstration pilot-scale system that can use switchgrass, but it's a demonstration. It's going to take another two years to get the demonstration done, and then it will take a while to actually expand outward into the country if the economics work. That's the question. Yeah, of course, what we wanted to have happen was to have bio-refineries using cellulosic feedstocks like switchgrass out in the field."

What were your primary means of sharing the knowledge you developed with CenUSA? Was it just the Extension website in particular, or were there other things?

"Certainly there was the website, but as I mentioned, we had Extension staff in all four states establishing switchgrass demonstration plots and conducting a large number of outreach events. We worked with the agronomists to design the plots. One plot could demonstrate the recommended fertilizer and the seeding rate while another would not, and you could observe how the recommended production processes actually impacted the yields. We harvested these plots every year, and the ones that were not done by the prescribed route did not yield as well. There were very visual systems out there as a part of our Extension program that people could view.

In addition, we didn't want to limit our outreach program to just farmers and ag-business people, so that's why we had the whole Extension Master Gardener (Master Gardener) program that ran a similar set of plots in gardens that reached nearly five-thousand people alone with programs at Master Gardener demonstration plots. The Master Gardener demonstration gardens had plots with no biochar, a half-rate of biochar and a full-rate of biochar, as well as all of the different fruits and vegetables that were grown in the plots. Then master gardeners would weigh the produce and evaluate it for not only its yield, but also for its quality. We had Master Gardener publications for that as well.

We did a number of videos and publications about using biochar in urban settings, and at each of those many Master Gardener meetings, we had an educational component about

what switchgrass is. We had some switchgrass at each of the demonstration gardens. We explained the environmental impacts of switchgrass compared to garden or row-crop practices, as well as pyrolysis, how to convert switchgrass through pyrolysis into other products and so on. We were able to reach a non-farming audience through that set of activities that I think were very valuable."

What is most likely to move producers to apply and adapt to these new skills and information from this project?

"Farmers need an established market. I was on a teleconference recently about the farm bill. There is now a market for hemp because of marijuana adoption in some states and because industrial hemp can be used for industrial purposes in other states, so the new farm bill has a new program on hemp. There is no such program for switchgrass. There is no market pull for switchgrass now."

What would it take to open that market for switchgrass?

"We need biomass conversion systems that can convert switchgrass and other cellulosic feedstocks into bio-based chemicals, biofuels, biopower and so on. We need an established market to which farmers can sell."

Is there anything your team learned as a part of your outreach effort that would change your approach to outreach in the future?

"I think what we learned was that social media is great for awareness and getting things onto people's radar. It's also great to share snippets of knowledge, but if you really want people to adopt a new crop, they have to see it, experience it, and most importantly of all, they have to have a market. All of the social media in the world is not going to encourage adoption. You've got to understand the whole system. You've got to see it and feel it.

Adoption requires in-depth learning and experience, but isn't that true in life? If you hear something or see a picture while sitting in a lecture, you learn a little, but when you're actually doing something in a lab, it's a whole new and different level of learning. I think this was the point that came home with me after 39 years that I've been doing Extension and Outreach. If anything, CenUSA taught me that this is most important. If you really want adoption, you need hands-on learning experiences.

We have a whole youth outreach program too. That was really fun, and again, we tried to

build in hands-on learning experiences into the program. If you look at the curriculum, you will find that we had hands-on activities throughout."

Are there any other tools, programs or resources that that could be developed to reach, educate and generally inform those who engage with it?

"Absolutely. When we get these conversion processes commercialized, we'll have to do a lot more of what we did with CenUSA. We created a whole decision tool on the web where farmers can go in and learn about the recommended crops and production practices, plug in their cost of land and fertilizer and such, and evaluate whether it made sense for them to grow it or see if there were other crops for them to grow. We will have to do a lot more of those kinds of things if we really want farmers to grow these crops."

What is the most noteworthy or most interesting facet of your work that you think that the interested members of the general public should know and understand about your work?

"There is a lot of publicly about 'big bad corn,' in Iowa in particular, but recently, a publication about how many people are killed per bushel of corn production was released. It was really drastic, but if you read the fine print of the article, it is the ammonia from the fertilizer we put on corn that combines with the sulfur from fossil fuel emissions from urban cars that creates pollution.

It all comes back to the fact that farmers have an established market for corn and soybeans. They have mortgages to pay and families to support. There are markets for these crops, so that's what they grow. If we want farmers to grow something else, we have to create the market for them, or we cannot expect them to do it."

You need to come up with the right incentives.

"Exactly! Certainly, CRP (Conservation Reserve Program) and other set-aside programs can just take land out of production. That's been done in the past, but our government is in such debt, and the farm bill is stretched so thin, that CRP is likely to get smaller rather than larger. We are really going to have to have markets for these things if we want them to happen. That's the biggest challenge by far."

How will you take your experience with CenUSA and put it to use in future projects?

"I've learned a lot about people and how they learn, and hopefully that will continue to be useful. I don't quite know all of what I'll be doing in retirement, so it's kind of hard to answer that, but I do intend to maintain relationships with people who are still active in

Extension and Outreach. Hopefully, I can continue the dialog about the most effective practices."

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Mark Hanna, Health and Safety

Mark Hanna[19], a former agriculture and biosystems engineer with Iowa State University Extension and Outreach, spoke in April 2019 about his work and involvement as a CenUSA co-project director focused on the health and safety of producers with CenUSA Communications Intern Tyler Worsham. Hanna elaborated on how he worked to control and minimize the risk of injury to producers.

How did you initially get involved with CenUSA?

"I knew that the project was forming. You always catch wind of things going on, but I was approached more formally as they were putting the project together. I was approached and asked if I would be a part of the safety component of the project."

What made you an ideal candidate for your position as a co-project director with CenUSA?

"I don't know that anyone is ever really an 'ideal candidate,' but I would say that my experience in extension and working with what I would call 'user groups' like farmers made me a practical choice due to my familiarity with what growers might do in different operations."

In what ways did the project challenge and broaden your professional knowledge and skill set?

"As you know, there is a wide range of disciplines in this project. You're bringing in economists, sociologists, engineers, agronomists, you know, different perspectives. You always get a much more complete picture of the situation when you have all of those different points of view."

In what ways have other projects you have worked on differed from CenUSA? Were they as large or well-funded?

"Most of the projects I've worked in have been smaller and more tightly focused on a

[19] Learn more about Mark Hanna at https://www.extension.iastate.edu/author/mark-hanna

narrower objective. You are sort of limited in the scope of what you can do, certainly by time and resources."

Could you go into a little more detail about how some of your previous projects have differed from CenUSA?

"There are pros and cons here. The smaller the project, the more tightly focused and structured it is. It's probably easier to see what is included in what we are trying to do and what is of interest, but you just don't have all of the funding and resources to fully pursue that kind of thing. There are fewer people with whom you have to check-in, and when it comes to the decision-making, there's a smaller group involved, however, there are limitations in terms of not getting as wide of an output of product when you're done."

Did you encounter any notable obstacles in your research, whether they were unforeseen or even if they were expected going into it?

"Two obstacles in the safety area come to my mind. One is a lack of data that you would like to have. For example, what is the accident or exposure rate if you are using forage harvesting equipment for switchgrass? There is always some information out there, but often not as much as you would like. The other thing that comes to mind is that this is really a new, evolving and emerging industry. There is a limited number of people out there who have some experience growing and harvesting perennial crops. They're not as easy to find."

Were there any noteworthy discoveries or successes that you achieved in your work with CenUSA?

"From a safety standpoint, I think it was the method involved in terms of establishing risk factors. What data sources did you use? How did you deploy a model to make use of that data by combining how much exposure you have to something? What would be the potential severity of risk in a particular operation?"

What was the trial-and-error process of determining what exact health and safety measures were absolutely necessary and which ones were not?

"We had to put together a list of what production practices were or could be potentially risky in growing perennial crops. We also wanted to compare that with an existing corn-soybean row crop operation. There's a lot of background information on the existing row crop operation, but not for perennial crops. When would you start harvesting them? When would they need to be planted? All of that presents a little bit more of a challenge."

What are the challenges in assessing and communicating potential risks to producers?

"I think that you always have to answer why anyone would be interested in this from a safety standpoint. 'What's in it for me?' Safety is a little bit like soil conservation, among other things. Are we all for it? Yes, but how does this affect my bottom line? Maybe it's a little further down the list of priorities for people, so you have to create an awareness of how different factors affect people."

How do health and safety play into the decision of whether or not farmers want to invest in these perennial crops?

"It is a factor, although not often at the top of the list. Folks look at the economics, what it's going to do to farm profitability, but there's always something to be said for how operations change and how health and safety can not only affect those around me, but also myself and the environment. I would say that there is an analogy here with nitrogen fertilizer application, with which you might be a little familiar. A lot of farmers here in the state of Iowa use Urea, either liquid or dry. Many people use anhydrous ammonia, and anhydrous ammonia tends to be more concentrated and less expensive, but there are some distinct safety issues, so you see what decisions people are making in terms of how much risk and responsibility people want to assume."

Beyond implementing health and safety precautions, is there any way that the hazards themselves could be reduced?

"Great question, there are always various operations involved, particularly for switching to a perennial forage crop. The emphasis somewhat shifts from (traditional) planting and seeding operations and more toward harvesting multiple harvests of a perennial crop. There are always issues of how to professionally work with and around forage harvesting equipment in terms of getting caught in the equipment and the transporting bales. It's a little bit different than what folks are used to doing in grain harvesting operations."

What kind of injuries do you often see reported in perennial crop production?

"Severe injuries are often associated with farm equipment. Certainly, livestock can also be a contributor here, but it's mostly farm equipment. People often think of the more severe injuries, getting caught in or under equipment if it falls on you, for example, but the most frequent injuries are when people are on top of a machine, whether on a combine or a forage harvester, slipping and falling off, and either breaking or straining something and needing some time off work."

Does your research reflect that using custom harvest contractors could reduce risk?

"No. First of all, it's difficult assessing that because there is a limited number of custom

forage operators for us to assess that information. More broadly speaking, when comparing custom operators versus folks who are just doing it on their own ground, we have a lot of difficulties seeing any difference (in risk) there. The hours of exposure are typically greater for a custom operator.

Because of that, we would expect the injury rate to go up some, but it often depends on the professional attitude of whoever is involved rather than whether or not they are doing custom work. Just because you have a familiarity with an operation and you're doing it more often doesn't necessarily make you a safer operator."

What's the most noteworthy or most interesting facet of your work that you want members of the general public to know and understand?

"There are two things. It's probably easier to explain to the general public that in terms of safety issues, as you shift more into perennial production, there is less emphasis on the seeding and planting issues and more onto forage harvesting issues. There is a different set of equipment and a greater frequency involved with harvest than with more conventional corn and soybean operation where the planting time for the traditional crops would have a greater degree of exposure to risk compared to planting perennials.

Also, from the general public's perspective, they should have the ability to look at two things. They need to look at the severity of the potential risk in an operation. 'How hazardous is it?' 'Is it life-threatening?' 'Is there only minor injury?' Then there is how the frequency at which they do an operation affects the overall hazard. A lot of times when it comes to safety, people don't stop to think that the potential for injury may not be great, but they're doing it every day or several times per week which increases the hazard. Then the safety aspect of things come into play a bit more (when they think about all of these things)."

Now that you are retired, how do you think your research can be used to further other projects in the future?

"I feel fairly certain that there are going to be some safety professionals that take a look at how we assessed risk and compared these two farming systems. It wasn't just looking at a single operation such as the risk of being around a power take-off shaft (PTO). We were looking at multiple operations over the course of multiple years in regard to working with perennial crops. What methods and what approaches did we use to do that? We got a chance to take a more detailed look at that and tried some things that withstood some scientific disclosure and publishing. That's all out there for people to see and think over."

So what do you hope will come from your own contributions?

"I'm hoping to get farm operators to think more professionally about how they interact with their machines besides just thinking about adjustment and operations for optimal crop establishment and harvesting. They also need to think about how to make a safe situation with the least amount of exposure involved. There's always going to be some risk there, but people need to think beyond just getting a job done to getting a job done both professionally and safely."

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Dermot Hayes and Keri Jacobs, Markets and Distribution

Keri Jacobs[20] and Dermot Hayes[21] are professors at Iowa State University. Jacobs is an associate professor of economics and is the Iowa Institute for Cooperatives Endowed Economics Professor, and Hayes is a professor in the Department of Economics where he is the Pioneer Chair in Agribusiness and professor of finance. In March 2019, they spoke about their work and experience as co-project directors focusing on markets and distribution with CenUSA Communications Intern Tyler Worsham. They emphasized the difficulty of multi-year investment for farmers and the all-encompassing importance of profitability.

How did you get involved with CenUSA?

HAYES: "Jill Euken, from the BioEconomy Institute, called and asked us to participate in the original proposal."

JACOBS: "The main thrust behind the project was Robert Brown, Jill Euken and Ken Moore. They were interested in assembling a team of investigators to submit a proposal to the USDA National Institute of Food and Agriculture Coordinated Agricultural Projects (CAP) in the area of regional bioenergy systems.

The economic component in this proposal is especially important because we were contemplating the development of a market for a product. I had done some work with producers in the use of alternative cropping systems. My dissertation was on CRP (conservation reserve program), so I have the experience in understanding producers' choice in land-use."

[20] Learn more about Keri Jacobs at https://www.econ.iastate.edu/people/keri-jacobs

[21] Learn more about Dermot Hayes at https://www.econ.iastate.edu/people/dermot-hayes

What made you an ideal candidate for your position?

HAYES: "I've worked on the economic viability of first-generation biofuels, ethanol and bio-diesel, so this was a natural extension."

JACOBS: "I understand production agriculture because of my background. I grew up on a farm, and I now work with producers in my Extension positions. I have experience with producers and the decision-making they go through, and my dissertation was on a working lands conservation reserve program. Dermot and I could provide the analysis and expertise this project needed."

Could you go into a little more detail on your dissertation?

JACOBS: "My dissertation focused on the Conservation Reserve Program (CRP). I was interested in the political economy and market forces that led to CRP adoption by farmers. The primary focus was on understanding how producers bid into the CRP. It's a competitive process where producers enroll their land in a retirement program. The analysis took the opportunity costs producers face for their land into account, and whether or not it made sense to bid into a long-term land retirement program."

HAYES: "There's a lot of similarity between someone deciding to grow switchgrass and someone deciding to enroll in the CRP. They both require you to seed down the land for multiple years, and it's that multiple-year commitment that makes Keri's work so valuable."

In what ways did the project broaden and challenge your professional knowledge and skillset?

HAYES: "Our project was intended to look at the cost of supplying the cellulosic material to the plants, corn stover in particular. When those plants are purchasing stover, they are the only stover buyer in the area, so they have what we call monopsonistic competition. That was an area of economics in which I haven't worked on before then."

JACOBS: "I think what I took most from that was the experience of working with a team. The analyses were not unlike others we typically do. It was just a new application. The project required working with a diverse team, with scientists in different disciplines who were feeding information and data that they generated into the analysis we were doing. Understanding the multi-institutional grant process and having a long-term project to work on was very valuable for me."

What new ideas and disciplines were you exposed to as a part of your work with CenUSA?

HAYES: "Well, I learned a lot about corn stover, but also about switchgrass and pyrolysis. I also got to visit and spend a lot of time with the people in the plant in Nevada, Iowa."

JACOBS: "We were working with project directors, leaders and scientists in other disciplines, learning about feedstock conversion, about efficiencies, and how to exploit certain crop traits that impact production characteristics and economics. As economists, we use data to understand the underlying processes of how those data are generated."

Could you go into a little more detail about what you learned specifically, or at least what you thought was most relevant?

HAYES: "The big takeaway from our work was that corn farmers are not going to deliver the kind of stover that is needed to meet the federal mandate. The plants aren't going to pay the farmers enough for them to do that, so we will need to use switchgrass in order to meet the second-generation biofuel mandate."

Have you worked in any other projects as large or as well funded as CenUSA?

JACOBS: "No, that was my first experience with a multi-state interdisciplinary project."

How have any of your past projects differed from CenUSA?

JACOBS: "This is different because it's multi-year with complex work plans involving graduate students and collaborators at other institutions. I did not have experience thinking about and conducting research projects at that scale."

Did you and your team encounter any obstacles in your research, whether unforeseen or as expected?

HAYES: "What we thought was going to be a relatively straightforward economic cost-benefit analysis turned out to be much more challenging, in part because the plants are monopsonistic as I previously mentioned, but also because farmers are very different in their willingness to supply stover. Lastly, I went into it thinking stover would provide all of the feedstock required to meet the federal mandate, and we quickly realized that switchgrass would be needed."

JACOBS: "Stover in our area is the dominant feedstock, but what we came to understand is that there is a role that grass and other alternative energy feedstocks can play because of the economics of stover and how it is used."

What would it take for producers to make the investment of growing perennial crops?

HAYES: "That multi-year commitment is a big deal. They don't like to tie up their land looking into the future. Let's say I decide to grow switchgrass because I can expect to make $100 per acre. Now we have these acres of land that are tied up, perhaps in a contract with a feedstock buyer. Because the agronomy of switchgrass requires you to commit your land for multiple years, economists call that the real option problem or real option impact. It's a pricy decision to get farmers to lock in their production for such a long period of time."

JACOBS: "Another example of where we see what it would take to make that happen is CRP. If you look at conservation reserve programs and other working land or land retirement programs, farmers often need some form of payment or incentive in order to participate because they are tying up their land for multiple years. That takes away the option of investing in other crops and getting the returns from other crops that may exceed them (grasses). It all comes down to economics in the end, and what the economists are saying is that you have to provide them some sort of incentive that the expected value of return from that (grasses) is higher than any other expected value of return. With a commodity market like corn and soybeans, the future expectations are unknown, so producers put greater weight on being able to benefit from that market."

I suppose that leads into the next question. What do you think is the tipping point that will convince producers to adopt these switchgrasses? What are these necessary incentives?

HAYES: "We were primarily interested in the large-scale adoption by farmers who would switch out their crops and grow switchgrass as a crop. I know that there are some people interested in grassy waterways and filter strips, but that's not something we were focused on because ours was about conversion of cropland into it (switchgrass). To do that will require the federal government to implement the second-generation biofuel mandate. That feedstock will be stover early on, and that stover will not be available to meet the full mandate. That's when large-scale conversion of cropland to switchgrass will occur."

JACOBS: "You're asking questions a lot of people ask, that if switchgrass or other bio-renewable feedstocks are 'better' for the land and environment, why wouldn't they adopt those practices? What's missing here, and what people don't understand, is that there are other benefits that are being provided by these other feedstocks, but they are not necessarily benefits that accrue to the producers. If the producers aren't getting value from those things, there's lesser value to them. I put myself in the producer's shoes. Would I switch if I was faced with the decision to make $200 per acre planting corn or soybeans or $150 per acre from switchgrass? Which would you choose? I don't think anyone would choose switchgrass in that environment. The decision comes down to the economics, and

right now, in most cases, the economics in the Midwest favor traditional row crop production.

As Dermot said about government mandates, the only way that is going to happen on a large scale is if the government mandates it and provides industry with the incentives to invest in it. The smaller things make sense in niche markets. It can be used in markets like cat litter or for biochar. If you consider biochar and the downstream co-products of this processing, although these niche (switchgrass) markets do add value, it doesn't make sense to take major land that is productive in other uses (growing conventional crops) at a higher value on a large scale at this point."

What advances can be made that can make switchgrasses more competitive faster than is currently anticipated?

JACOBS: "They have to get a handle on logistics. What they are realizing is the importance of how hard it is to transport, so making the logistics and storage more cost-effective would be one way to help the economics of that system. That's the supply side of that issue. The demand side is a bigger issue that is probably going to dominate."

What do you think is the best way to communicate the financial opportunity in growing switchgrass?

HAYES: "I guess what we're saying is that there is no financial opportunity to grow switchgrass right now, but if the mandate is implemented as scheduled, then farmers will quickly learn of the financial opportunities because companies will be out there asking them to commit acres. I think the private sector will take care of the incentive to grow the products if the government implements the mandate that we have expected it to implement, but so far, it's not implementing it, so things are kind of dead in the water."

What are the most interesting or most important facets of your research beyond what we have discussed that you think that the general public should understand about your work?

HAYES: "I think the number one thing is that stover is not available in sufficient quantities to meet the mandate, and that's why this other product (switchgrass) will need to be there as a supplement."

JACOBS: "The general public is looking at these markets and wondering why producers aren't doing more of these things that they believe have environmental benefits. They need to understand that it is a big deal to ask producers to make multi-year commitments to something without a proven market. I think they need to have an understanding of the

decision processes that producers are faced with, as well as the commitment and risks that they require.

The bottom line is that producers will respond to the market. They always have and always will. They are making the best decisions that are in the best interest of their land and the sustainability of their operation. Some people would think that producers aren't making the right decisions, that they should be making better decisions for environmental reasons, but unless the market incentives signal for that, they are going to make decisions along profitability lines as they always have. It's just like any other business."

How will you both take your experience with CenUSA and put it to use in other research projects?

HAYES: "I learned about an area of economics with which I wasn't familiar called spatial competition, so now that I am interested in that and know enough about it, I will probably write more papers in the area."

JACOBS: "I would probably say the same as Dermot, but in terms of the experience and future research, it helped me understand the mechanics of production in multi-year commitments and what that means for producer decisions. How to solve multi-year commitments are interesting from the market and policy perspective."

In what new directions do you personally hope to take your own work moving forward?

JACOBS: "I was kind of already on that trajectory. I don't know that it necessarily implied a new direction, but like Dermot said that in the process of this, we did more research and learned about an area of research involved in spatial economics and spatial market pricing. I think we can incorporate that into future research."

HAYES: "Something in which I had always been interested in and have had an opportunity to develop is understanding what the BioEconomy Institute is about and what the other projects are that are going on there. I'm now interested in fast pyrolysis and biochar and have work going on in that area."

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Jason Hill, System Performance Metrics, Data Collection, Modeling, Analysis, and Tools

Jason Hill[22], professor at the University of Minnesota in the Department of Bioproducts and Biosystems Engineering, spoke about his work and experience in system performance as a co-project director with CenUSA Communications Intern Tyler Worsham in March 2019. Hill outlined how he went about the task of evaluating biofuels for environmental sustainability.

How did you initially get involved in CenUSA?

"The director of the University of Minnesota's Institute on the Environment put me in touch with Ken Moore."

What made you the ideal candidate for your co-project leadership position?

"I don't know about ideal, but I had experience in the life cycle assessment of biofuels. The USDA-NIFA (National Institute of Food and Agriculture) had requested in their call for proposals that newly-developed biofuels should be assessed for their environmental sustainability."

In what ways did the project broaden or challenge your knowledge and skill set?

"The people of CenUSA came from many professional backgrounds and locations, and it was necessary for me to learn about their fields of study so as to better understand how to integrate our work. I was also challenged by the intricacies of helping administer a multi-institutional grant."

Could you describe your experience working with these other co-project directors?

"It was fantastic! I learned so much from them!"

Have you worked in any other projects as large or as well-funded as CenUSA?

"Yes. I'm part of a $10 million US EPA (United States Environmental Protection Agency)-funded project called CACES (Center for Air, Climate and Energy Solutions)."

How have these other projects of yours differed from CenUSA?

"CACES focuses on air quality and climate change, while CenUSA explored biofuels from switchgrass in the Midwest."

What new ideas and disciplines did you encounter in your CenUSA work?

[22] Learn more about Jason Hill at https://bbe.umn.edu/directory/department-faculty/jasonhill

"I learned about conversion technologies, biomass production, Extension activities and so much more!"

Did you and your team encounter any obstacles in your research, whether unforeseen or otherwise?

"When CenUSA began, oil prices were high. By the time CenUSA finished, oil prices had fallen, so public interest in biofuels had waned. The real challenge we faced was that CenUSA only lasted five years. There was so much more we could have done."

Could you describe some of those papers and explain what more research could be done?

"I'll give you two examples. In an early paper, we showed that different federal agencies (USDA, US EPA, and the Department of Energy) were using vastly different estimates of future biomass availability in their analyses, including for switchgrass. We pointed out that there was massive uncertainty about how the cellulosic biofuels industry might develop.

Just last year, we published a paper on the air-quality impacts of switchgrass production. Farmers often fertilize switchgrass with nitrogen to increase yields, but some of that fertilizer volatilizes as ammonia. Ammonia forms particulate matter in the air which can lead to heart attacks, strokes and cancer. We showed that farmers could reduce the number of people who die as a result of switchgrass production by using nitrogen fertilizer types that emit lower amounts of ammonia."

What were some noteworthy discoveries and success that you achieved in your work with CenUSA?

"We trained graduate students and post-doctorates who have gone on to good jobs in academia and industry. We also hosted a conference in St. Paul, Minnesota on how switchgrass can be used to improve water quality."

How did you determine the environmental impacts of switchgrass establishment and production?

"We used a method called life cycle assessment which tracks the flow of energy and matter in biofuel production. This allowed us to understand what resources are used and what pollution is created when growing switchgrass, converting this switchgrass to biofuel, and burning this biofuel in vehicles."

Could you go into more detail about what those environmental consequences are?

"Like gasoline and diesel from petroleum, biofuels derived from switchgrass affect air quality, water quality, and climate change. We sought to compare these fuels on the basis of these environmental impact categories."

The dead zone in the Gulf of Mexico is an important environmental concern. Can planting switchgrass on marginal land in the Corn Belt help reduce the size and impact of that dead zone?

"Yes. If strategically planted on the landscape, switchgrass could help by reducing nutrient loading in streams and rivers."

How do you inform and interact with policymakers to make sure that they get the necessary accurate data to help them in their policy-making efforts?

"We invite them to our conferences and meetings and we send them copies of our papers. When they ask us to discuss our work with them, we rapidly respond to their requests."

What do you think will be the greatest benefit of achieving CenUSA's vision of planting perennial grasses on marginal lands throughout the Corn Belt?

"One important benefit is that it has the potential to offset some of our current petroleum use. Many of the real benefits would be environmental as a result of converting land in conventional agriculture to a perennial system that could be a carbon sink, as well as improve air and water quality."

What is the most interesting or most noteworthy facet of your work that you would like for interested members of the general public to understand about your work?

"CenUSA's vision has the potential to improve the environment while benefitting farmers and the public."

How will you take your experience with CenUSA and put it to use in future research projects?

"I learned a lot from other CenUSA personnel about grant management and advising graduate students and postdocs."

In what directions do you hope to take your own research moving forward?

"My research has moved into the environmental impact of food production and into the air-quality impacts of agriculture."

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Cathy Kling, System Performance Metrics, Data Collection, Modeling, Analysis, and Tools

Cathy Kling[23], formerly of Iowa State University and now a Tisch University Professor of Environmental, Energy, and Resource Economics at Cornell University, and the Faculty Director of Cornell's David R. Atkinson Center for a Sustainable Future, spoke in March 2019 about her work and experience in the area of system performance as a CenUSA co-project director with CenUSA Communications Intern Tyler Worsham. One particular area of emphasis was her focus on using her skills as an economist to examine policies intended to ensure water quality and combat water pollution.

How did you initially get involved in CenUSA?

"I have been working on-and-off with some of the other Principle Investigators on issues related to soil carbon sequestration, water quality and second-generation biofuels, so when that project came around, it seemed like a natural fit for us to team up. They invited me in, and I was delighted to participate."

What made you an ideal candidate for your co-project leader position?

"The areas I brought to the project were an important piece. I am an economist, so thinking about some of these issues as an economist is certainly an important component. More importantly, I am an economist who studies the environmental aspects of many policies and market failure situations, including water quality and water pollution.

One of the cool things about the CenUSA project was the use of perennial grasses to simultaneously produce multiple products of value to consumers in terms of energy and bioplastics and to include the improvement of the environmental performance of agriculture land, specifically with respect to water quality. I brought that aspect of the water quality component to the project."

How did the project both challenge and broaden your knowledge and skill set?

"It is both a challenge and a joy to work with a wide variety of disciplines, and CenUSA certainly had that. There were engineers, people who worked on logistics, economists like me, communications people, agronomists, other water-quality monitors and so on. Learning each other's language in order to engage in fruitful discussion takes time, and it's a part of the fun of a project like this, but it is also a learning experience. You take those lessons with

[23] Learn more about Cathy Kling at https://dyson.cornell.edu/faculty-research/faculty/clk228/

you at the end of these projects, so it certainly expanded my professional skill set by working in these large collaborative projects.

Have you worked in any other projects as large or well-funded as CenUSA?

"Yeah, at the same time that CenUSA was ongoing, there was another kind of CAP (Coordinated Agricultural Project) at Iowa State University. This one was a corn-focused CAP that was run by Lois Wright Morton out of (the Department of) Sociology. I was on that team as well. It was very similar as well. It had many of the same kind of challenges and successes that CenUSA had."

How did these other projects differ from CenUSA?

"Most of my other research projects are not as large and collaborative as CenUSA, and frankly, they were not as ambitious as CenUSA to address problems of either that kind of magnitude or scale on which they were focused. The ambitiousness of the overall effort was incredibly unique, to rethink and develop alternative ways to farm agricultural land and to think about applying it on such a scale at which CenUSA was thinking. It was really, really unique."

What new ideas and disciplines were you exposed to as a part of your experience with CenUSA?

"I think I worked and learned more about agronomy, particularly about perennial feedstocks, in a much more substantive way than I have ever learned before. I learned a lot about what those types of plants need to survive and what kind of environmental benefits they bring. It was really fascinating to work directly with those who were growing and improving that feedstock, to learn about how that happens and what they can do for the landscape."

Could you go into further detail about what those environmental benefits are?

"The main distinction between these perennial feedstocks, or perennials of any sort, and those annual row crops that we grow in commercial agriculture in the U.S. with respect to the environment is that perennials are year-round land cover by definition. They have roots in the soil year-round. There's contact with the soil year-round, at any point at which the soil is warm enough, there is processing between the plant and the surrounding soil. All of that fundamentally changes the environmental aspects of that land.

They were studying perennials, miscanthus in particular, but switchgrass as well. They have incredibly long root systems that store carbon under the ground within those root systems.

They also retain soil through storms, wind and from erosion in a way that annual crops do not.

Consequently, they have very large benefits for water quality because they keep nutrients in the land and process it through plants and the biological processes. With annual crops, any excess nutrients that are not taken up and used by the crops work their way through the soils, either through the surface or groundwater, into the waterways and water systems. Some of it is also evaporated into the atmosphere as well. It's really fascinating to learn what a major change that a perennial on the landscape has on carbon storage in soils, soil-organic matter, resulting water quality and pollution impact."

Did you and your team encounter any unforeseen challenges in your research?

"Well, there was probably nothing unforeseen. You just know that there are going to be snafus with data, finding that there aren't models that you thought would be developed, and that some aren't quite doing what you expect or hope that they will do. There are always snafus, but nothing unexpected."

What obstacles did you expect going into the project?

"I expected that it would take a lot of time and energy to work with such a large group of people, and that was true. I expected that the modeling developments and improvements that my team wanted to do and did do would probably take longer than we expected or hoped, that we would be slower to deliver on some of the things we hoped to deliver. I suppose I would have to admit that that was also probably true.

There are also always communication challenges across teams. I happily wasn't the lead and didn't have to deal with that in this project. That fell upon leaders like Ken (Moore) and others, and they did a fantastic job. They were a great leadership team. That's kind of standard fare when you have been at this for a while."

What were some noteworthy discoveries and successes that you achieved in your work with CenUSA?

"I think the work that we did in water quality was pretty exciting. We were able to show through large-scale modelling efforts that if we were to get extensive coverage of switchgrass and perennials on marginal lands across the Midwest, this could have major improvements on water quality, on nitrogen and phosphorus. These are the key components of both local stream and lake-water pollutants from agriculture, as well as on the downstream impacts in the Gulf of Mexico on the hypoxic zone."

How did you determine the environmental impacts of switchgrass establishment and production?

"I learned by working with the agronomists and by working with models. Of course, we didn't see the large scale planting, so it's not something one can do observationally, but by using large, integrated models that integrate both the hydrology with detailed land use analysis, one can do what-if scenarios where one has a model calibrated to the current land use and landscape and does a counter-factual. Let's pretend in this model world that we remove corn and soybean production in these marginal lands and instead have switchgrass on them. What does the model predict will happen to water quality? That's the methodological approach."

The dead zone in the Gulf of Mexico is an important environmental concern. Can planting switchgrass on marginal land in the Corn Belt help reduce the size of the dead zone?"

"Yes, there is no question about it. A large proportion of the nitrogen and phosphorus that seeds that dead zone comes from the upper Midwest. Iowa and Illinois are heavy contributors in particular. If we can prevent the amount of export in nitrogen and phosphorus from that region, down the Mississippi River and into the Gulf, significant progress can be made toward the reduction in the size of the dead zone.

Perennial switchgrass can very effectively hold nitrogen and phosphorus on the soils and prevent that movement. It would, however, take a very extensive amount of coverage. This (retention of nitrogen and phosphorus in the soils) would not happen with a very small amount. We would have to put switchgrass on a lot of the marginal land, not just a small amount. It's an important part of what could be done, and we know it works, so we could do it now."

Is there anything preventing that from being done if it can be done now?

"The reason it isn't happening isn't because it isn't physically possible, it's because there are no adequate markets to make it profitable and cost-effective for people to do so."

How do you interact with policymakers to make sure that they receive accurate data to inform their policy-making efforts

"Well, I'm not sure it's possible to make sure that they receive it, but we do our best to take our results when we can and write them into bulletins, briefings and presentations when invited. That's the sort of role that CenUSA leadership can really help perform. As researchers, we get pretty enamored with our research and forget about taking the next step of getting it to relevant users by producing outreach materials as they did in CenUSA.

There was a large Extension and Outreach component of that project. That is the main way that many of our results get out there."

What will be the greatest benefit of achieving CenUSA's vision of planting perennials on marginal land throughout the Corn Belt?

"Certainly the water-quality benefits would be substantial. That's sort of the lens through which I see things, so I am sure that others can talk about those other benefits, but from my angle, it's all about the water-quality aspect. If we were to have extensive perennial grasses, we would reduce soil erosion and nitrogen-phosphorus export of nutrients. This would improve local rivers and streams, as well as address the hypoxic concerns in the Gulf of Mexico.

Furthermore, it would probably have some substantial impact benefits for wildlife. Providing cleaner water for wildlife is one piece of that. It would provide habitat that corn and soybeans do not and would be beneficial for soils. I don't know that we have fully quantified what all of those wildlife and habitat benefits might be.

Another possibility is to see lowered nitrate levels in ground and surface water. This would possibly lead to reducing costs of removing nitrates in drinking water. That's another dimension through which water quality improvements can benefit people, by lowering those costs and reducing exposure to nitrogen in water."

What is the most noteworthy or most interesting facet of your research that you want the general public to understand?

"I think that on a broad level, there is an incredible connection between what we grow on our land, how we manage that land and the resulting air quality, water quality and wildlife habitat in the environment. Those large-scale land-use decisions we make have a really large effect on the environment of a region. I don't think the public understands that."

How will you take your experience with CenUSA and put it to use in future research projects?

"Well, I already have in the sense that it really helped me understand how teams can accomplish what no individual can, and how to hopefully work a little more effectively at trying to lead and energize teams. Ken Moore and his crew were really good, and watching him do the work of leading a large and complex project like that helped me to understand what works."

In what new directions do want to take your own research moving forward?

"I continue to be super interested in water quality, so I will continue to work in that area. I want to learn and work more in a variety of ways in which water quality impacts people and ecosystem services. It's along the same lines of what CenUSA was doing, but going further into the areas of additional ecosystem services from water quality."

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David Laird, Sustainable Feedstock Production Systems

David Laird[24], a professor in the Iowa State University agronomy department, spoke about his work and experience as a CenUSA a co-project director with a focus in soil research and biochar. In December 2018, Laird spoke with CenUSA Communications Intern Tyler Worsham about how in his role as co-project director, he helped develop the original proposal and worked on developing sustainable bioenergy management systems in order to accrue environmental benefits that will mitigate climate change.

How did you initially get involved in CenUSA?

"I was a part of the team that initially developed the proposal that went to the USDA (U.S. Department of Agriculture). I worked with the project director, Ken Moore, and the rest of the team and helped develop the proposal. I was in it from the beginning."

What made you the ideal candidate for your leadership position?

"Understand that CenUSA is a rather large group. About 20 scientists were involved in one capacity or another. They covered a diverse range of research topics that centered around the development of feedstocks and sustainable bioenergy systems. I am a soil scientist, so my interest is in sustainable production of bioenergy feedstocks and how agronomic systems impact soil quality and soil carbon sequestration.

Soil contains a lot of organic carbon. Roughly four times as much carbon is in the soils on planet earth as is in the atmosphere or in the plant biomes that surround the planet. Soil is a huge reservoir of carbon, and if we manage our land in such a way that we degrade our soils, it will result in carbon leaving the soil and entering the atmosphere. This will exacerbate global warming.

On the other hand, if we can manage the land in such a way that we can pull carbon dioxide out of the atmosphere, turn that carbon into plant material and turn that plant material

[24] Learn more about David Laird at https://www.agron.iastate.edu/people/david-laird.

into soil organic carbon, then we will be pulling greenhouse gasses out of the atmosphere to help mitigate or reduce the threat of climate change. My research and my contribution to the CenUSA leadership revolved around how we develop sustainable bioenergy management systems that are carbon net-negative, pull carbon out of the atmosphere and build soil organic carbon."

We just touched on it, but what specifically did you do in your work in feedstock production systems?

"We ran a series of test plots on which we were growing some of the bioenergy feedstocks. Switchgrass, prairie polycultures and corn stover were the three main crops we were comparing. We were also investigating the use of a material called biochar as a soil amendment.

A part of the vision of CenUSA was to take all of this biomass and process it into bioenergy products via a biochemical platform known as pyrolysis. Pyrolysis is like heating. You can take any kind of organic matter −corn stalks, switchgrass or any organic compound, and put it in an oven. If you keep the oxygen out of the oven, the biomass won't burn. Instead, the biomass (organic matter) thermally decomposes, producing a gaseous product, a liquid product, and a solid product. That solid product is char, or biochar. The liquid product is bio-oil which we envision refining to produce liquid transportation fuels and other products, and the gaseous product is called syngas. It's a combustible low-energy density gas, so you can get some heat out of it, and you can potentially use that to drive the whole process forward.

Only two products are leaving the pyrolysis plant, oil and char. The oil goes to a refinery and is turned into liquid transportation fuels and other products. The char, the solid residue from this process, goes back to the cornfield or the switchgrass field from which you harvested the original biomass feedstock. There's value in this for multiple reasons.

One of those reasons is that a lot of nutrients such as potassium, phosphorus, calcium and magnesium tare extracted from the soil when you grow a plant. The plant takes these nutrients up into its roots, and they get incorporated into its biomass. If you harvest the biomass, the nutrients are removed from the soil system and typically have to be replaced by adding fertilizer or soil quality will degrade, but when you pyrolyze the biomass, those nutrient ions are concentrated into the biochar. Therefore, if you later return the biochar to the soil from which you harvested the biomass, you are recycling the nutrients.

One of the unique features of biochar is that it is a highly stable form of carbon. That is, it is only slowly decomposed by soil micro-organisms. Most of the soil organic matter present in

soils comes from roots, leaves and other plant tissue that are deposited on the soil and are then slowly decomposed by those micro-organisms. Normally only a small amount of crop-residue carbon gets incorporated into the soil as hummus, the stuff that makes the soils dark in color. Most of the crop-residue carbon is quickly returned to the atmosphere as carbon dioxide.

Biochar is a component of soil humus, but it happens to be the most stable component. If you can imagine a leaf from a plant falling down onto the soil, the carbon that is in that leaf is going to be consumed by micro-organisms and returned to the atmosphere as carbon dioxide. The half-life of that carbon is only about six months, which means that after four or five years, 99 percent of the carbon in that leaf is back in the atmosphere. It's only temporarily stored in the soil.

The half-life of biochar carbon is hundreds, if not thousands of years, so you're taking a material such as the plant leaf that normally decomposes rapidly, and you are turning a portion of it into biochar. This means that you've changed the carbon dynamics so that you can start to increase soil-organic carbon levels by sequestering this very biologically recalcitrant form of carbon to the soil.

The third thing that biochar does is that it changes the physical and chemical properties of soil. Biochar is a low-density material, so when you add it to soil, it makes the soil less dense, increasing the soil porosity. This allows air, water and roots to penetrate the soil more easily. It increases the ability of soil to hold onto water and nutrients, and thereby reduces leaching loss of nutrients out of the bottom of the soil. This increases soil fertility and makes the soil more productive.

This is particularly true for poor quality soils, so by selectively applying biochar to degraded or poor quality soils, you can have a positive impact on agricultural productivity. So again, the three primary benefits of biochar are; 1) recycling of nutrients back to the soil that are otherwise taken away when the biomass is harvested, 2) building soil organic carbon levels by adding a highly recalcitrant form of carbon, the biochar, which helps to mitigate global climate change, and 3), improving soil quality, making soils more fertile and more productive."

How did you learn that biochar made for a good soil amendment?

"This is a long and complicated story, but suffice it to say that there are soils down in the middle of the Amazon jungle that are human-made soils. Some of these anthropogenic soils date back thousands of years. The Amazon region naturally has very poor quality soils. But

farmers discovered that by incorporating biochar, manure and other things into their soils, they were able to improve the fertility and productivity of these soils.

This practice in the Amazon goes back nearly 6,000 years. Other cultures – tropical Africa, Japan, France and others also have long histories of applying biochar to soil. I was aware of this history, but my interest in biochar really took off in the mid-2000swhen it dawned on me that the biochar co-product of pyrolysis bioenergy production systems could be used as a soil amendment. I realized that we had a way of making bioenergy and biochar at the same time. We could use the biochar to enhance the sustainability of biomass harvesting, thereby making the whole bioenergy production system more sustainable and carbon-negative.

This revelation occurred to me around 2004, and I've been pursuing sustainable bioenergy systems ever since. It's a really cool idea, and CenUSA greatly helped in advancing the research. With the support of CenUSA, we were able to do the research and write the papers that documented the viability of the concept that biochar can make bioenergy systems more sustainable and potentially even carbon-negative. It's not 'the solution' by itself, but it can be integrated into complex biomass production systems and bioenergy conversion technology where you grow switchgrass, run it through a pyrolysis plant and turn it into energy products and biochar and then return the biochar to the soils. My contribution to CenUSA really focused on that piece of the story, how we can hopefully make the overall bioenergy production system more sustainable by sequestering carbon in the soil by recycling nutrients and enhancing soil quality and productivity."

I heard some of your presentations that were posted on the CenUSA YouTube channel (https://www.youtube.com/user/CenusaBioenergy), and you mentioned that biochar was used for bioproducts. How else can biochar be used other than as a soil amendment?

"The reason it is called biochar rather than charcoal is because biochar is used for some environmental applications, primarily as a soil amendment, whereas charcoal is burned and used as a fuel. Otherwise, there is very little difference between charcoal and biochar.

The research on biochar is now focusing on a number of high-value applications. Biochar is not just one material, rather it is a huge family of materials that have different properties and characteristics. You want to use the right type of biochar for the right application. If you put the wrong biochar on the wrong soil, you could have a negative impact on crop productivity. If you put the right one on, you have a positive impact. You can also engineer chars for a number of different high-value environmental applications: cleaning

environmental contaminants, removing phosphorus from ground water, improving conditions of urban brownfields and revegetating former mine lands.

A lot of work is going into using biochar to clean up a number of environmental contaminants. If you have groundwater that is contaminated with an organic solvent, we have engineered biochars that have a property which will actually remove chlorine ions from chlorinated solvents and clean up the contaminated groundwater. It's a cool application. Now imagine that you've got this plume of contaminated groundwater that is moving down grade. All you have to do is dig a trench deep enough to intercept the groundwater and back-fill the trench with the right kind of biochar. The contaminants will be removed as the groundwater moves through the biochar.

Another application for biochar is the removal of phosphorous from groundwater. You've got bodies of water like the Chesapeake Bay that have eutrophication problems. You have algae blooms that then die and create toxic dead zones. The problem is that there is a lot of phosphorus in the soils, and that phosphorus is moving with the groundwater, ending up in the rivers and flowing to the Chesapeake Bay. There's been work showing that you can dig a trench parallel to the creek, back-fill it with a type of biochar and as the water moves through that biochar, the phosphorus is removed from the water before the creek water gets to the Chesapeake Bay. These kinds of high-value applications are being studied.

Another example would be urban brownfields. You have an industrial site in a city in which the soils are contaminated with heavy metals or other toxic compounds. If you incorporate the right type of biochar into those soils, you can sequester, trap or sometimes degrade the contaminants and allow those urban brownfields to become green and grow.

Another application that is being pursued is mine-land reclamation. Let’s say that you've got an old coal mine There are mine tailings left over which can then be toxic and have other environmental problems associated with them, and nothing will grow on some of these mine tailings. Specific types of biochars are being developed that can be plowed into the tailings which will help remediate specific environmental problems and help to revegetate those areas.

These are some of the higher value applications that are being commercially developed with biochars right now. Those are the low hanging fruit because they generate higher profits for biochar companies than agriculture. CenUSA was primarily about developing sustainable bioenergy systems in which the biochar is applied to the soil off of which the biomass was harvested for bioenergy production. In that kind of a scenario, the biochar

makes economic sense as a part of the system. Right now, biochar is a bit more economically challenging if you just want to apply it on agricultural fields.

The economics are a little weak because the only thing that counts is the increase in crop yields at the end of the day. If increased crop yields are the only value considered, the biochar isn't worth very much. Maybe it's $50 to $150 per ton, but if you start factoring in carbon sequestration and the increased sustainability of the system by putting the biochar in the ground, then the value of the biochar increases. With biochar, a farmer might be able to grow continuous corn and sustainably harvest both the grain and the corn stover. Without biochar, the long-term harvesting of both grain and stover leads to degradation of soil quality and eventually declining productivity. At a systems level, you can find more value in biochar applications."

What kind of future do you see for the biochar industry and what innovations do you hope to see in the future?

"Value-added products are an area of research and industry growth right now, and biochar is a promising technology for addressing climate change. I think a time will come when our society will realize that it is time to get serious about addressing climate change and will put a value on carbon sequestration. This could be through a carbon tax or some kind of cap-and-trade program. The biochar industry will really take off if or when that happens.

Quite frankly, the biochar system we are talking about, where it is a co-product of bioenergy production, is one of the low-hanging fruits for addressing climate change. I think the pyrolysis-biochar-bioenergy platform will be widely adopted when there is economic value associated with carbon sequestration. If you can find a political mechanism to pay farmers to put carbon in their soil, this could become a very effective piece to the solution of climate change. It's not 'the solution', but it is part of the solution.

Our best estimates right now are that the pyrolysis-biochar-bioenergy platform could be 15-to-25 percent of the whole solution, uniquely so, because it literally provides a means of removing carbon from the atmosphere while generating carbon-negative products that displace fossil fuel.

The pyrolysis-biochar-bioenergy platform is effective because, on the front end, fossil fuels are displaced by carbon-negative bioenergy products such as liquid biofuels. On the back end, when biochar is applied to soils atmospheric carbon is being sequestered for a very long time, hundreds or even thousands of years. The biochar is what makes the system 'carbon negative.'

The only problem with the pyrolysis-biochar-bioenergy system right now is that it has to compete with low-cost petroleum, and under the current paradigm, the environmental externalities associated with fossil fuels are discounted. When you put gas in your car, you're not paying for the environmental cost of that gasoline. Furthermore, when you put biofuels generated through the pyrolysis-biochar-bioenergy platform in your car, there is currently no credit going back to the biochar and the biofuel for the environmental benefits associated with it. The real problem is that environmental externalities are not currently factored into energy systems."

In what ways did CenUSA challenge and broaden your professional knowledge and skill set?

"I think one of the challenges that we all faced was learning to work together as a broad, interdisciplinary team. Through CenUSA, I was working with cropping system scientists, engineers, and economists. I was not working in the isolated silo of 'soil science.' When I work with other people from other disciplines, I have to know their interests and concerns and learn to 'speak a different language.' That's a real value that came to me professionally from the CenUSA project."

Could you go into further detail on some of the other disciplines and ideas to which you were exposed?

"I worked closely with the engineers. This includes Robert Brown and his team over in Mechanical Engineering at the Bioeconomy Institute. There were also people in biosystems engineering involved in the project, by the way. They were primarily working on how to develop fast pyrolysis plants, factories that can take biomass and can turn it into these liquid bioenergy products. Of course, they have a different language, priorities, and interests. We had to learn to compromise and figure out what will work as an engineer and what will work as an agronomist and soil scientist in order to make the whole system economically viable and agronomically sustainable.

Similarly, when collaborating with the economists, we worked on developing a biochar model. This is a computer model that can potentially be used to predict agronomic and environmental outcomes. All of these outcomes impact crop productivity, and when you throw biochar into that, it's only one of a long list of variables that can impact crop productivity. Our way of trying to predict the agronomic outcome, i.e. the impact on yield at the end of the growing season, was to try to develop a computer model.

That model was then used in collaboration with the economists. The economists, however, are interested in broader market impacts; they think in terms of a global trading system. All

of these economic feedbacks have an impact on carbon sequestration. They not only impact the price of the crops, but it may mean that, for example, there's no economic incentive to cut down some piece of rainforest to grow more crops if the price of crops goes down. There might even be an economic incentive to abandon some marginal land that is currently being used for crops and let it grow back into forest.

As it grows back into forest, carbon is pulled out of the atmosphere. This is what's called an indirect land-use effect. Biochar impacts on crop productivity needed to be integrated into the economic models so that the economists could predict the effect on market forces, production systems and land use on a global scale."

Have you worked on any projects as large or as well funded as CenUSA?

"I worked on a NSF-EPSCoR project that was funded at a similar level. That project was focused on capacity building. My role involved mentoring junior faculty and building up technical and equipment capabilities.

I also worked on a project a number of years ago that was basically a soil-carbon sequestration project that was a multi-university, multi-institutional project. I've been in several large scale projects. I would say that of those, however, CenUSA was by far the most interdisciplinary project. We've had a lot of interesting features and collaborations across the board."

More specifically, could you describe how CenUSA differed from these other projects?

"Well, I think interdisciplinary collaboration was the key difference. As I said before, CenUSA was all about collaborations that involved economists, engineers, agricultural engineers, sociologists, the switchgrass breeders over in Nebraska and people from all of these different disciplines who were trying to work together on a common systems level vision. Other projects have been somewhat interdisciplinary, but not to the same extent that CenUSA was.

Extension was also a large part of CenUSA. You are doing Extension now because you are trying to communicate the outcomes, ideas and products of CenUSA to a broader audience. Most scientists are focused on communicating with other scientists by publishing in scientific journals. The Extension team helps us get the message out to the rest of the world. That outreach effort is a neat part of CenUSA.**"**

What were some unforeseen obstacles you encountered in your research?

“Some of the challenges were that biochar evolves in soils over time. Therefore, the influence of biochar on soil’s physical, chemical and biological properties also evolves with time. When you produce a mechanistic model like the model we worked on, you cannot possibly capture all of that complexity.

One of the real challenges is trying to figure out what the most important dynamics are and how they can be incorporated into a model. The model is by no means perfect. Of course, our goal in the modeling effort was to capture enough of the reality so that we can make a prediction about impacts and for the predictions to be right most of the time. We have no delusions in thinking that we can capture all of the complexity. Being able to produce and identify the critical processes and components are some of the challenges we faced.

Another challenge we faced was the reality of agriculture. We planted out switchgrass and our prairie crops in the spring of 2012. If you go back and check the history, you’ll find that 2012 was a massive drought year here in Iowa and across much of the Midwest. One of the setbacks we had was that the switchgrass that we planted in 2012 died! It wasn't able to survive the drought, so we had to replant the switchgrass in 2013. We had to face the agronomic reality that climate makes on crop.”

What were some of the most noteworthy discoveries and successes in your work of which you are proudest?

“The system-level understanding that I described for you is probably the single most important piece overall. We proved that biochar is a critical part of the pyrolysis-biochar-bioenergy platform. The biochar supports the long-term sustainable production of the biomass feedstock for bioenergy production systems. By integrating biochar into the system, it is possible to make the whole pyrolysis-biochar-bioenergy platform carbon-negative. This is huge. We're talking about a system that is potentially 20 percent of the solution to global climate change. That's not trivial.”

How will you take your CenUSA experience and put it to use in other projects?

“Again, what stands out is the ability to work in interdisciplinary teams. I think that's a real key value that comes out of CenUSA on a professional level. Having built a professional network of people with all of those contacts is certainly valuable for the next project that comes down the line.”

What is one core idea about your work that you would like to communicate to the average person in the generally interested public?

"At a systems level, you can grow bioenergy crops, harvest biomass and produce liquid bioenergy products through the pyrolysis-biochar-bioenergy platform. The biochar recycles the nutrients, sequesters carbon, builds soil quality and enhances productivity. That whole systems-level idea, that this is something that has the potential contribution to the mitigation of climate change while generating economic value is the key message I would like people to understand. This is a sustainable system that has potential to be used to produce renewable liquid fuels that could replace fossil fuels while improving soil quality and enhancing productivity at a systems level."

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Frank Lipiecki, Commercialization

In April 2019, Frank Lipiecki[25], former Research and Development Director at Renmatix, spoke about his work and experience as a CenUSA co-project director focused on commercialization with CenUSA Communications Intern Tyler Worsham. Lipiecki notably described how sugars were discovered to be valuable in the creation of various useful bioproducts because of the partnership between CenUSA and Renmatix.

What was your position at Renmatix when you first got involved with CenUSA?

"I was Director of R&D (Research and Development)."

How did that position at Renmatix lead you to your involvement with CenUSA?

"When I was at Renmatix, I was looking at different feedstocks to check their ability to economically convert into sugars using our super-critical water technology. That encompassed everything from hardwood, to softwood, agricultural residues, municipal solid waste, and perennial grasses. I was on the look-out for different kinds of feedstocks. At that same time, Robert Brown, who was a member of the CenUSA group, reached out to Renmatix because CenUSA was interested in seeing if the perennial grasses they were studying could be converted into different kinds of products. He reached out to us, and we were open to exploring various feedstocks."

Could you describe why Renmatix was interested in working with CenUSA?

"Robert Brown reached out to us. Another element was that there would be a sharing of cost. As a start-up company, we rely on joint-development agreements and other

[25] Learn more about Frank Lipiecki at https://www.linkedin.com/in/frank-lipiecki-428b23/

opportunities for organizations to help us along financially. Working with CenUSA was particularly interesting because it provided reimbursement for our work."

What were some noteworthy discoveries that you and Renmatix achieved in your work with CenUSA?

"There were quite a few. One was that we could economically convert the grasses into C5 and C6 cellulosic sugars and lignin. We also established the fermentability of those sugars from the conversion process, from the switchgrass and corn stover into ethanol. We also provided sugars to Dr. Bruce Dien from the USDA-ARS (Agricultural Research Service) in Illinois where he was able to successfully convert those sugars into lipids which were then studied for jet fuel sourcing. We were also able to establish that the lignin from switchgrass and corn stover could be used to partially replace adhesives used for wood panel manufacturing. The lignin could also be used in composite plastics formulations, both due in part to it being an inexpensive blending material, as well as providing UV-protection and additional mechanical properties."

What are the most impressive or surprising ways that Renmatix can use perennial biofeedstock material in its commercial products?

"We were given about nine grasses overall. CenUSA was interested in having us do the full Renmatix Plantrose® conversion process for switchgrass and corn stover in particular. We showed that switchgrass could be converted in sugars which in turn could be converted successfully into ethanol. That ethanol can be used to help support the agricultural industry in the Midwest, providing farmers with economic benefits. When used commercially, this could also help eliminate the hypoxia zone in the Gulf of Mexico which is caused in part by the run-off of nitrogenous fertilizers from Midwest farmland into the Mississippi River out to the Gulf. That this could be done was impressive."

Did you and your team encounter any obstacles, whether unforeseen or ones that you anticipated?

"It was a challenge that the amount of nonstructural inorganics was quite high in grasses. Wood has almost no ash in it, but grasses take up quite a bit of ash, both structural and nonstructural. The latter largely depends on the harvesting method. If the grass is allowed to touch the ground during the harvesting process, that would be costly to the farmer who would have to take a second pass to collect the grass, and it would also incorporate a lot of nonstructural inorganics like dirt. Those would add to the cost of the grass feedstock. We didn't envision just how high that ash content would be at first."

Although there are some niche markets developing for switchgrass and other perennials, there still isn't a large demand for investment in switchgrass production. What is the tipping point that would incentivize producers to plant more switchgrass acreage?

"What you need are end-products that pull it along. These niche markets help, of course. Using the lignin as a partial adhesive replacement in the production of both plywood and OSB (oriented strand boards) wood panels would also be important because that adds to the economy of the entire biorefinery. Having some of the lignin incorporated into bioplastics would also be beneficial.

On the sugar side of things, the work of the USDA-ARS lab showed that it (switchgrass) was a very good feedstock for lipids that could be used to produce jet fuel. That might also be another important market. When it comes to transportation fuel for cars and trucks, you really need a big scale, so perhaps aviation fuel, being a somewhat smaller market, might be another excellent stepping-stone along the way. The airline industry is very eager to move into renewable fuels, so that might be another good stop along the way."

What needs to happen in order for switchgrass to be more competitive in the biofeedstock market?

"Right now, there's no supply chain. It's important to establish that. At Renmatix, we were using wood chips, both hardwood and softwood. There's already a supply chain there in the pulp-to-paper industry that involves sustainably harvesting trees, debarking them, chipping them, transportation, storage, all of that. All of this is already lined up, so that was an already existing supply chain to tap for feedstock.

It will be an important thing to establish a complete supply chain for switchgrass, but we have to make sure that the supply chain is economical. You want to harvest in one pass. You don't want the switchgrass to touch the ground because it drags in too much dirt and adversely impacts it economically. It's important to keep out those nonstructural inorganics."

You mentioned the difference between switchgrass and wood. Could you describe that in more detail?

"Woods have about one-tenth to three-tenths of a percent of ash. It's 10 times that for grasses. If you don't harvest it correctly, if it hits the ground, it could be upwards to 15 percent because of the dirt. You'd be transporting a lot of dirt around, and it would have zero value. That's why it's important to keep it out. Together, the C5 sugars, C6 sugars and the lignin are similar. The extractives are higher in switchgrass than wood. Perhaps

a commercial biorefinery based on the Plantrose® process could convert them into another commercial product."

In what new directions do you hope to see perennial biofeedstocks go moving forward?

"We'd like to have grasses eventually supplant corn as a feedstock for transportation fuel. I believe that was a part of the objectives of CenUSA. I think that we've shown that you can successfully use switchgrass to replace corn as a feedstock for ethanol for transportation fuels. I hope that we figure out a way to get that off the ground from a commercial standpoint."

What new ideas and disciplines were you exposed to as a part of your CenUSA experience?

"My background is in chemical engineering. Most of my work up to this point had been with more traditional feedstocks, natural gas, and oil. In CenUSA, I was exposed to agronomists and geneticists, two disciplines that I have never encountered before while working with fossil fuel feedstocks. Those were completely new disciplines for me."

In what ways did your participation in the project challenge and broaden your professional knowledge and skill set?

"To repeat a little from the last question, my background has mostly been with traditional fossil fuel feedstocks, oil and gas in my past work for different employers, and my background is in chemical engineering. Now through participation in the CenUSA project, I have been exposed to biorenewable feedstocks, to grasses in particular. That was very interesting and very challenging. I enjoyed it very much."

Have you been involved in any other government-funded research projects other than CenUSA?

"Yes, the biggest one was with the U.S. Department of Energy's Hydrogen Storage program some years back. The objective of that was to develop a transportation fuel economy based on hydrogen instead of fossil fuels. I was involved in the chemical hydrogen-storage program. The project included scientists and engineers from different universities, national labs, and companies. The company with whom I was working at the time helped provide the commercial perspectives."

How has CenUSA differed from these projects specifically?

"Both programs involved universities. Both the USDA (CenUSA) and the DOE projects had high-caliber scientists at first-rate universities, no doubt about it. Everyone had a passion

for their program and worked to get the results. They really wanted to make a difference, and everyone wanted to be economical. From that standpoint, both programs were similar.

As far as I know, the USDA doesn't have the kind of national laboratories that the DOE does, so that was a little different. With that said, all of the people involved were really excellent and high-caliber, so in that way they were very similar."

What is the most important or most interesting facet of your research that you want the general members of the interested public to know and understand about your work with CenUSA?

"We definitely want everybody to understand that by using Renmatix's Plantrose® technology, we can take materials like switchgrass that grow in the Midwest and successfully and economically convert these perennial herbaceous materials into sugars and lignin that can be used to make a wide range of products. We can make transportation fuels, renewable chemicals, and materials that people touch in everyday life like plastics, nylon and PET bottles, just to name a few. The most important element here is that by using Renmatix technology, we can successfully and economically convert these grasses into a whole litany of renewable materials."

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Robert "Rob" Mitchell, Feedstock Development, Sustainable Feedstock Production Systems

Rob Mitchell[26] is a research agronomist for the USDA's Agricultural Research Service (USDA-ARS). In December 2018, Mitchell spoke about his work and involvement with CenUSA in the areas of feedstock development and sustainable feedstock production systems with CenUSA Communications Intern Tyler Worsham. A highlight of the discussion was how Mitchell, his team and other co-project leaders were able to develop and release 'Liberty,' a switchgrass hybrid that takes advantage of the various strengths of different switchgrass varieties from across the United States.

How did you initially get involved with CenUSA?

"Ken Vogel and I met with the participants at Iowa State before the proposal was submitted and we talked about opportunities to collaborate. Ken Vogel and I first met with Robert

[26] Learn more about Rob Mitchell at https://www.ars.usda.gov/plains-area/lincoln-ne/wheat-sorghum-and-forage-research/people/robert-mitchell/

Brown, Jill Euken and David Laird, and we discussed the possibility of presenting a proposal together. CenUSA came out of that meeting."

What made you the ideal candidate for your co-project leadership position?

"I have a background with switchgrass and other warm season grasses. I also have a good understanding of the agronomics and other aspects of plant growth and development that need to be evaluated."

In what ways did the project broaden and challenge your professional knowledge and skill set?

"One of the ways was the logistics required to carry out a project of this magnitude. It was really an amazing feat when you think about how many plots and fields we established. Coordinating field sites and handling a lot of the data from people involved in the project were pretty amazing feats. That stretched me a lot."

Have you worked in any other projects as large or as well-funded as CenUSA?

"No, this is the largest project that I've ever worked on. In fact, it's one of the largest grants with which I am familiar that have ever been awarded through NIFA (National Institute of Food and Agriculture)."

What was your experience having worked in other projects?

"I've worked on a number of multi-institution grant projects and I am a part of two other large grants right now. I've also had experience with DOE (Department of Energy) grants. One of the early biomass feedstock programs that was around was called the Sun Grant Initiative, and I was an active participant in Sun Grant. I also participated in numerous other grants from different funding agencies."

What made CenUSA different from these other projects?

"The scale was a huge difference for one thing. Looking at it from this side of the project, one of the things that I see now is that it allowed us to evaluate feedstocks at a scale that we would have otherwise never been able to do. For most of our small plot trials, we will coordinate with one, two or maybe even three locations, but to have plant material scattered around more than 50 sites in the central and eastern U.S. is really unprecedented."

To what new ideas and disciplines were you exposed as a part of your experience with CenUSA?

"The biggest new exposures were probably to biochar and the fast pyrolysis platform. Those were the two areas where I had very limited experience before CenUSA, but being introduced to that platform was a real eye-opener to me. Prior to that, we'd been focusing on cellulosic ethanol for the last decade-and-a-half, so focusing on fast pyrolysis was a change in mindset for us. Those two areas were some of the biggest changes and were both areas in which I had very limited experience."

What was the extent of your involvement with pyrolysis and biochar?

"When we have historically evaluated plant materials, we have evaluated them from a cellulosic ethanol perspective, so I have a pretty good understanding of that whole process. As we were moving into the fast pyrolysis side, I didn't know what plant constituents were important or which ones maybe even had a negative impact on fast pyrolysis processes. That was new to me.

When I got started with CenUSA on the biochar side of things, I had really not evaluated biochar from an agronomic value perspective. Having been exposed to the work that Dr. (David) Laird has been doing and to some of the work that is now coming out of CenUSA, it was really eye-opening to see the positive attributes of biochar. I was kind of suspicious of the true value of biochar prior to this project because I had limited exposure to it. Now I see a lot of value in biochar as a soil amendment."

Were there any obstacles that you and your team encountered or didn't expect in your work?

"No, not really. We went going in knowing that one of the biggest challenges would be coordinating so many scientists. It actually ended up being a great pleasure working with so many people. Ken Moore did a great job leading the project. It's also hard to understate the value that Anne Kinzel brought to CenUSA. She did a really great job keeping us on task with all of our reporting requirements because in a lot of ways, those onerous items that show up in these large scale grants are making sure you do a good job at reporting what you're doing.

I knew there wouldn't be any issue with reporting things in a scientific journal because it was a collection from a bunch of very productive scientists. The unknown for me was all of the administrative side. Ken and Anne did a wonderful job in that area. Jeff Volenec and I worked well together. He did a great job on the project and was an invaluable team member."

What were some of the noteworthy discoveries or successes that you achieved through your research?

"Probably one of the biggest things that we were able to achieve was releasing a bioenergy-specific switchgrass cultivar. Releasing 'Liberty' switchgrass was certainly a huge milestone for us. The other, as I mentioned earlier, was our ability to test the different plant material at so many different locations. We had over 50 field sites as a part of CenUSA, so having the opportunity to evaluate plant material at that many locations was just incredibly valuable.

The other thing that I would say was a huge accomplishment for us was that we were able to get the Extension people involved in the bioenergy area, which we have never really been able to do before at scale. We had demonstration sites scattered across the CenUSA states, and we had field days at those sites, particularly in Nebraska where we had two demonstration fields. Those field days were well received and really allowed farmers to get their first exposure to some of these bioenergy crops. Those were some big leaps forward, in my mind."

What was the extent of your involvement with Extension?

"I collaborated a lot with the Extension personnel. Some of the things I did were to make all of the seeding recommendations, put together all of the seed materials for the demonstration fields that we established and provided management guidance to Extension personnel. One of the things that we had done prior to CenUSA was write a large-scale Extension publication that was on establishing and managing switchgrass for biomass energy production. We were able to get that in the hands of a lot of people.

We updated that during the CenUSA project as well. I was involved in the establishment and management side of the demonstration plots and answered questions from a lot of individuals. I organized a lot of their sampling, and I was able to provide some guidance for a lot of their sampling activities there."

How did you participate with the Casler/Vogel team that was instrumental in the development of "Liberty" and other new varieties?

"I was the one who did the agronomic field testing of 'Liberty,' so that was really one of my key roles, doing the field evaluations for 'Liberty.'"

What went into that process?

"Well, the establishment and management side is pretty broad, so one of the things we had to do was develop a good understanding of what herbicides the particular cultivar could

tolerate and what was necessary for establishment. We did the field work of evaluating the necessary herbicides and measures for establishing 'Liberty' and looked at nitrogen fertilizer recommendations which we would then broaden through the CenUSA project. We then looked at harvesting effects at different times of the year.

Traditionally, we harvested most of our plant material for biomass energy around anthesis (flowering period of a plant). That would have been around August 1 here in Nebraska. As we began evaluating more and more of our biomass types, we found that we could harvest more precisely and harvest a more desirable feedstock after frost. We really changed our harvesting paradigm, and a lot of that came through our evaluations of 'Liberty.'"

What are your thoughts on the new switchgrass varieties being developed, and how will they contribute to the potential of switchgrass as a biofeedstock?

"One of the things I see is a really big potential for switchgrass varieties that have a higher yield. Yield potential is really one of the big limitations for any of our biomass feedstocks.

One of the things that we saw with CenUSA, which was a really nice evaluation for us, was that we were able to evaluate 'Liberty' and some of our other plant material at a field scale. We weren't harvesting it with small plot equipment or hand-harvesting, it was being harvested with swathers and then baled in the field. Those were some real-world evaluations for these biomass feedstocks."

Where do you see switchgrass breeding in 20 years?

"I see switchgrass cultivars that probably yield 10 tons of biomass per acre at the field scale. I think we have the potential for moving forward to that 10 ton per yield goal. That would be a big step forward because if we can reliably produce 10 tons at the field scale, that makes it very, very competitive as a biomass feedstock."

How do you think that will be achieved?

"One of the areas that is probably the most poorly understood is the plant's ability to use nitrogen, so as we look at ways to evaluate some of the nitrogen-use efficiency and understand nitrogen fertilizer rates. I think that is going to be a big step forward. Mike Casler is starting to do some of that work, and we've got some plots in the ground that we are going to work with as well. Being able to select for plant material that not only has excellent water-use efficiency, but also nitrogen-use efficiency will be very helpful for moving us forward."

What is it about switchgrass from an agronomic perspective that makes it well suited for marginal soils?

It sounds kind of funny to say it out loud, but one of the things that makes switchgrass agronomically friendly is its seed. It's got a pretty small seed, but it's also pretty slick, so it flows well through a drill. Some of the problems we have with the other native warm-season grasses are that they're kind of a pain to deal with from a drill perspective.

Switchgrass flows well, it typically has very high germination rates which can do a really good job of controlling quality in the seed lots. It tends to be a pretty vigorous seedling, so as we've selected for improved seedling vigor in some of these switchgrasses, those are agronomic characteristics that make it pretty desirable. Because establishment is such a huge key for us, if you can get it established and have a harvestable yield within the first year, it makes the economics really attractive."

What are the biggest agronomic obstacles to increased switchgrass planting on marginal land?

"One of the biggest barriers right now is a viable market for bioenergy. For the past decade or two, we've been able to grow switchgrass fairly reliably, but without a dedicated switchgrass feedstock market, that has been the biggest barrier. There's a lot of interest in switchgrass from a grazing perspective, as well as interest in switchgrass as a component of feedlot rations, but from a bioenergy feedstock perspective, it's all up to the market when it comes to growing at a large-scale on marginally productive cropland."

How do you think that market can be created and fostered? Do you think CenUSA has helped address these problems?

"I think CenUSA has helped address a lot of those problems, and one of the biggest problems is really the large-scale operation of cellulosic ethanol plants. There are a few now that have been started up in the central United States. At some point, as we potentially make the transition from using corn stalks to switchgrass, that opens up a market opportunity for switchgrass that isn't available now. That's probably the biggest hurdle, making it commercially feasible and developing it that way."

What do you think needs to be done from the research side of things to reduce those obstacles?

"We need to continue to demonstrate economic feasibility. That's one aspect. The other is the continued use of long term research projects to demonstrate the long term sustainability on marginally productive lands. We've got one study in which we are

comparing switchgrass and corn grown on marginally productive land that we started in 1998. That long term project is still ongoing.

We're now starting to produce some long term data on the effects of nitrogen fertilizer and the soil-organic carbon changes on switchgrass compared to corn. We are carrying on some of these long-term projects that we started during the CenUSA project. As we carry those on, we will just get a better understanding of the long-term sustainability of switchgrass, but also the ability to maintain stands over the long-term so we can harvest productive stands for a decade or more."

What is one of the most important or most interesting facets of your work that you would like for the general public to understand?

"It's an interesting process in that we're working on research that maybe doesn't have a direct application for the economy at this point, but what we are doing here has the potential to develop new renewable transportation fuels that are positive for the environment and for farmers. To think that we might be utilizing switchgrass to produce ethanol or bio-oil in the next decade or two is exciting. Again, these are long-term processes that you just never know how they are going to work out.

One of the things we do know is that the information that we are gathering now is certainly not going to be wasted. If necessary, we can put this on the shelf. As we begin to deplete more and more of our energy resources, as fossil fuels become less abundant, we can take these switchgrass projects off the shelf and put them into practice pretty quickly."

How long do you think it will be until we will be able to use those switchgrasses for transportation fuels?

"Well, I really think that we could do it now because we have the technology to do it. The limitation is really the economics of that process. We could slide switchgrass as a feedstock into that process now, We've got all of the pieces in place. It just needs to become more economically feasible to move forward.

How will you take your experience with CenUSA and put it to use in future projects?

"One of the biggest things in the work we do in our field sciences is collaboration with other scientists. One of the real values of CenUSA was that it allowed us to develop some very productive collaborations with other scientists, and we are continuing those now. Even though we finished our work with CenUSA, there are a number of us who are continuing to work together to move our research forward."

In what new directions do you hope to take your own research?

"I'll continue to do a lot of work on the agronomics of switchgrass and looking at harvest and storage management. We'll continue to evaluate plant materials with NIRS (near infrared reflectance spectroscopy) so we can get a better understanding of the constituents in those plant materials. We're going to continue moving forward with agronomics and testing new plant materials as our research geneticists get those materials developed and field-ready. In many ways we will do the same things we've been doing, looking at new ways to address these issues with nitrogen-use efficiency and trying to better understand mineral nutrition in switchgrass and other native warm-season grasses as I mentioned earlier."

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Patrick "Pat" Murphy, Education

In June 2019, Patrick Murphy[27], an agricultural researcher and president of Digital Agronomy LLC, spoke with CenUSA Communications Intern Tyler Worsham about his experience as a CenUSA co-project director in the area of education. Murphy, one of the original co-project directors, spent much of his time running a multi-institutional bioenergy curriculum program.

How did you get involved with the CenUSA project?

"I was one of the original Co-Pds (Principal Investigators) on the project. He had run an undergraduate research experience (REU) program previously, and I was interested in curriculum development in the bioenergy area. That's sort of how things got started. Of course, we put the program together, and it evolved as CenUSA was carried out."

What made you an ideal candidate for that particular objective? Why did they choose you in particular?

"To be frank, I was familiar with the leadership group here on campus, and I guess that one of the things that was beneficial for me to carry out the CenUSA mission was the fact I have an interdisciplinary background. I'm an engineer as well as an agronomist. It was helpful that I had that background."

How did the project challenge and broaden your professional knowledge and skill set?

[27] Learn more about Pat Murphy at https://www.linkedin.com/in/patrick-murphy-3a8a79a6/

"When CenUSA started in 2011, there were clear parallels to what I was already doing as a faculty member at Purdue. I tried the best I could to utilize those synergies, both in my teaching program and the CenUSA activities. Things changed pretty drastically when I left in 2013 in terms of how I intended our education program with CenUSA to function operationally. Although I was on campus, I wasn't in the same type of role. We had to involve some other people and push some financials elsewhere to make sure that the objectives were fulfilled in the end."

To what new ideas and disciplines were you exposed as a part of your involvement?

"I guess there are two areas. Although I have a crop science background, I have no plant breeding background whatsoever, and the plant breeding area was one of the cornerstones of the project. I think the co-project directors in that area did a fine job of not only doing all of the work they did, but also educating larger groups on the importance and impact of what they were doing.

The other aspect was the things on which Jason Hill (CenUSA co-project director) was working. Within the project, the idea that the use of readily available data to estimate health and safety impacts of changes in the production system was and still is a little bit controversial."

Have you worked in any other projects, and if so, how did they differ?

"CenUSA is the largest project I have worked on by far. I suspect that it's the largest project that any of the co-project directors have worked on because it's such an extremely large project in terms of its team and the financial backing. Most of my other projects were funded exclusively by industry, and they all operate on such a long timeline.

That was probably the big difference. Industry is typically a year-at-a-time, and projects are doled out per year. They don't provide funding to execute a vision over a long period of time, so you have to take a different approach. The nice thing about CenUSA was the size and length of some long-term operations. Some of these areas take a long time to make real headway on long-term investments. Those areas really moved forward."

What was your involvement in the education efforts?

"I primarily ran a bioenergy curriculum program. That was a team from Iowa State University, Purdue University, University of Nebraska, Ohio State University and various others from the project who contributed material. There were some individuals who had industry and government backgrounds who were involved as well.

The purpose was to provide an online curriculum that was broken up in pieces so that educators, both within and external to the project, could utilize those in either an existing education environment such as a classroom setting or arrange them together and build a course around them that is delivered online. In the third and fourth year of the project, we utilized material from the education and Extension and Outreach objectives to deliver a massive open online course (MOOC) that covered all of the areas of the project."

Did you and your team encounter any obstacles, whether they were things you expected or things that you didn't going into it?

"One of the other pieces of the education program which Raj Raman had previously run was a graduate summer training program, and I really enjoyed it as a doctorate student. Our intent was to do something like that on a smaller scale for CenUSA. Unfortunately, the bulk of the grad students on the project were doing things that were field related. Pulling the students away from the project for two weeks in the middle of the summer was difficult. It was executed, but as far as student involvement in it, we had to rethink that in the second iteration, so changes were made that we thought were more conducive to the limitations of the students and to their interests. The second iteration was very different from the first, but as far as achieving the objectives and bringing grad students together, I think that happened."

What were some of the noteworthy successes that you achieved with CenUSA?

"Well, I think that throughout the project, at least with the education objective, we certainly had to pivot a number of times. Our education design team switched from one institution to another, and that created some changes there. Some pieces that we had planned to change didn't quite come out as expected. In the end, as far as meeting the objectives that we initially laid out is concerned, we met those expectations and even exceeded them in some places."

How receptive were students to the education programs?

"I think they were very receptive, with the REU program in particular. I believe that the part of the project that is the most enduring is the generation of human capital. We essentially train the next generation of students in that area. In particular, we had a number of REU students who were studying from programs and institutions that weren't necessarily represented in the project. I know that a number of our students chose to pursue graduate study with members of the program, and many also moved forward with the work they were doing as REU students in their graduate programs."

So how did researchers determine which tools and programs were the most effective at teaching the students and audiences you were trying to reach?

"As far as instruction goes, my assessment is that those students in the programs are the ones who, although not the most in terms of numbers, were the greatest in terms of impact. It's not necessarily something that we presented to them as a part of the education program, but the experience they had with the co-project directors on the project, as well as with their immediate mentors, was the most impactful education aspect of the program."

What was the most noteworthy or the most interesting facet of your work with CenUSA that you would like the generally interested members of the public to understand. What is the most important takeaway?

"In a sense, if I look at the way that the greater project of CenUSA and the funding authorization with which it was created, it was a very different approach for NIFA. Typically, five-year projects were not done before this. Two-to-three year projects were more typical. Those projects may have rolled over into five years, but for NIFA to make the commitment of a five-year project, along with the financial aspects of that was significant.

That led to the project institutions building teams of not only researchers, but also educators and Extension and Outreach people. USDA's mission was not only developing ideas and technology, but making it a requirement to bring education, outreach and research or discovery together in a cohesive way that works. As far as administering these things, it becomes a challenge, but as far as impact, this is very much a positive and impactful way to build research programs within NIFA."

How will you take your experience with CenUSA and put it to use in future research projects?

"I guess that from my own past and current research activities after CenUSA, I would say that exposure to the greater project and the work that was being done was very positive, not just in the technical aspects, but in the approaches and various disciplines that are used. I think that's the piece that I've been able to utilize in my work the most. Another aspect of it is that it's the first time that I've worked with and managed such an extensive team of this nature. I had more than students, but peers who are a part of that larger team as well. That's something that has been useful and helpful to me."

So in what new directions do you hope to take your own work after CenUSA?

"My own research wasn't necessarily represented in the project. At the time, I guess I was primarily doing post-harvest storage work, and I'm still somewhat active in that area. At present, I'm doing more applied crop production work, but all of that is company or industry-funded work. I hope that there's sustained opportunities in that area. I would like to continue working in this field."

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D.Raj Raman

D. (Raj) Raman[28], Morrill Professor of Agricultural and Biosystems Engineering, spoke about his work and experience as a CenUSA co-project director focused on the CenUSA education objective with CenUSA Communications Intern Tyler Worsham in April 2019. Raman outlined how through CenUSA, many educational endeavors, but especially the summer research programs, were used to teach university undergraduates and graduate students about the potential role of perennial grasses in Midwestern agriculture.

How did you initially get involved with CenUSA?

"When the grant was being written around 2011, I remember very distinctly that I was the Associate Director for Education Programs in the Bioeconomy Institute working with Robert Brown [Distinguished Professor of Mechanical Engineering]. I had been in that role since 2007, so I had been doing that for about four years at that point. The Bioeconomy Institute was helping a team led by Ken Moore [Distinguished Professor of Agronomy] to go after this large NIFA-CAP grant, and they needed an education program. Since I was the education director, they asked if I could do this.

The funny part is that I was already pretty heavily involved as the University Education Director for the Center for Biorenewable Chemicals (CBRC), and I was chairing the Agricultural and Biosystems Engineering Curriculum Committee which had an upcoming accreditation visit of two programs, including the new BSE program whose development I led. I wasn't sure that I had the bandwidth to do all of this. The reason I did it at the time was not only because I knew Ken (Moore) personally, but also because I felt that I had a responsibility as the Associate Director to do this if people asked it of me. I could not say no, and I'm glad that I didn't because it turned out to be a role that I enjoyed doing. I like to think that I was able to contribute in that setting."

[28] Learn more about Raj Raman at https://www.abe.iastate.edu/d-raj-raman.

What were some of the difficulties in managing all of those different roles all at once?

"It's a bandwidth issue for me. Through that time period, I continued to have a teaching role. The first reason why I'm in academia is because I love teaching and think that it's a central part of the mission. I never really dropped teaching in order to do administration. To do administration properly takes time, and the way that I managed that for many years, especially during the years I was with CenUSA and CBRC, was by hiring and retaining outstanding staff. There were some years of really heavy lifting, and we went through an accreditation of our engineering programs in the middle of that."

"At that time, I had a phenomenal staff member working with me who was funded by those grants and by Iowa State who then went by MaryAnn Moore. Her name is MaryAnn Grapp now, and she's over in Agronomy (Hall). She was fantastic, and she enabled me to not drop too many of the balls I was juggling. MaryAnn was my right hand for the summer research experience programs. There were two summers when we had 38 interns here. Twelve is plenty, but 38 is a real stretch, and that made for some very busy summers.

I am not ashamed to say that the summer of 2019 is the first summer in a decade when I won't have summer research students. I miss them all, but I'm glad I don't have them. I have done what I think that the directors of the CenUSA and CBiRC (The NSF Engineering Research Center for Biorenewable Chemicals) programs, Distinguished Professors Ken Moore and Brett Shanks, wanted. Both of them are outstanding faculty members by all metrics, and they have been very successful in the realms of teaching and research. Both of them think that the role of education is important, and they wanted those education programs to go well, so I have tried to live up to those expectations.

One highlight of our programming each summer was that we developed and delivered mentor training for the folks mentoring the 66 students in the CenUSA internship. I think we had 130 in CBiRC and another 35-or-so in a departmental program that I ran, so there were well over 200 students total. In addition to the mentor training – which we have shared through publication, presentation, and making a video available to other departments and universities – we did pre-and-post evaluations on what the mentees got out of it. I'm still in touch with many of them, and sometimes I unsolicited letters from them saying that I may not remember them, but they're getting an advanced degree and want to thank us. I think that the program we ran was very impactful."

What made you an ideal candidate for your position? Was it more than the position that you had at the university, or did it include other work experience that you had in the past?

"If you think about it from CenUSA's perspective, I was a good candidate because I already had a directorial role at CBiRC, a large, multi-year, federally-funded project at Iowa State. We kicked off CBiRC in 2008, so by the time CenUSA came around, I had been doing that for about three years. I already had experience doing the kind of thing that CenUSA wanted to be done."

"I began my career at the University of Tennessee, where I spent just over 12 years before coming here (Iowa State University). I ran a USDA higher education challenge grant at Tennessee that had summer internships. Several of those students were in my lab, and I oversaw that. Because of CBiRC and my work at Tennessee, this (CenUSA) was not my first rodeo. The project's goals of coming up with perennial ground covers that can be grown on marginal land to make biofuel fits the kind of things I'm interested in, so there was a lot of confluence."

In what ways did the project challenge and broaden your professional knowledge and skill set?

"The sheer size of the effort made me step up my game, for a lack of a better way to put it. You can sort of get away with things when you have an eight-student summer internship that is run with students in your department, but you can't do that with 30-to-40 students or more from all around the country. You can't do a proper job of building diversity in the students who participate by doing business as usual.

To do a good job, you have to do what I was fortunate enough to be able to do. I got to work closely with people like Thelma Harding and the graduate college at Iowa State to get a list of names of diverse students who are selected to direct outreach, to go to multiple events on our campus and community colleges, and to recruit from a broader swath of students who would normally not get these opportunities.

"A lot of that learning and growing was with the help of MaryAnn Moore whose abilities to keep track of things and tend to all of the details were phenomenal. Without her, I don't think I would have been able to make it happen. We were a great team. I had to learn to delegate and couldn't get away with any tendencies to postpone or procrastinate because the project would have failed, and I don't like failing."

In other words, she helped you with the details which allowed you to look at the bigger picture?

"She was very much a part of it. We brainstormed together and she took care of both big and little details."

To what new ideas and disciplines were you exposed as a part of your work?

"I had a unique seat with CenUSA because I saw the breadth of projects that were being done by these students, and in a weird way, I often thought that these students integrated across the projects almost better than anyone else in the whole program. They were doing weekly meetings where they got to talk about each other's work. The faculty have to be deep in their area; they must have that priority. That's not a critique of the faculty. If you told the faculty that they have to meet weekly to hear about what each other are doing, they'd be asking when they have time to do that."

With the students, you can say that we're doing this since we're paying them. I was really impressed by the breadth of understanding that the students had in all of the areas across the project from the processing, to agronomy, genetics, et cetera. Those students did well really well across all of those areas."

Have you worked in any other projects as large or well-funded as CenUSA?

"Center for Biorenewable Chemicals was very similar, specifically in that it had faculty from all sorts of different disciplines."

Were there any other projects that you worked on, and how were they different?

"Like most faculty members, I've been involved in multiple $300,000-to-$500,000 grants, and they're distinctly different in their scope, in the number of moving parts and the level of synergy that comes from it, whereas these bigger grants are obviously much greater. The big grants are very interesting to me, having been involved in two large ones in the last decade, in that they force us faculty to step out of our disciplinary silos and really try to understand the system that we're working with a little more than we would otherwise. I'm interested in that as an agriculture and biosystems engineer since I'm a jack of all trades and a master of none anyway. That's not true of all agriculture and biosystems engineers, but that is true of me. That's just a little bit of my makeup. I was an electrical engineer as an undergrad student. I probably have an excessively diverse background.

These kinds of projects are very different because you're required to work a little bit in that interdisciplinary space, so their potential to be high impact is increased by that. There are also significant transaction and reporting costs for those large projects. I am in the process of chasing another big project with Ken Moore, and we believe that one of the only ways to make the changes that we need to make for a greener agriculture is a large project like this with larger funding which could really spearhead this new idea that Ken has been

developing right now. In order to take it to a higher level of technology readiness, we need a large grant."

What was your specific involvement with the education efforts?

"There were two parts to the education effort. Patrick Murphy can tell you about how he did a tremendous amount of the modules that we created. There was this summer programming that was primarily for undergraduates. We did do one summer graduate program, and it did not go the way that I expected it to go. There were some good things that came out of it, but in general, the participants didn't feel like it was a good use of their time. I hate running a program like that, and I felt terrible after that when I looked at the feedback.

We ran a two-week summer program here at Iowa State a few years earlier that was really well-received by students from around the world, and I tried to recreate that for CenUSA, but I think that I misunderstood how busy a time that summer was for students who were doing a lot of their own field work at the same time. I think the programming that I lined up did not reach those students in the way that I thought it would. That was a part of the project where I did not deliver what I hoped I would."

Continuing from how you feel like you didn't quite deliver in one area, were there any obstacles that you encountered in your work?

"That was the biggest problem I had. If you look beyond that to the summer internship programs that we ran for undergrads, that went extremely smoothly. There were teething problems that I had early on with CBiRC, and I learned from that. That's part of the mentor training that we did. We created a mentor-training video that is widely available online and that I share with people across the country. I think that we were able to fine-tune those summer programs really well."

What are some noteworthy successes that you think you and your team achieved?

"I think we learned about the qualities of good mentoring. I think that the contributions that the students made to their labs were things that I hoped would happen in a program like this. Most of the students did work that was eventually reported in meeting papers and published in refereed publications, a large fraction of whom decided to go on to pursue post-graduate education. A huge fraction of them reported that participation in the program broadly increased their understanding and interest in working in this area. I think the internship program was a resounding success."

So young people were receptive and interested in your educational programs?

"Yes. There was huge, positive feedback specifically on those summer internships. There was huge interest and a lot of positive feedback. On the one hand, we did a good job training mentors and soliciting students to participate. On the other hand, the PIs (principal investigators) on the project did a fantastic job of preparing, being there and working with their students. We had a great group of investigators who did right by the students."

Could you give some examples of the exact feedback you've received from students?

"A common theme was that 'it was a life-changing experience. I really learned how to do good research, and I realized that I have a passion to work in this area.' We have that kind of feedback on a regular basis."

How did researchers determine what education programs and tools were and were not most effective?

"I'm not really sure that we did that. Virtually all of the faculty PIs on this project had experience working with undergraduate students, so my job was attracting students to apply. What we had what I thought was a very good process of matching students to projects. This area is so broad that you cannot just take any student who applied to the program and stick them into any lab and have success.

We had a great process where MaryAnn and I would do an initial sorting of students and provide each principal investigator with three-to-six students who met the baseline criteria and who were actually interested in their labs. We would then have them rank those students, and we would go through the process of making sure that these students weren't all from one school or one part of the country. We had a very well-developed process, and we've written about that. This enabled us to meet the program goals of a group of students with a wide range of backgrounds, getting into labs that were a good fit for them."

What is the most important or most interesting facet of your work that you want the generally interested members of the public to understand about your work?

"I want the general public to understand that we take education seriously, whether it's in the classroom or in the lab. We don't just sit around expecting good things to happen, we know that planning and preparation cause good things to happen. We took our job and the money that the public gave us very seriously. We had a responsibility to those students and to the public whose money we were spending to place well, to get good research done and to give those students experiences that really helped them grow. We did that."

How will you take your experience with CenUSA and put it to use in future research projects?

"II now have an understanding of large, multidisciplinary and transdisciplinary projects, as well as how to structure educational opportunities for students in a way that lets them benefit from the transdisciplinary nature (of the project). We did specific things: weekly meetings, building the posters early on, presentations by faculty, and so on. We did things to make sure that students didn't just disappear into 'lab number seven.'

"We also tried to ensure that students were not just going into situations where their work was nothing more than grunt work. I had a handful of times where that maybe happened, but out of the 66, it probably wasn't any more than three times. The vast majority of our students got to do intellectually meaningful work. That was really important for those experiences to have value."

In what new directions do you hope to take your own work? You mentioned something that you and Ken Moore are trying to start.

"Ken and I were working on a project that he really initiated, but into which I've inserted myself. It's a project focused on the introduction of a perennial ground cover into conventional row-cropping in the Midwest, that is, corn and soybeans. I think that this vision that Ken has for perennial groundcover is game-changing."

"We have been thinking and worrying about soil erosion and water quality in the upper Midwest arguably since the Dust Bowl, but certainly for the last 30 or 40 years. There are a lot of neat solutions, and to their credit, a lot of people are starting to implement them, but we do not have the range and rate of implementation that we need to make a huge dent in soil erosion and in nitrogen and phosphorus emission. I believe that this project will do that, and I do not say this lightly. I tend to be a pessimist and a skeptic. The reason it could do it is because if we look at some of the preliminary data and make some not-crazily-optimistic assumptions about what could be achieved, we think that we could get people to do this (implement proposed solutions) because they might make a little more money doing it.

If the environmentally beneficial practice is also economically beneficial, you'll get what we're seeing in the energy sector right now, adoption rates for wind and solar that are greater than anybody could have imagined. Is this happening because they want to stop carbon emissions? No, it's because it's cheaper now. There are a lot of people working this, and there are a lot of different solutions that could work, but I believe that this PGC, perennial groundcover vision, is particularly powerful because I think people might be able to make money doing it. If that happens, and you hit the kind of uptick rates that could follow, we might finally make a dent in this problem in a way that we never have in decades."

Charles "Chuck" Schwab, Health and Safety

Dr. Charles Schwab[29], a professor for the Iowa State University Department of Agriculture and Biosystems Engineering, spoke in February 2019 about his role as a CenUSA co-project director in health and safety with CenUSA Communications Intern Tyler Worsham. Schwab expounded on the difficult nature of collecting exposure data and how to most effectively parse through that complex data.

How did you first get involved with CenUSA?

"I believe I was contacted by Jill Euken to work on the safety component of the project."

What made you an ideal candidate for your position?

"Well, I've been working with farm safety and Extension and Outreach since 1990, and I'm kind of the primary point of contact for farm safety at Iowa State University. There was a time when all land-grant universities would have a farm safety specialist, but more recently, only some of the larger schools keep that position filled. That's kind of where I've been. Part of my role in safety as an Extension and Outreach specialist is to keep things working with youth and adult farm safety education, awareness and developing resources. The tagline for ag safety is '*Developing Resources: Making Iowa a Safer Place to Live and Work*.'

To what new ideas and disciplines were you exposed in your work with CenUSA?

"Prior to this, I've worked with faculty from all seven colleges at this institution, but I have never worked as closely with people in a specific project about plant genetics, crop introduction, bio-refinement and economic models which are all major components of the CenUSA project. In other words, most of my work dealt with equipment, crop harvesting or processing, but not the bio-refinement in the fuels or with a product like biochar."

Have you worked with any projects as large or well-funded as CenUSA?

"Yes. Don't get me wrong, CenUSA was a unique opportunity, but I have been connected with some agriculture safety centers that typically receive $5 million each year for multiple years. That's kind of what CenUSA was like, but I didn't see CenUSA as a center as much as it was a project where these other collaborators were at specific sites with a variety of

[29] Learn more about Chuck Schwab at https://www.abe.iastate.edu/charles-schwab

disciplines. There was kind of a mixture of disciplines like CenUSA, so in some respects, yes, in others, no."

In what other ways have these projects differed from CenUSA?

"In contrast with the other projects, I thought that the Extension part of the CenUSA project was integrated from the beginning and throughout the entire duration of the project. That was very unique and beneficial to me as an Extension person. What you often see is that Extension is the afterthought when the project is done.

From the very beginning of CenUSA, there was this Extension and Outreach effort, making that contact, so that was the big thing for me that really differed in this project. There was much more integration of Extension than I've ever seen compared to other projects. Even in more research focused projects of which I was the director, the Extension component wasn't actually a part of the program. The funding source didn't necessarily have to have that Outreach component in it."

Did you and your team encounter any obstacles in your research, either unforeseen or things that you expected going into it?

"We knew the obstacle in the area we were covering. We think we resolved the issue, but for us, the collection and access of agricultural injury data is and always has been an issue. We're always trying to understand what is happening and how it's happening. We understand that we are trying to get a better picture of the prevalence of something like exposure or injury rate. To what are these injuries connected? From our standpoint, we have always struggled with getting that type of data.

When you are dealing with other industries like the manufacturing industry, there are different reporting mechanisms. The detailing of the reporting and how things are reported are so different, so you can really get down to figuring out what needs to happen. With agriculture, however, we just don't have that level of detail. That creates part of the problems we were dealing with because we were trying to forecast if the bio-production system is less dangerous than a traditional corn-soybean rotation or just the corn farming rotation. The fact that this information about the risk exposure rate is very hard to find was the biggest obstacle for us. We knew it going in, so it wasn't unforeseen, but it was still an obstacle."

What were some noteworthy discoveries and successes that you achieved in your work with CenUSA?

"I think the biggest one for us was utilizing the agricultural injury data that is collected by national agencies in a way that forecasts expected injury rates between two production systems. There are two facets, knowing that the modeling efforts can constantly be improved as we find better injury and exposure data. The two factors that limit what we can do is what we know about the types of injuries and what the exposure rates are.

I think the bigger part of what we figured out was that we should look at it from a comparison standpoint. This is subtle. When you are comparing two agriculture-related systems, there are certain things that set them apart, so instead of trying to figure out all of the variations that could happen within a course of a year with all of the tasks a person does, ranging from sitting down, climbing, and so on, you are comparing the two systems and making the assumption that the common tasks are all the same. You have a plethora of individual tasks that you're doing every day. Comparing all of those is a harder way to calculate. By comparing systems, all you're looking at are the things that differ between tasks.

It's sort of like looking at a big equation. These common terms cancel out, so when we compare farmer A and farmer B, you're comparing variables and realizing a lot of them are similar no matter what type of farmer you are. Cancel those things out and clean out all of the clutter. Now you can look at what is on one side with Farmer A compared to what is different on the other side with Farmer B, and really compare those exposures and types of injury differences. I think that from my perspective, it's a simple process that gets rid of the muck of all of the little details and just focuses on those critical differences."

What was the exact trial-and-error process that determined what health and safety measures that were absolutely necessary and those that weren't? What went into that?

"I think it's interesting to use the term 'trial-and-error process' because the safety component of the project did involve multiple attempts at finding the right approach to exploring that main question of performing a detailed risk analysis. In other words, there are a variety of tools that can be used and different industries use them, but when you get down to it, we went through a process of figuring if this or that worked and what's involved if we use them. That's how we came about looking at a comparison model. It removed some of the issues we had with using other risk-assessment models that other industries use.

They usually have more data like the specifics of those injuries, how those injuries occurred, the exposure rates and so on. They had all of those details that made the model easier for them to look at individuals, whereas we couldn't look at individuals in our

approach. It was interesting because as we approached these different analysis tools and looked at why they were nice and good, but we found we couldn't apply them."

What were the challenges of assessing those potential risks to farmers and then communicating those risks to them?

"I guess the biggest challenge was in assessing the potential risk to farmers. That was the hardest component for me, no matter if it was for biofeedstock or traditional crop production. There are so many barriers to success. Again, it goes back to the lack of injury and exposure data for formulating accurate risk assessments.

To put it into perspective, if you were trying to determine which vehicle is safest to drive, we're determining which of the two production systems are safer. If you translate it into something everyone does, there is so much data about which cars are involved in collisions and what the speeds and conditions are. Every time something like this happens, there is a report being generated that is being collected by all of these agencies into these massive databases with all of this information.

In agriculture, however, you're not going to get any of that information. You're not going to know what the weather conditions there were, you won't necessarily know all of the things that led up to that specific injury, and at best, you sometimes don't even know what (part of a person) was injured, how it was injured or how long a person has been doing those things. There are just so many factors. Even cars have so much diversity from the number of manufacturers to the number of years, but when you think about an agricultural operation, you have so many regional, geographical, philosophical, and equipment differences."

How much does health and safety play into decision about whether or not farmers want to invest in perennial feedstocks?

"It's hard to answer because health and safety aren't necessarily evaluated in the same way as decisions to produce one crop over another. I'm not saying that people don't think of their safety. I just don't think that choice for safety bubbles up to the top. What plays a bigger role is the economics behind it, right? What are the things that a farmer has available? Are the land, the equipment and the skill levels easier to transfer? Health and safety are much lesser variables in the decision process about whether or not they are going to do this transfer.

People make health and safety decisions about their actions every day, but when you look at it from the strategic perspective of what type of job someone will be doing, I don't think safety plays as much of a role. There are certain jobs that have a level of risk associated with

them, and being in agriculture is a risk. Once you're in it, I don't think health and safety play much of a decision in what area of agriculture you enter."

In what ways can the hazards themselves be diminished as opposed to implementing these precautions?

"You can take any specific operation and see where the risks are and implement change. When you are looking at risk, you can minimize exposure so you're doing something less. You can remove the hazard of something you're not doing anymore altogether. Maybe you contract it out for someone else to do so you're not involved in that risky operation, or you can change the process of what it is that you are doing.

When you're talking about the production and harvesting of perennial grasses, they are actually a lower risk than the more traditional crop approach. Again, based on what we understand, part of it is that we removed exposure. How do we come up with that? One of the biggest differences between perennials and traditional crops is that you have much less exposure time on operations that can be dangerous.

This is just an example, but when you plant a perennial grass, you do it one every ten-year cycle, maybe twice if you have to replant some if it didn't take. In a traditional crop, you're planting every year, so there is that planting difference in exposure. You have exposure once every ten years in one area, and you have ten exposures to risk every ten years in another. The fact you are being exposed more (in traditional cropping) gives you a higher risk of being injured."

Does your research support the conclusion that using custom harvesting contractors reduces the risks to producers?

"I guess I would say that it was not necessarily the purpose of my research. Academically, this statement would hold true because custom contractors are typically more skilled in the singular activity of custom harvesting. It's kind of a double-edged sword. They have more experience because of the repetitive nature of doing the same task over and over again. They probably have a very unique set of equipment that is fine-tuned for the operation that they are doing, but at the same time, they're performing an operation more often than most other individuals. If you look at the flip side, however, a person who doesn't do it on a regular basis doesn't have that vast experience. They may not have all of the best or the most effective equipment to handle the job safely, so they're making do with certain types of equipment that creates other types of hazards."

What is the most interesting or most important facet of your research that you want the general public to know and understand?

"For me, the best part is having that comparative analysis process that allows us to work with data that is less detailed than what we would like to see, and it gives us greater ability to forecast things. Does the general public need to know that? It has a benefit, but probably not. What's relevant to the general population is understanding that all of the decisions we make have an impact on our potential of being injured or causing injury. It's a matter of understanding that we don't realize that the decisions we make can have an impact on our health and safety."

How will you take your experience with CenUSA and put it to use in other research projects?

"It probably was one of the largest group projects I've ever had. I've had big ones, but this is by far the biggest. I think that for me, the experiences from the intense communication and coordination efforts are what I deem a success in this project. Something that I will probably walk away with is making sure that you use all types of communication when you are in a project. Anne Kinzel was always communicating and sharing information with us. We had the group meetings. All of the various communication efforts were extremely valuable for moving things forward.

Right now, my newest project is looking at how to reduce mortality rates of victims trapped in grain materials. That is not necessarily directly related to the CenUSA project. I guess what I get from it is that in CenUSA, we had a good group with members who communicated well, and we had a diversity of teams that shared ideas. I think these things help in any project. I guess that's what I'm taking from CenUSA to the projects on which I am working moving forward."

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Kevin Shinners, Feedstock Logistics

In February 2019, Kevin Shinners[30], a professor of agricultural engineering at the University of Wisconsin-Madison, spoke about his work and experience with CenUSA as a co-project director in the area of feedstock logistics with CenUSA Communications Intern Tyler Worsham. According to Shinners, optimizing bale density for transportation and creating a model that helped them harvest crops more effectively were some of the objective's greatest successes

How did you initially get involved with CenUSA?

[30] Learn more about Kevin Shinners at https://bse.wisc.edu/staff/shinners-kevin/

"They asked me to join. I got a call from Ken Moore, and he asked that I join the grant."

What made you the ideal candidate for your co-leadership position at CenUSA?

"Well, I've had a long history of engineering work in the area of hay forage and biomass, and I have a pretty good track record of publishing in this area. Honestly, there are not a lot of academics who are involved in that area. Wisconsin is also reasonably close to Iowa which was the center of the grant."

How did the project challenge and broaden your professional skillset?

"It's very hard to change that capital-intensive system that we have for harvesting, processing and storing biomass. The real challenge was in the funding level that we had to make changes in the area of feedstock logistics. It's kind of like trying to change the direction of an aircraft carrier. It can't be done very easily, and it takes a lot of effort. Some of the biggest progress that has been made in the area of feedstock logistics was made with multi-million-dollar funding activity that focused almost exclusively on logistics. Additionally there would be very good industrial partners associated with these big grants, which helped facilitate machinery and logistics changes.

Sometimes it was kind of hard to make progress under the structure of the feedstock portion of CenUSA, but I think we found and attacked some niches in which we made some real progress. We produced some nice publications from our work, but it was a challenge to make a real, meaningful, industry-wide impact."

What new ideas and disciplines were you exposed to as a part of the experience?

"That's a good question. I suppose it was mainly in two areas; mainly how the agronomists were moving forward with the genetics of switchgrass, and how they were making progress on switchgrass yield. I think that was very nice development. I hope that they are making a commercial impact now with their 'Liberty' switchgrass. I think another part of this was that nobody in the group really had a great feel for what we were going to do with the material once we harvested and put it into storage. Often times, the end product was a lot of vapor. We had a lot of industry partners. Looking at how many of those industry partners are still ongoing, are any of them making any money off of this material?"

Did your team encounter any obstacles that you didn't foresee going into the project?

"The first one was just getting enough acreage of grass produced in order to conduct experiments at our scale. People can sometimes work at a scale for which they are taking teaspoon material, working on that scale in a lab and getting publications out of it. We're

not talking teaspoons or tablespoons, here. We're talking about tonnage in the type of work we were doing.

It was a real challenge to get enough acreage produced so that we could go out there and collect the kind of data we needed. Once we actually did that with the help of some of the agronomists, specifically Rob Mitchell who helped us get acreage established, we struggled to get rid of that material after we harvested it. We could hardly even give the harvested material away. There just wasn't a market for it in our area. We actually ended up composting some of the material because we couldn't get rid of it."

Have you worked in any other projects as large or well-funded as CenUSA?

"I was a part of a large corn stover harvesting and logistics project in the early 2000s. That was actually a little better funded and more focused on logistics than this CenUSA project. I would say that CenUSA was probably one of my biggest, so there aren't many others beyond the corn stover project."

Other than funding, in what other ways did these other projects differ from CenUSA?

"I guess we were focusing on the feedstock in our work. It was mainly perennial grass here, but most of my prior work was involved with corn stover. That was a unique thing here, both a fun and frustrating thing about the project. In the case of corn stover, we had a lot easier time finding utilization for this material given our proximity to large-scale livestock operations."

What were some of the noteworthy discoveries and successes that you achieved through the project?

"I think one of the big ones was that we showed that we could work with manufacturers and that we could get bale density to what we needed it to be in order to achieve the optimal transport weight. We also showed how much power it took to get there, as well as how much capital investment it was going to take to do that. Achieving weight limited transport by filling the volume and weight of a truck is critical to optimizing logistics. I think we did that with switchgrass and got a nice publication from that work.

I think we also developed some new ways to treat that crop after it was cut to achieve a faster drying rate with intensive conditioning and tedding. I think we made some progress there. We then built a nice model that helped us explain how conditioning level and environmental conditions can alter the harvest progress throughout the fall. This was a model that was started by one of our undergraduate interns. She started the model and we

built it up into something a little bigger after she left. We got a nice publication out of that too.

What we also showed with this research and the modeling work was that we might not want to focus too hard on the weather during cutting and on the adverse effects of rain on cut grasses. Perennial biomass grasses are like forages for animals. It's a different material. Our model showed that we should be cutting that crop any time the weather allows us to be out in the field. I don't think it's that much of a concern if it rains on the crop. The model suggests that you should keep cutting as much as you can and get as much done with the smallest fleet of equipment as possible given the weather conditions across the upper Midwest. Those were the biggest discoveries and successes that we had there."

Could you go into further detail about how you came to develop that model?

"Well, we had some drying rate equations that we developed based on our intensive conditioning and tedding research work. Then we went into historical weather data for several locations across the upper Midwest. Knowing some environmental conditions like humidity, wind speed, rain fall and solar insulation, we could then predict how long it would take for each field of that material to dry. Then we said, 'Okay, in this particular area, if you have this many acres of switchgrass and these environmental and weather conditions, and if we want to get it harvested by this date, how much equipment and labor will you need?' I thought that was very nice work and a very nice publication that came out of that. It hasn't been cited very much, but I think it has been very useful information."

How might future advancements in harvesting methods and machinery continue to help farmers?

"I'm not sure that there's much there that can help farmers because I'm not exactly sure that I have a lot of confidence that we are going to see a lot more perennial grasses grown across the landscape given our economic situation. What we have done is take some of the models that we built through CenUSA and extend them into more traditional forage baling systems. Now we are sharing that with some of the producers to help them chose more economical baling systems, not necessarily for perennial grasses, but for traditional hay and forage."

Are there ways in which transportation can be improved that could help?

"Yes, there are two things, and it's easy. Reducing the number of times that you handle the material is number one. Don't handle the material, and you won't add cost. Every time you touch it, we'd like to get some value added to it. The second thing we found is that reducing

the size of the material at the time we harvest it rather than leave it in the long form is going to make a big difference in biomass logistics in the future. I showed some things that would help in terms of density and productivity, but that's about it."

Could you talk more about the obstacles to improving biomass density and harvest capacity?

"We continue to work on things like bale density and things of that nature, but what it really comes down to is that we are really struggling to find an economic value enhancement. The cost that we are putting into doing some things don't seem to be giving us a sufficient payback to continue commercialization. The biggest obstacle is that the price for the material is too low to justify some of the things we are thinking about in terms of improving bale density and harvest capacity. It's just a real struggle to make money at this stage. If I could be succinct about it, there are a lot more things that we could do if we could raise the price of this commodity, but there is just not much there at the current price. There's not much meat left on the bone."

So it's not a matter of throwing more research at it to solve the problem?

"Let's put it this way. More research will probably be needed for something that can utilize this material and that can add additional value to raise the price on the commodity coming out of the farm gate. A lot of people are really anxious to see this cost reduced, and I don't know that we will be able to achieve our goals with that low of a cost. Until we can see more added value, it will be hard to justify the cost of production. That's the most noteworthy thing."

How will you take your experience with CenUSA and put it to use in future projects?

"The biggest thing is that we will continue to work on ways to increase bale density, and we continue to work on ways to reduce the number of bales that need to be handled. We haven't given up on some of those things. That's the one avenue of research that I am continuing, but I am also nearing retirement, so there's a limited future there for me."

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Jeff Volenec, Sustainable Feedstock Production Systems

Jeffery Volenec[31], a CenUSA Bioenergy co-project director in sustainable feedstock production systems and a professor of agronomy at Purdue University, spoke with CenUSA

[31] Learn more about Jeff Volenec at https://ag.purdue.edu/agry/directory/Pages/jvolenec.aspx.

Communications Intern Tyler Worsham in December 2018 about the nature of his role and how his work with CenUSA centered on determining best practices for cost-effective feedstock production.

How did you get involved with CenUSA?

"Well, like most of these large USDA-NIFA (National Institute of Food and Agriculture) grant projects, everyone was talking about how to best create a project that met the needs of the program. There were a number of us talking about what our strengths were and how to meet the goals of the RFA (request for application).

In actuality, there were a couple of groups. Ken Vogel in Nebraska was conversing with us, and others at Nebraska were conversing with people at Iowa and Minnesota. In the end, rather than having two competing proposals from the central U.S., it was decided to coalesce the various strengths across these institutions, and as you know, Purdue in Indiana was pulled in as one of the partners."

What made you an ideal candidate for your leadership position in feedstock development?

"We did a couple of things. First of all, we sort of knew that bioenergy was becoming a point of interest for the federal government again with climate change and other things happening, so we had already put a large number of plots in place that were ready to go. Otherwise, it's a two-year proposition before we can even start researching switchgrass. We were already planning plots and already had perennial grasses established. We also did a fair amount of work on switchgrass research in the late 80s.

The third thing is we have a team and some facilities that are unique; facilities that allowed us to really look at the environmental impacts of growing perennial grasses. This includes the ability to measure greenhouse gas production, off-site water contamination, nitrate losses to water and our ability to directly compare the agronomic and environmental performance of biomass systems to conventional agriculture, including corn and soybean production.

I really wasn't the lead. I was one of several co-leads in feedstock production along with Rob Mitchell (ARS-NE) and David Laird (Iowa State University). We had a good group."

What in your previous work history best prepared you for your work at CenUSA?

"I think the work we did in the 1980s for the Department of Energy was crucial. We compared switchgrass as the native prairie system to cool season systems like reed canary

grass, tall fescue, sorghum and other annual systems, so we had a fair amount of experience, but then my academic training was also in perennial grass growth, development, their responses to nitrogen and other related topics. That was my formal training at the University of Missouri, but then we also did a fair amount of work here on that topic directly."

In what ways did the project challenge and broaden your professional knowledge and skill set?

"The fun part was the large number of disciplines involved, going all the way from breeding and genetics to bioprocessing and economics. I am familiar with the breeding aspects, and I enjoy it because almost all of our work involves contrasting genotypes, varieties or lines, as well as how they respond to environmental or agronomic management.

Then we also got to talk with people in engineering like Robert Brown at Iowa State and with those in the conversion process about their challenges. We talked with the people involved with safety issues, economic issues, social science issues, farmer acceptance and what it's going to take to actually grow these things. There were a lot of aspects along the complete supply chain that were important."

You mentioned all of these different fields. Was there anything with which you had little experience going into the project?

"it's probably the conversion part. I pay attention to the forage conversion in the context of livestock. That's critical. I've worked with alfalfa and other forages for 35 years. Forage quality is important, so I was keenly aware of the role of fiber quality, composition and lignin, as well as how they affect animal performance, milk production and stuff like that. I'm less familiar with the chemical conversion in an industrial sense, so that was interesting."

Have you worked with any other projects as large or well-funded as the current project?

"No, this one was about $25 million. The next one in terms of scale was a project with NASA which had $10 million. It was many years ago. The movie "The Martian" sort of mimicked this. It was about what it would take to put a colony on Mars and what it would take to supply food and water there. Our role in that project was using perennial plants to recycle water coming out of the waste streams."

So other than funding, what made CenUSA different from any of your other government-funded projects?

"Well, I think the breadth of activity across all of these disciplines made it different, as well as the number of people involved, especially (the number of people) in the area of Extension where they dedicated a third of the money to education and outreach activities. It's just that typically with most grants that are a half-million or a million dollars, you often don't have the option to invest this much money into undergraduate education, Extension and outreach. We do that after the research is done, and we translate it in order to produce fact sheets and other educational materials. This effort was directly embedded in the grant."

What was your specific role in feedstock development research? If you would, describe your day-to-day involvement in CenUSA?

"My day-to-day is sitting in an office answering emails and writing papers and grants. What we wanted to do was try to improve the efficiency of production. The cost of the feedstock is still a critical limitation. Getting it below $50-to-$60 per ton is critical to making this work, so you need to have very minimal nitrogen water inputs and things of that nature. We're doing this on marginal ground where you wouldn't normally grow your corn, soy or some other plant. It has to be done on inexpensive, cheap land, so our goal was to see how much biomass we can produce with minimal inputs and how that alters the composition. We were very interested in putting on less N (nitrogen), so there is less N in the tissues since it can alter the lignin composition in ways that make the feedstock utilization different.

That was our real concern, looking at radiation use efficiency, N-use efficiency and water use efficiency for an array of feedstocks. We didn't only look at perennial feedstocks. We also looked at corn stover and sorghums to have other comparisons. We also monitored soil health characteristics. If you're growing these things, you want to do it in a sustainable way, so we're really interested in knowing soil microbial populations to see if they changed.

We could only do so much plot work on research farms and places like that. We also had a significant modeling component where we looked at how much marginal land is there in the Midwest based on the production results in Indiana, Iowa, Nebraska and other places. We were involved in some SWAT modeling, that is the Soil Water Assessment Tool, which has a crop production module. We actually built a switchgrass module for that model, the excellent engineers we worked with at Purdue did this so we could estimate how many billions of tons of switchgrass we could produce marginal lands. That was a lot of fun as well.

I spend a lot of time in the office in my day-to-day. The most interesting work is done by the staff and the students who get to go to the field. We have a nimble group of six-to-eight

people who go out and measure greenhouse gas emissions on the plot every Wednesday starting in March and going through November. I get to go out and give tours, take a look at plots and answer questions for the team if there are things that are out of the ordinary, but my day-to-day activities have unfortunately evolved into writing and trying to keep up with the data analysis. I make that available to the modelers, answer emails and teach."

Where do you see switchgrass and other perennial grasses 20 years from now?

"I think they're going to remain on the sidelines until the price of gas and petroleum changes. When the price of fuel goes up to $5 or $6 per gallon, which it inevitably will since petroleum is a limited resource, this research we have done and these plants we've created will have the dust brushed off of them, and we will have a start on what to do.

Right now, with cheap petroleum and current government policies favoring gas and petroleum, the (perennials) are going to remain as plants used for forage in the forage-livestock industry and wildlife. The real key is that someone is going to have to say it's worth building conversion plants because the price of the product will be worth something. Right now, it just can't compete with petroleum. It's an economic decision and a policy decision, not really an agronomic decision."

What are the most significant barriers to establishing a significant production of bioenergy?

"It's the economics and the policies. With cheap gas, it's just not going to happen any time soon. I don't even know if the conversion plants in Iowa are operating now with corn stover. I think they may have even shut them down. It's just not a good value proposition. I think they demonstrated that it can be done at scale. They've shown that it can work."

How do you think your research in particular will help make switchgrass a more viable alternative?

"I think what we've got is a basis for launching the industry when it's ready. I think we can provide the feedstocks, not only the switchgrass but also Miscanthus, the other perennial with which we worked a lot. The challenge is getting it established. If you can, with almost no nitrogen, produce 20 to 30 tons of dry matter, twice or three times what switchgrass can produce, if there is a place to sell it and it can be turned into fuel, that has some potential. Both switchgrass and miscanthus are viable candidates. I guess it's just a matter of the will of the people. If we as a country want to wean ourselves off petroleum, truly get into a bio-economy and work on climate change, this is a better way to do it."

You mentioned that it's all policy more so than actually being capable of doing it. What do you think it would take to overcome that barrier? What do you think would have to happen for policy-makers to catch on to this?

"I think we'll need to sit back and look at the true cost of taking carbon reserves out of the ground and putting it into the air. No politician wants to talk about the cost of climate change. I've seen estimates in the last couple weeks with all of the wildfires, flooding and tornados. I've been around a long time, and I've never seen tornados in November and early December like the ones we've had in Illinois and Missouri. Things are happening that are costing a lot of money, and nobody wants to talk about it in the current political administration, but it's really the people, the voters who own this. If they don't want to vote people in who will serve their long-term needs, then it just isn't going to happen.

I also understand how politics work. I'm not naive to that. For politicians, the goal is to get re-elected, not to talk about things that make people uncomfortable, that might cost money to do or that might change the job structure. Take coal for example. It's almost funny how some of the politicians in Washington talk about saving the West Virginia coal industry. Well, I'm very sensitive to local economies and the fact that people will be put out of work if the industry continues to wind down, but in the end, the total employment in coal is very small. It's all been mechanized. This is a big conversation point, and locally it's really important, but let's figure out how to get Amazon to put new facilities in West Virginia, for example. That's something I'd like to see. They put it in New York or Long Island, well, let's put it in West Virginia. Let's give those thousands of people a huge boost.

There are some things that can be done that the politicians don't want to do, and the voters don't seem to care too much, so when the environment continues to deteriorate, that will make people move and vote in the people who care. Maybe even the current people will realize we've dropped the ball. They're not evil folks, they're just reacting to what the voters want."

Could you describe how the facilities at Purdue helped you with your research?

"We've got some really unique facilities for measuring the environmental performance of cropping systems. The water quality field station is the key facility where there are huge lysimeters. Think of a concrete box with no bottom in it. It's actually made out of a special kind of clay…There are 48 of those lysimeters. Some are about half the size of a football field...but most lysimeters are probably about the size of your kitchen table, maybe your bathroom floor. These are large, and they're expensive to build and run, but they allow us to get a really good idea of how much nitrogen goes on the corn, how much goes in the air,

how much goes in the water and what's left in the soil. So with a system like this, we can really get a handle on mass balance and where things are going. Be it a herbicide, a fertilizer or if we put on manure and look at antibiotic movement...things like that, this (the facility) was really good for these things."

What made Purdue the most ideal place for that research as opposed to some other facilities at other universities?

"This facility was built in the 90s. We would have built it in Iowa, Nebraska or some other place, but the estimated cost would be between $5 to $10 million dollars. A good chunk of the money would have gone to just building the facility and not even to doing the work. We shouldn't duplicate these things. We have to leverage what we've got, as we should.

Robert Brown and others brought the biochemical conversion strengths of Iowa State to bear, so we didn't have our people, our engineers participate in that. I think every institution has its own strengths. That we leveraged those strengths is what made this a special project. Even though they're location hundreds of miles apart, they worked out pretty well."

What were your personal contributions to the development of Liberty and other switchgrass varieties?

"We did some testing on 'Liberty' just as it was released, so we didn't have direct involvement in selection, but we did some final testing in small plots. A colleague of mine at Purdue, Keith Johnson, tested 'Liberty' against 'Shawnee' and some other genetic lines along with a whole array of other germplasms from Ken Vogel. We had 'Liberty' in small plots, testing it against Indiangrass, big bluestem and Miscanthus at several locations in the state. We did some final testing of it to get some potential information for the group."

Let's refine that question. What was your role in that testing?

"We grew it, fertilized it using best management practices, harvested it and then provided that data from all of these locations back to Ken (Vogel) and others so that they knew what the yields were relative to existing switchgrasses growing on adjacent plots. In the end, it was about a 15 percent bump over Shawnee and other switchgrasses that we normally grow."

What were some of your noteworthy successes, discoveries or opportunities you have achieved through this research?

"I think one thing that is very interesting is that we can grow considerable amounts of these

perennial grasses with minimal inputs of nutrients. One field site we had was incredibly depleted of phosphorus and potassium. A large part of one farm was very low on PNK (polynucleotide kinase). We had been cropping alfalfa and corn there. The PNK concentrations were so low the yields of alfalfa and corn would be reduced by at least 50 percent.

Even with very high N rates, the corn was really low yielding because of the PNK rates. Switchgrass and Miscanthus, but especially switchgrass, was incredibly productive under these really low PNK conditions. People often think of aspect, drainage, slope or shallowness of the soil. In this case, these soils were very marginal for soil fertility, and the plants did great. That's important because high potassium in the tissue kills the catalyst used in pyrolysis, so what they want is really low K (potassium) concentrations. It appears we can grow switchgrass quite readily with extremely low tissue potassium levels.

That was interesting, as well as getting good estimates of the input use efficiencies of radiation, water and nutrients like nitrogen. Those things were all very helpful. I think the modeling was a success. We were able to have a really good understanding of the breadth of where we might grow switchgrass and be able to produce tens or hundreds of millions of tons of material should the bioeconomy ever gain traction."

What were some unforeseen obstacles that you didn't expect to encounter?

"I don't know if there were many. Things ran pretty well. I think one would always say that we could've done even more if we had more resources. Having more money would have allowed us to hire another student or two to do more work and expand what we are doing, but if you were to ask anyone, they would probably say the same thing.

There's probably one big obstacle that remains an obstacle. What I'd like to see, if it is still doable, is the unifying of all of the data that was generated by the $25 million project into one database that is available for public use analysis and broader use because there is a lot of data collected at a lot of locations. One thing that didn't survive the budget cut when the project was originally going to be funded at $50 million before it was cut back to $25 million was the data curation and management piece. I'm a little sad that we were not able to bring all of our data together, and while it might not sound like a really hard thing to do, it's a monumental task. I could probably spend up to six months or a year personally doing it for the whole group, , but we can't afford to do it."

In what directions do you want to take your CenUSA research?

since everything is grant funded. One thing we are doing right now is that we're going back and using some of the same CenUSA plots on the water poly-fueled station in which the switchgrass and miscanthus remained. What we are doing now is coming in with other systems, particularly cover crops, to look at growing biomass after corn crop or with the corn crop.

So we are looking at how to capture radiation water and nutrients within cropping systems that farmers might already have in place. What we are doing is comparing the productivity of those systems back to those that we had in the CenUSA program. It's looking at how a farmer might actually grow biomass around their corn-soy production and make money. That's one of the things we are currently doing. We'll keep looking at opportunities to leverage the perennial grass systems and use them as controls in other biomass-related research."

How will the work done in CenUSA impact the goal of 10 tons per acre? How close are you to that?

"We've achieved that with the work we've done with CenUSA, but not with switchgrass. We achieved it with miscanthus. So you're talking 20 thousand kilograms per hectare. With the 'Liberty' switchgrass, we were able to get close to 15,000, not 20,000. We were pretty close, but the miscanthus on the same site was at 30-to-35,000. If you want to get 10 tons per acre of dry biomass, we can get close with "Liberty." We're already there with Miscanthus. We're 50 percent above that."

Where do you see switchgrass agronomic practices in 20 years from now and what advancements need to happen in order to get them there?

"What I would like to see is more of a systems approach to switchgrass, miscanthus too, but especially switchgrass. It's a plant that has mainly been looked at for a hundred years as a forage crop. Then in the 80s, it got some interest as a biomass crop, but it could be both. There are probably ways to manage it for livestock production along with bioenergy production to make farms profitable. A part of it is thinking about multiple purposes for these plants in the various systems that farmers might have. We should also think hard about the ecosystem services that switchgrass provides and start putting value on those. I think there needs to be a more holistic view of valuing what plants like switchgrass bring to agriculture, to communities and to people."

What was your role with Extension and Outreach objectives?

"I wasn't formally involved in that, but I always have an Extension appointment. I take

questions and participate in programming related to forages and bioenergy all the time whenever they come. I think there was a team of about 30 Extension people involved at various levels across the whole CenUSA project. It's kind of a crowded space, so I just kind of stuck to my own part for the most part."

So to the extent you were involved, how was this different from preparing for an article in a scientific journal?

"I think Extension can do certain things that are nice for demos. There was a lot of that done, and that was good, but Extension is a big part of a continuum that starts with creating ideas, testing them with research and publishing the research. That leads to the Extension fact sheets and information for farmers. Sometimes that middle piece gets left out, and people do a run around the science. Extension needs to get back to evidence-based practices where the evidence goes back to rigorous, scientific, peer-reviewed articles, not just doing some farmer demos and small plot work, publishing those results and telling farmers what to do. Those latter approaches don't generally undergo rigorous peer review, so what's really critical is that we should get back to the linear process of making sure that the science is done well, gets peer-reviewed by others and gets published. From there, we extract the Extension publications. Then it's evidence-based and authoritative. That's not just about CenUSA, that's about a lot of other programs in the country."

What's the most important or most interesting facet of your research that you want the interested public to understand?

"I think the potential for a bioeconomy is huge. We can grow tremendous amounts of biomass. It can be tailored through breeding and genetics to a certain extent, then the people who can engineer and modify those materials can make the bioproducts. The potential is there, it's about the political will and financial model."

What work are you looking forward to next after CenUSA?

"We've got this other project where we are using cover crops like rye and comparing them as a biomass production system to corn stover and switchgrass production. We're not only looking at the productivity, but also the environmental performance at the water quality field station. This kind of goes back to my little Extension blurb a minute ago when I was criticizing the process. I'll own it. Here at Purdue, there's a group that talks at great lengths about the virtues of cover crops, yet farmers aren't using them. Some are, but very few are and there is a reason for that. A part of it is economic.

They also talk about the environmental virtues, but most of those are without evidence. What we're doing is seeing that when you grow cereal rye after corn, how much N does it actually trap? How much does it protect groundwater quality? By how much does it reduce greenhouse gas emissions? Then grow their stuff for biomass and compare it to well-known systems like switchgrass, something we've been studying at CenUSA for about seven or eight years now. We are continuing the legacy of CenUSA, but with a twist using cover crops, looking at agronomic and environmental performance and getting the evidence that will help people make decisions, whether this works economically and also for the environment."

Selected CenUSA Bioenergy Work Product – 2011-2019

Administrative Team

- ✓ Dykstra, Breanna, Iverson, Alyssa, Jacobs, Keri, Kinzel, Anne & Raj Raman. Emerging Markets for Biochar: Challenges and Opportunities – A CenUSA Bioenergy White Paper. July 2019.
- ✓ Dykstra, Breanna, Iverson, Alyssa, Jacobs, Keri, Kinzel, Anne & Raj Raman Emerging Markets for Switchgrass in the US Midwest: Challenges and Opportunities – A CenUSA Bioenergy White Paper. July 2019.
- ✓ Kinzel, Anne & Tyler Worsham. CenUSA Closing Statements: Views from CenUSA Leadership. July 2019

Stuart Birrell CenUSA Bioenergy Work Product

- ✓ Fact Sheet: Logistical Challenges to Switchgrass (Panicum virgatum L.) as a Bioenergy Crop. Amy Kohmetscher, Ohio State Univ. & Stuart Birrell, Iowa State Univ. (2013). http://articles.extension.org/pages/68053/logistical-challenges-to-switchgrass-panicum-virgatum-l-as-a-bioenergy-crop
- ✓ Webinar: Switchgrass and Bioenergy Crop Logistics. 2012. (36:44). http://youtu.be/OGEd4KZOE2Q

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Chuck Schwab CenUSA Bioenergy Work Product

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Raj Raman CenUSA Work Product

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Kevin Shinners CenUSA Bioenergy Work Product

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Jeff Volenec CenUSA Bioenergy Work Product

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* * * *

CenUSA Bioenergy CenUSA Project Team

Germplasm to Harvest

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Objective 3. Feedstock Logistics

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Objective 6. Markets and Distribution

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Objective 7. Health and Safety

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Objective 8. Education

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Health and Safety Team

- Mark Hanna, Iowa State University
- Chuck Schwab, Iowa State University

Objective 10. Commercialization

Project Directors

- Tom Binder (ADM, Ret.)
- Frank Lipiecki, Renmatix

cenusa bioenergy

"Our vision is to create a regional system for producing advanced transportation fuels derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels, the proposed system will improve the sustainability of existing cropping systems by reducing agricultural runoff of nutrients and soil and increasing carbon sequestration."

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