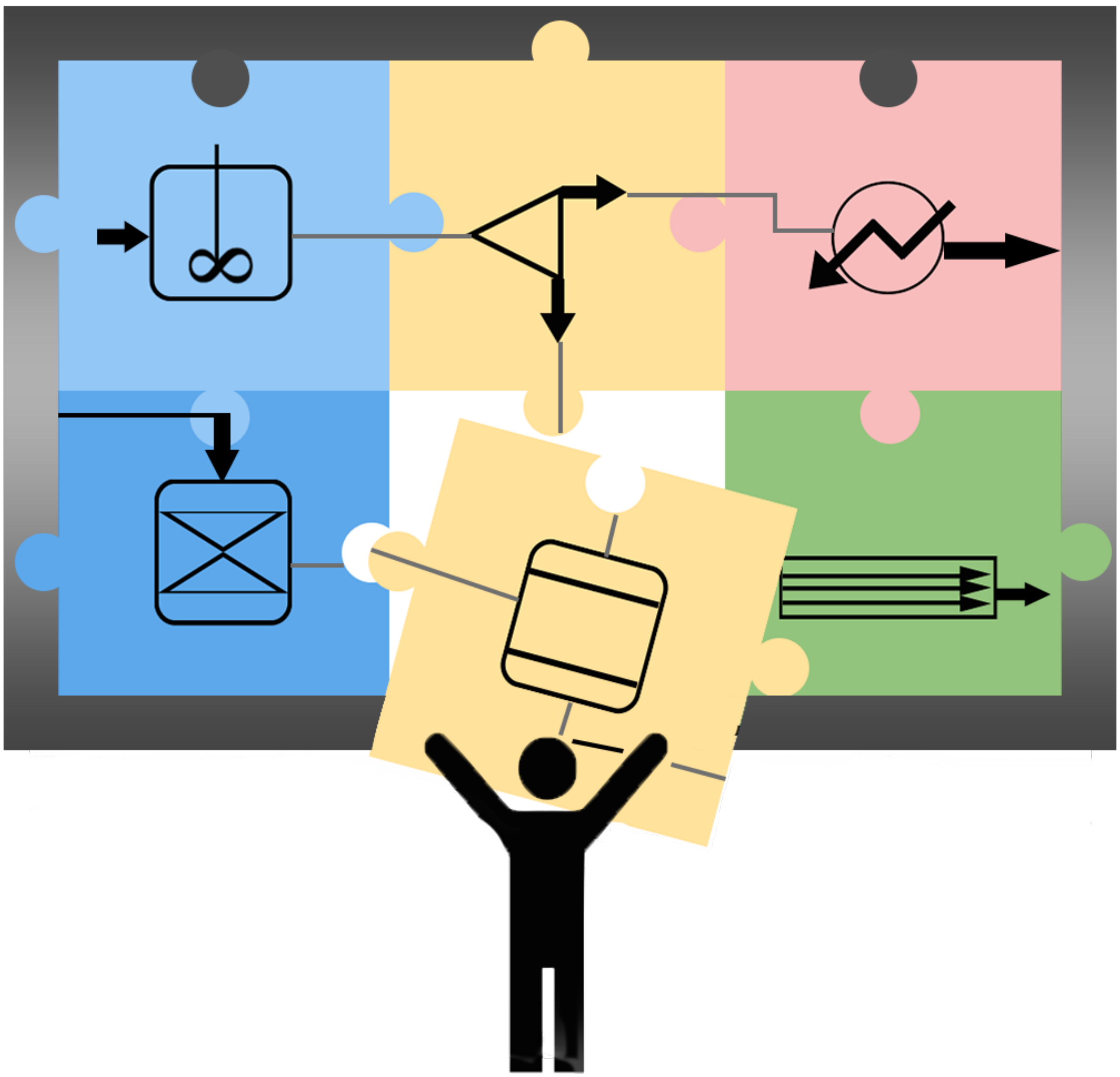
Energy Manufacturing Workshop 2015

May 11-12, 2015

Broomfield, Colorado



Energy Manufacturing Workshop 2015

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ACKNOWLEDGMENTS

The Iowa State University Bioeconomy Institute would like to thank the workshop's numerous participants hailing from academia, government, and industry for their valuable contributions to this collaborative effort. A special thank you to our speakers:

- Jonathan Male, Director, Bioenergy Technologies Office, DOE
- Daren Daugaard, Director of Research and Development, Cool Planet Energy Systems
- John Holladay, Energy and Environment Directorate, Pacific Northwest National Lab
- Anthony Bridgwater, Director of European Bioenergy Research Institute, Aston University, UK
- Kevin Kenney, Energy Systems & Technology Directorate, Idaho National Lab
- Dane Boysen, Gas Technology Institute
- Rudi Roeslein, Roeslein
- Phillip Keith, President and CEO, Aspen Automation
- Kelli Malloy, Plant Automation Specialist, Applied Controls
- Ted Amundsen, Mainstream Engineering
- Mark Wright, Assistant Professor of Mechanical Engineering, Iowa State University

Participants in the 2015 Energy Manufacturing Workshop

INTRODUCTION

Background

On May 11-12, 2015, Iowa State University hosted an Energy Manufacturing Workshop that brought together over 30 leading experts to explore the feasibility of utilizing stranded and dispersed energy and carbon sources through deployment of modular chemical processing systems. These would be mass produced at scales appropriate to the technical, logistical, economic, social, policy, and environmental constraints prevailing at the location of the resource.

The goal of the workshop was to formulate a plan to accelerate commercialization of distributed, modular biorefineries. Participants included representatives from industry, government, research, and academia. They reached consensus on the best path forward for collaboration between the bioenergy and manufacturing industries.

Objectives

Objectives for the workshop were:

1) Participants will increase their knowledge and awareness of strategies for mass production of modular energy systems,
2) Participants will identify technical, economic, and policy barriers to the manufacture of modular energy systems, and
3) Participants will discuss opportunities to innovate and adopt advanced manufacturing strategies that reduce the costs of small-scale modular systems.

The workshop was designed to facilitate discussion amongst experts in feedstock logistics, chemical processing, and manufacturing technologies on the feasibility of mass producing modular chemical processing systems. By sharing their expertise through presentations and group discussion, participants were able to formulate a draft vision statement and analyze aspects of the project in detail. These aspects included: advantages proffered by modular manufactured systems, barriers to their implementation, opportunities to reduce costs through innovation, research needed to advance the concept, and specific action items that are necessary in order to speed adoption of modular manufacturing technologies for energy production. Finally, each participant was invited to provide recommendations as to the best means of carrying on the project following the close of the workshop. This report will detail their feedback, both collective and individual, in an effort to build upon the body of knowledge that existed prior to the workshop's occurrence.

Problem

Fossil fuel power plants and chemical processing facilities have traditionally been built at very large sizes following the principle of "economies of scale"; that is, the amount of material and labor required to construct a plant and the number of employees required to run it do not increase linearly with plant output. Accordingly, unit costs of production are expected to continuously decrease with increasing facility size, encouraging the construction of giant plants.

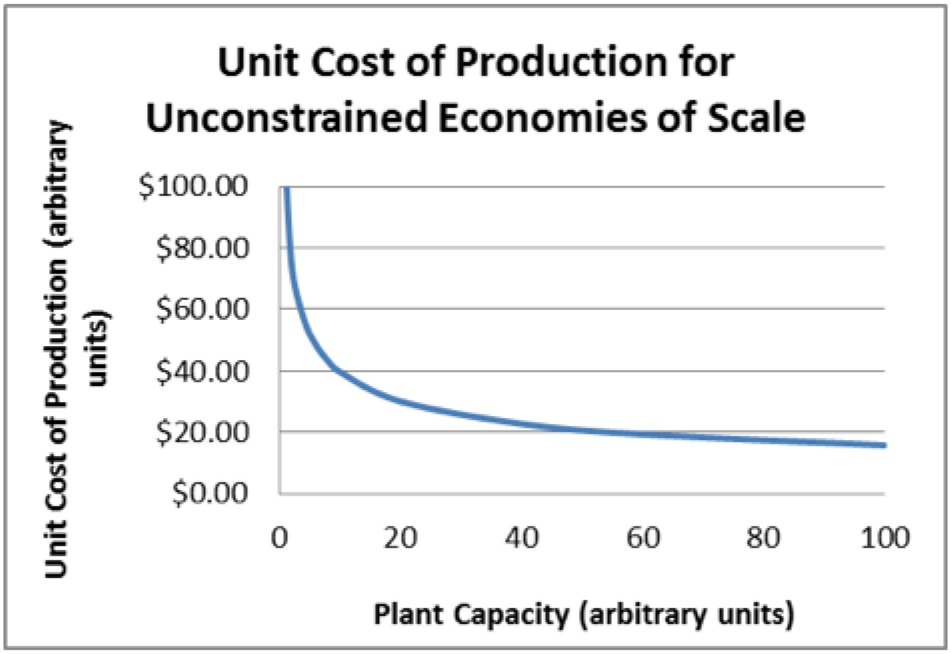

Figure 1: Subject only to economies of scale, unit cost of production decreases monotonically with facility size.

This principle is frequently applied without considering the effect of other factors such as:

- Cost of financing a plant
- Time to permit a plant
- Public acceptance of large facilities (NIMBY)
- Logistics of collecting widely distributed feedstocks
- Availability of local infrastructure and labor

Adding such constraints can dramatically change the scale for an enterprise. For example, if feedstock is widely distributed, such as for biomass, the cost of transporting it to a plant is strongly influenced by the size of the plant. In this case, there is an optimal plant size to achieve the lowest unit cost of production. If multi-variant analysis was routinely applied to the sizing of facilities designed to process distributed carbon and energy resources, it would likely reveal that a variety of financial, social, and environmental factors favor smaller conversion facilities than has historically been the case for concentrated fossil resources.

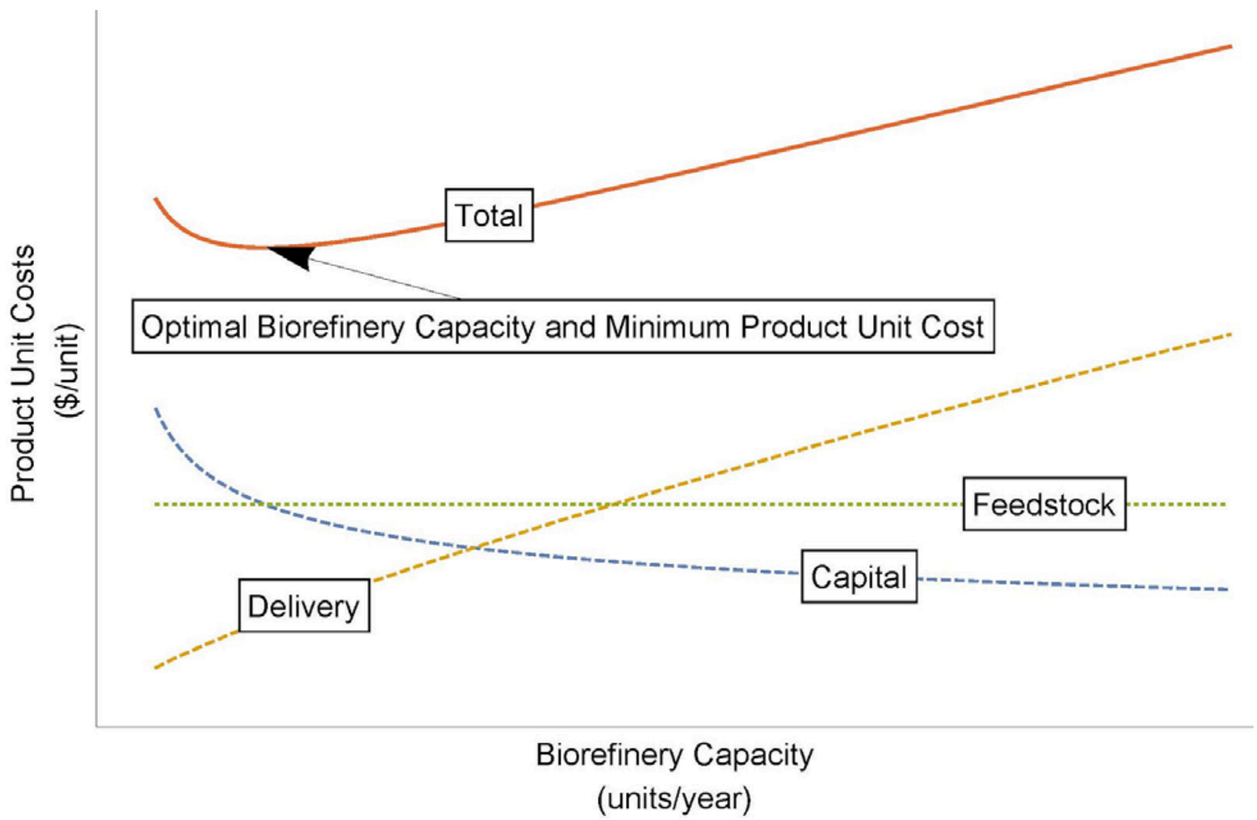

Figure 2: Trade-offs between increasing biomass delivery and decreasing biorefinery capital costs lead to a minimum total biofuel production cost based on capacity.

Potential Solution: Chemical Processing Modules

Constructing manufacturing plants that will mass-produce relatively small chemical processing modules could revolutionize the energy industry. Instead of relying upon a few large processing facilities that are spaced very far apart and spending the money to bring distributed energy and carbon resources to them, modular systems would be more numerous, and would be strategically placed very close to resources. The modular systems would be standardized and automated, thereby reducing manpower in set-up and operation, as opposed to traditional processing plants that are unique and less automated. The small size of modules would allow plants to expand to meet demand more precisely while minimizing financial risk, rather than building one facility of great size and endeavoring to contort supply and demand to match it. This initiative seeks to look beyond the rule of economies of scale in order to optimize cost effectiveness and demonstrate that modular manufactured biomass processing systems are a viable option for utilizing distributed and stranded resources.

Small-scale processing facilities will only be able to compete with large-scale facilities if “economies of size” can be replaced with “economies of number”; that is, the principles of mass production can be applied to the factory manufacture of chemical processing modules. A module is defined as “a major section of a plant resulting from a series of remote assembly operations and may include portions of many systems.” If these modules can be constructed as standardized, replicated units in the assembly line of a factory, then it is possible to capture the same economies of scale inherent in mass production of automobiles and other consumer products.

It is well known that unit *costs* of energy products decrease with industry cumulative capacity following a power law relationship. The power law factor is known as the learning rate (LR). It has been documented for a wide range of energy technologies including integrated gasification combined cycles (IGCC), coal power plants, wind turbines, and solar panels. Furthermore, small-scale processing facilities could gain the same economies of scale in staffing as large plants through expanded use of automated sensors and controls and remote system management.

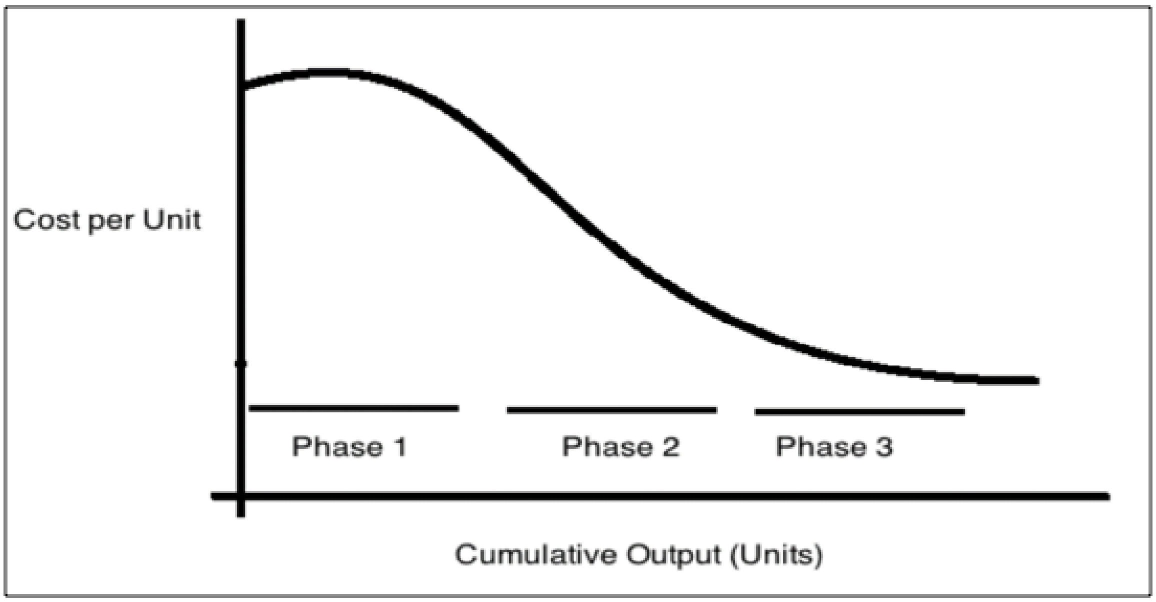

Figure 3: Unit cost of production decrease with cumulative output, which is attributed to the "learning rate" within the industry.

WORKSHOP FEEDBACK

Vision Statement

Participants were asked to help formulate a vision statement for the initiative. They settled on the following:

Our vision is to democratize access to energy by deploying modular chemical processing systems to utilize stranded and dispersed energy and carbon resources. These systems would be mass-produced at scales appropriate to the technical, logistical, economic, social, policy, and environmental constraints prevailing at the location of the resource.

GROUP FEEDBACK

Participants were asked a number of questions relating to modular manufactured biomass processing systems. Their insights are summarized below.

1. **What are the advantages of modular manufactured systems as compared to traditional on-off plant construction?**

Overwhelmingly, participants cited lower capital expenditures and lower operating expenses as key advantages of modular manufactured systems. The smaller investment risk allows for accelerated innovation and can encourage adoption amongst a wider variety of communities, including niche markets and the developing world. Because modular manufactured systems would be identical and relatively small, plant owners can expect faster and more predictable construction and repair schedules, coupled with less training time for workers. The amount of manpower needed to run the plants would be significantly reduced, as the majority of the machinery would be automated. Thus, standardization would accelerate the learning curve for operations and bring down costs. Furthermore, modular manufactured systems would greatly simplify feedstock transportation logistics and decrease transportation-related expenses, because they would be placed near the resource. The participants stressed that the scalability of modular manufactured systems translates to flexibility and maintainability.

2. What are the technical, economic, and policy barriers to the deployment of modular manufacturing technologies for energy production?

Technical

Participants wish to determine optimal conversion technology, which remains unknown at this stage. They are anxious to modularize at the right moment when technological maturity has been reached, because modularizing too soon could stifle innovation. The foremost technological priority is settling upon a standard design that can be built at the appropriate scale and operated with minimal human intervention so that quality controls can be improved. Infrastructure needs and compatibility also need to be addressed, as well as solids handling, including delivery and variability in feedstock.

Economic

Major economic challenges will include determining the ideal business model and convincing financial markets to invest in new technology. Market entry is always a daunting task, as producers must provide products that the market wants and can sustain, while competing with the low-cost fossil fuels that are already available. In the development stage, labor lost per output is high, so establishing the first ten units will be a major accomplishment. Participants agree that they must combat unconstrained economies of scale arguments with convincing research.

Policy

Participants concur that convincing stakeholders to buy into products from a small, modular system will be a challenge. First, they must agree upon standardization amongst academic and industry players, and streamline the permitting process in order to ensure environmental compliance. There is a lack of educational opportunities to learn about modular manufacturing, so it will take effort from the members of this initiative to clearly articulate the concept to the public. Meanwhile, attention should be paid to what actually motivates small-scale producers, landowners, and communities, in order to gain acceptance of modular systems from the labor force.

3. What opportunities do we have to innovate and adopt advanced manufacturing strategies to reduce costs of modular energy production systems?

There are many opportunities to reduce modular energy production costs through innovation, including finding multiple value chains via co-product utilization. Additionally, employing automation technology that already exists will reduce labor costs. The participants wish to focus on finding ways to fine-tune innovation while still using the modular design concept, perhaps by incrementally freezing the design to integrate modularity with advances in manufacturing science. They suggest that using a pilot-scale run to test modularity and automation could reduce costs, as well. They also point out that co-location, or placing modules in locations where co-products from other industries are available, would be a cost-saving innovation.

4. What research is needed to address the barriers identified by workshop participants?

Participants were able to identify many avenues for future research that would be beneficial in overcoming the barriers mentioned above. First, they would like to consolidate the body of knowledge in modular manufacturing. They also look forward to much more in-depth market and business analysis, as well as a better understanding of socio-political barriers to wide acceptance. Participants would like to construct an economic model, create a technology roadmap, build demo plants, and complete a centralized Life Cycle Assessment (LCA). This means that research on standardization in equipment and instrumentation needs to continue, in addition to studies on feedstock supply, logistics, and sustainability.

The notion of economies of scale still poses more questions for research, as the participants wish to see more evidence that standardization and mass production can overcome this traditional barrier to small-scale conversion systems. They propose researching circumstances that overcome the economies of scale power law, and identifying technologies that do not have a ⅔ power function (scale 0.6). They would like to see the establishment of multi-user facilities to develop these ideas. Finally, they are interested in evaluating opportunities for co-partnering, with its multiple benefits and co-products. Research should be done on technologies that can benefit from parallelization.

5. What specific action items are needed to speed adoption of modular manufacturing technologies for energy production?

There was a general consensus amongst participants that setting up a multi-user facility would speed adoption of modular manufacturing technologies for energy production, as it would allow research and development to occur in each of the many facets of the project. Demonstration of unit operations and integrations will build confidence in the modularization strategy, help derisk technology, and disseminate knowledge.

The participants would like to see more techno-economic analysis that includes characterization and product development in addition to market analysis, market strategy, and risk analysis. Consumers need to be informed, as well as policy makers and federal agencies. It was suggested that the the Department of Energy (DOE) should sponsor an industry/stakeholders workshop to stimulate interest and garner support. Other ideas were put forth, such as holding a pre-commercial industrial consortium analogous to the Next-Generation Vehicle Partnership (industry standardization of electric vehicle charging plugs) or a Gordon Research Conference. Participants estimated that 4-5 founding producer partners and 4-5 product utilizers are needed to get to the demo phase of the project.

Other immediate action items desired by participants are: identification of a subset of conversion pathways suitable for modularization, determining standards/constraints on weight and size per module, and agreement upon interface protocol for the mechanics, signals, and instrumentation of modules. They would like to determine where modularity can be done now (e.g. feed handling).

INDIVIDUAL RECOMMENDATIONS

At the end of the workshop, participants each turned in an anonymous list of recommendations for the future of mass produced modular energy production systems. The following is a compilation of their ideas:

- **Determine Project Identity and Spread the Word**

First, participants felt it was important that the workshop be documented by means of a concise report with prominent display of the vision statement. They recommended that the report be disseminated on the ISU Bioeconomy Institute website and wherever else possible, accompanied by a blog so that interested parties may share knowledge on the subject. They feel it is vital that the initiative be more definitively characterized, with a catchy name and a clearer identity. Will it become a professional/academic/regional/open group? This, along with the specifics of what is being proposed and what the task is, needs to be established.

Next, the initiative's "big idea" must be shared with policy makers and funding agencies in some formal way, such as a workshop in Washington, D.C. for congressional aides. National laboratories should continue to push it as a "big idea" for the Department of Energy (DOE) to put in the President's budget. While doing so, they need to establish a better understanding of economies of scale, economy of modularization, and their interaction in order to clear up any misconceptions. Market analysis and multi-discipline risk analysis also need to be performed so that a market strategy may be shared with the public. Overall, the organization must communicate a vision of the democratization of renewable energy production.

- **Find Funding**

Participants were in agreement that securing funding and sponsors for the next phase of the project is of great importance. They recommend engaging with funding agencies and industries, and encouraging the U.S. Department of Agriculture (USDA) to issue Funding Opportunity Announcements (FOAs) for demonstrating technologies at modular scale. They also wish to incorporate design for manufacturing and modular design in the BETO strategic plan, future FOAs, as well as FOAs from the USDA, DOD, AMO, etc. Other financial suggestions included selling the value propositions to stakeholders and "thinking like a teenager," meaning being persistent in requests for support.

- **Demonstrate Success**

Participants were eager to have a pilot project show that the concept can be successful. Once a pathway has been deemed viable via economics, market assessment of the product, and market assessment of modular system demand, there is a need to demonstrate the process at the appropriate scale. Demonstrations need to be of appropriate time frame and take process variability and upsets into consideration. They must prove with techno-economic analysis (from feedstock to final product, including nutrient recycling to fields) that the distributed/modular approach has some chance of being economically competitive. Alternatively, one participant suggested doing reverse techno-economic analysis, starting with a defined product output and working backwards to determine the maximum CAPEX for a black box as a function of feedstock cost. This CAPEX figure would provide an idea of the challenge that the initiative faces. Another participant recommended that ISU start on their own first and demonstrate “doability” to entice the industry to follow.

- **Collaborate and Ensure Organization**

All participants recognized that organized, interdisciplinary collaboration will be essential to the future success of the initiative. To begin with, they suggested making a roster of people and institutions who will be involved with the next phase of the project. Not stopping there, they recommended recruiting more subject-matter experts, people from other industries with experience in modular manufacturing, and stakeholders. Next, they advised aligning on a clear role for each team member and creating a work breakdown structure and schedule for the first working model.

Recognizing that modular manufacturing requires a wide range of competencies to be successful, participants asked for ways to introduce manufacturing concepts to scientists in order to find synergy between modularization and research. Possible avenues included several different types of workshops, such as:

- A bigger workshop or Gordon-like conference
- An industry workshop to utilize industry stakeholder input to fill gaps in the techno-economic, market, and risk analyses
- An industrial consortium to standardize modules/interfaces/protocols
- A conference on standardization of dimensions, weights, etc.
- A module best practices workshop
- A workshop at Rudi Roeslein’s manufacturing facility in Red Bud, Illinois to view how modular concepts are currently being utilized in other industries including oil and gas, and how those concepts apply to the alternative biofuel industry
- A follow-up Energy Manufacturing Workshop in 6 to 8 months

Beyond periodic meetings, participants also felt it was important to forge more constant collaborative bonds such as a joint industry, university, ARS and National Lab consortium developed for ongoing research to address technical, economic, and social barriers. They also proposed identifying university laboratory interactions, forming teams to write proposals to fund research and development activities, and establishing market focus groups. These diverse working groups could include WWTP operators/owners, municipalities, farmers, and chemical producers.

- **Develop Technology**

Participants also made recommendations for technology development, targeting systems that are sustainable, profitable, have a low carbon footprint for the production of chemicals, fuels, and products, and are transferable to the developing world. They added that it will be necessary to determine whether there are size limits to modules, in scale or physically, and to assess conversion processes for the suitability of modularization. They recommended management flexibility, to be achieved by fully automating plants. Finally, they felt it was best to write a communication, business, and technology development plan to keep the project on track.

THE PATH FORWARD

The ISU Bioeconomy Institute, as well as the other experts assembled at the 2015 Energy Manufacturing Workshop, will continue to facilitate collaboration, organization, and execution of the next stage of this initiative. Securing funding, continuing research on the topics suggested by participants, and informing the public of the project's identity and progress will be chief amongst its activities in the near future. For more information on the workshop, visit www.biorenew.iastate.edu/energymfgworkshop/.