**The Grand Challenge**

**Presented by;**
**The Ohio State University**
**Ohio Agricultural Research and Development Center**

The U.S. Department of Agriculture (USDA), in cooperation with the 25x’25 Alliance, is sponsoring The Grand Challenge with a goal to support academic institutions as they assume leadership in achieving solutions to issues associated with energy supply and consumption. The competition provides an opportunity for agricultural and forestry colleges and other institutions of higher learning to share their visions of how they will contribute to achieving the goal of the 25x’25 Alliance. This goal is:

> “By the year 2025, America’s farms, ranches and forests will provide 25 percent of the total energy consumed in the United States, while continuing to produce safe, abundant and affordable food, feed and fiber.”

## Vision of Agriculture and/or Forestry’s Contribution to the Energy Economy in 2017

Rethinking the Preamble

In August of 2004, the 25 by ’25 Alliance issued a draft Blueprint for Action (“Blueprint”) describing agriculture’s role in ensuring U.S. energy independence. That was less than four years ago. The Preamble of that Blueprint stated that “environmental and health concerns and risks associated with carbon based fuel sources are escalating”. The problem is not carbon per se but the fact that carbon is being added to the atmosphere from fossil based fuel sources. The key to effective utilization of natural sources of carbon is the management of the carbon cycle. For example why put carbon into a landfill?...or why just burn it to get rid of it?

The environmental concerns in this statement refer to concerns over the gases emitted when fossil (carbon) fuels such as coal, gas and oil are burned; one of the most significant is carbon dioxide, a gas that traps heat in the earth's atmosphere. These fossil fuels are materials that absorbed $CO_2$ from the atmosphere millions of years ago. As fuels they offer high energy density, but while burning the fuel to make use of the energy, the carbon is oxidized to $CO_2$ and the hydrogen to water vapor. Unless they are captured and stored, these combustion by-products are released to the atmosphere returning carbon that had been sequestered millions of years ago to the atmosphere and increasing concentrations.

The health concerns in this statement are associated again with the primary pollutants that are produced by fossil fuel combustion: carbon monoxide, nitrogen oxides, sulfur oxides, hydrocarbons, and carbon particles (soot). In addition to health concerns, total suspended particulates contribute to air pollution, and nitrogen oxides and hydrocarbons can combine in the atmosphere to form tropospheric ozone, the major constituent of smog.

Many things can change in four short years. Based on new understandings since 2004, some of which may not be obvious, this paper offers as its vision a way to rethink part of the Blueprint preamble. This restating of the Blueprint can be done in such a way that agriculture can be true to its “roots” and be unafraid in utilizing carbon sources as solving America’s energy puzzle while continuing to produce abundant, safe and affordable food and fiber.

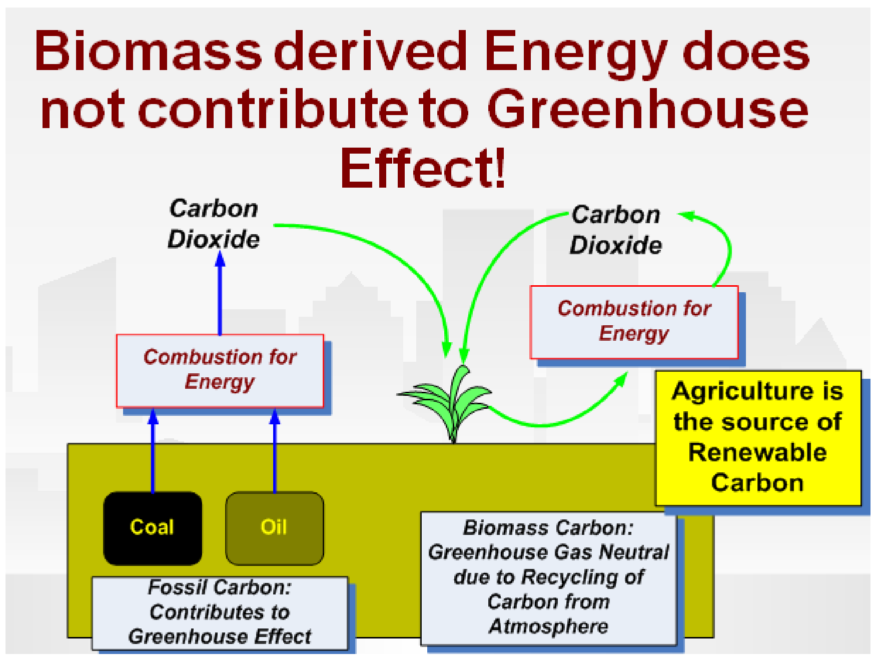
Agriculture = Biomass = Renewable Carbon

Agriculture refers to the production of goods through the growing of plant, animals and other life forms, and includes production accomplished in farm, urban, forest, and grassland environments associated with organized cropping, landscaping, or "wild" lands. Biomass is routinely defined as biological material derived from living, or recently living organisms. And, in the context of this paper about energy, biomass is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material. Biomass is carbon based and is composed of a mixture of organic molecules containing hydrogen, usually including atoms of oxygen, often nitrogen and also small quantities of other atoms. The carbon of biomass was assimilated from atmospheric carbon by plant photosynthetic activity and growth, and is non-fossil renewable carbon that does not contribute to additional greenhouse effects when utilized by oxidation.

**So, agriculture is all about carbon and biomass is carbon; it cannot be denied or avoided**.

The vital difference between biomass and fossil fuels then becomes one of time and scale. The process of using biomass to produce energy means that the biomass takes carbon out of the atmosphere while it is growing, and returns it to the atmosphere as oxidized. The key then becomes to manage this process on a sustainable basis so as to maintain a closed loop carbon cycle with no net increase in $CO_2$ levels.

This paper lays out the vision for a small-scale but scalable biomass based system to produce energy. **This vision yields a carbon neutral strategy that replaces a carbon positive strategy without compromising and in fact enhancing food production.** The focus on small scale increases the probability of success for development of manageable and sustainable systems.




Biomass is an inherently distributed resource. Thus small scale distributed systems allows biomass to be utilized at its source (i.e., "on the farm") instead of requiring extensive transportation logistics for its harvest and delivery to a large scale centralized facility for its conversion to energy or products. When utilized for production of energy, such small scale biomass conversion also provides distributed generation of energy or power, thus reducing the load placed on infrastructure for transmission of fuels or power (i.e., reducing the burden on the electrical transmission grid). The power will be generated at the periphery and throughout the grid area and near its users.

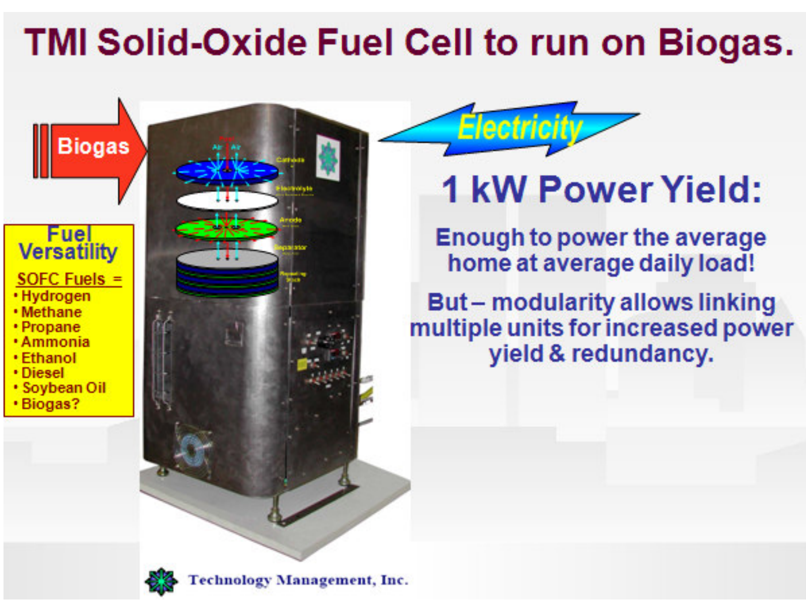
While the hydrogen economy of the future is appealing for its theoretical clean energy with no pollutants when converted to power or thermal energy, hydrogen alone cannot be produced in bulk quantities from biomass without also releasing carbon dioxide from the carbon to which it was bound. The technologies for producing, storing, transmission, and utilization of hydrogen are simply not available today or in the immediately foreseeable future. However, the vision offered in this Grand Challenge allows utilization of renewable carbon from biomass as the primary energy source for technologies that exist today or in the near future to produce clean energy through reliance on renewable carbon-based biomass which can ameliorate further greenhouse gas accumulation, and perhaps can reduce net atmospheric carbon dioxide through carbon sequestered by the conversion process.

Importantly, the vision offered in this Grand Challenge proposal targets not just any biomass, but waste biomass that by its very nature does not compete with food production capacity.

**The Role of The Ohio State University / Ohio Agricultural Research and Development Center (OARDC) in this Making this Vision a Reality**

Our Vision is:

**An Integrated Technology System for Biomass to Energy: Anaerobic Digestion combined with Gasification and a Solid-oxide Fuel Cell for Scalable & Complete Utilization of Harvested Biomass Carbon for Renewable Energy**. Most approaches for conversion of biomass to energy are applicable to only a portion of the biomass types available, cannot be implemented at small scale as needed for many biomass sources or local energy use, and rely on biological processes unable to fully convert the biomass and hence leave a portion of the harvested biomass carbon as unconverted and residue requiring disposal. Wet biomass is efficiently converted by biological processes but is too wet for thermochemical conversion, and can leave 30-40% of feedstock biomass carbon unconvertible to energy. Conversely, most dry biomass cannot be efficiently converted to energy by biological processes, but is well suited for thermochemical conversion by either gasification or pyrolysis to renewable fuels for energy. Combining thermochemical processes such as gasification or pyrolysis with biological processes such as anaerobic digestion provides a system potentially able to fully convert renewable carbon from almost any biomass type to energy. a unique concept when applied at small scale.


Generally, each biomass and conversion technology produces a different fuel requiring different technologies to convert each to electrical or thermal energy (i.e., boiler, engine, or turbine). To overcome this barrier, the integration of a scalable and fuel-versatile solid-oxide fuel cell (SOFC) with the biomass conversion systems would enable any fuel produced from biomass to be directly converted to electricity by the SOFC, a single platform for conversion of diverse fuels to electricity.

The vision will be built starting with the anaerobic digestion systems now a part of OARDC's Biomass to Energy Research Facility that currently uses wet biomass to produce Biogas fuel, and expanded by acquiring and installing a small-scale gasifier to also use dry or indigestible biomass fractions from the anaerobic digesters (i.e., high-lignin plant/crop residues, livestock manures, etc.) for conversion to Syngas fuel. Both Biogas and Syngas fuels can be fed in real time to a Solid-Oxide Fuel Cell able to use both fuels and a range of additional gaseous and liquid fuels, including vegetable (soybean, corn, other) oils. This scalable and biomass- versatile system will allow economical and simplified conversion of nearly any biomass resource at small or large scale in distributed decentralized settings - **"Close to the Farm or Community".**

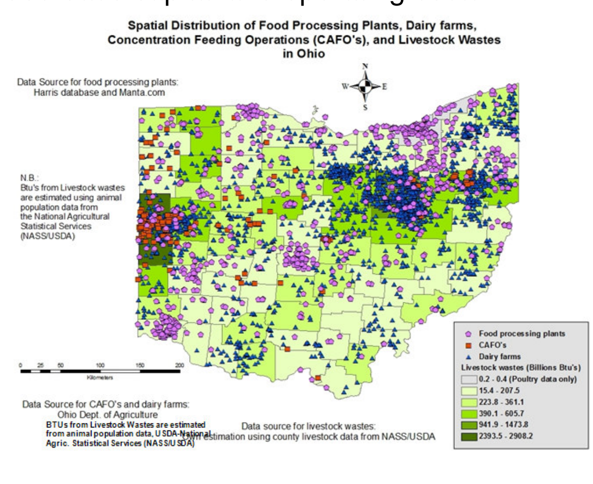
This integrated system for converting all biomass types to a common energy product - electricity via a single energy conversion platform - will be installed at OARDC's Biomass to Energy Research Facility alongside existing pilot-scale anaerobic digesters and biomass feedstock handling and preparation systems, and a demonstration scale fuel-versatile SOFC designed to receive and use fuel from either or both biomass conversion systems, or other fuels (i.e., vegetable oils).

This system will allow determination of the energy value and reliability of scalable renewable energy production from nearly any of the wide range of biomass types available in Ohio and typical of those throughout the nation. The focus on small-scale distributed systems is important for this proof of concept program and its commercial potential since most biomass resources are small focal sources that if used on or near their origin can produce transportable electricity or fuels without incurring unaffordable costs for biomass transportation to a centralized larger facility. Ohio's distribution of agricultural, livestock, urban, and food processing wastes makes it an ideal test ground for this concept and system aimed to affordably meet the needs of small-scale distributed systems while also able to satisfy the larger scale and scope of centralized systems without sacrificing biomass and fuel versatility.

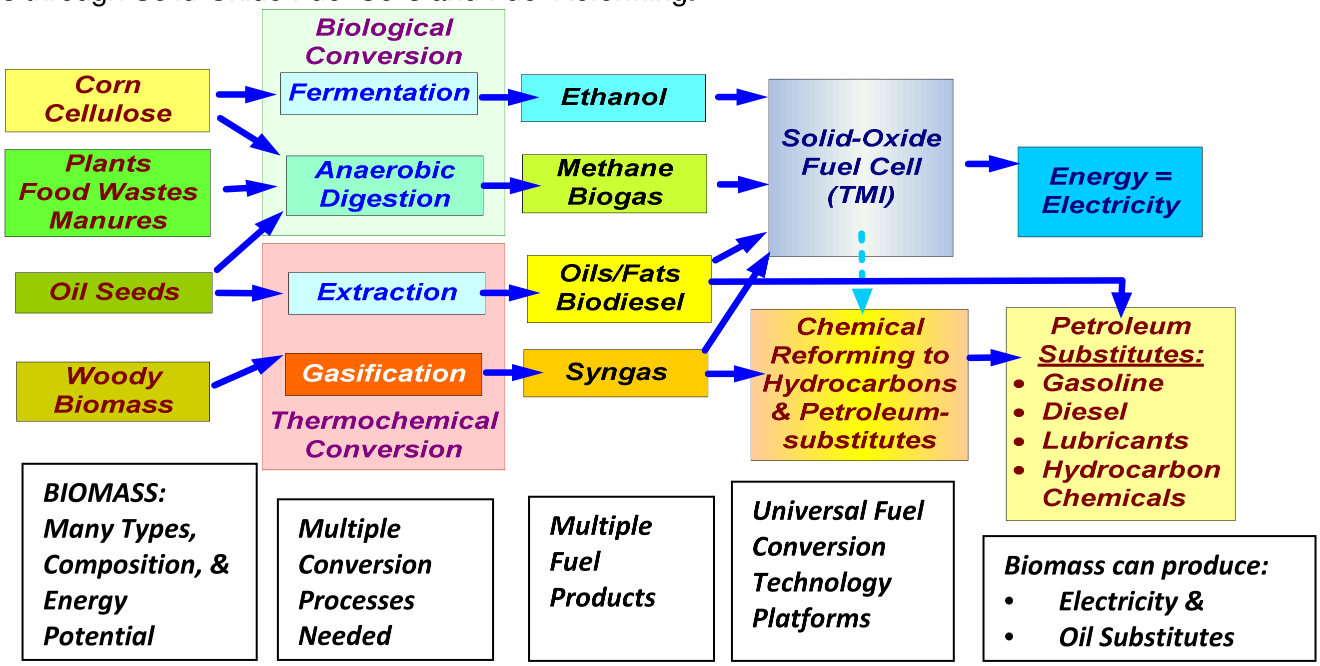
Further, waste biomass is diverse in type and composition (especially wet or dry, high or low energy density) such that no single technology can convert all types of biomass to energy. Hence we propose to integrate conversion technologies such as biological conversion of wet or wettable biomass with thermochemical conversion of dry or poorly biodegradable biomass to energy products. Most biological conversion processes leave unconverted biomass fractions (i.e., lignin that survives anaerobic digestion) that can be retrieved for subsequent thermochemical conversion. Hence, an integrated conversion technology strategy can convert nearly any and all of the biomass carbon to energy, thus utilizing all harvested renewable carbon for energy production.

Multiple conversion technologies for complete utilization of nearly all biomass types will also produce different fuel types as the energy end products for many of those technologies. Conversion of the different fuels to energy would ordinarily require a different fuel conversion technology for each fuel type. However, we propose here a second tier of integration and unification by proposing a solid-oxide fuel cell (SOFC) as the single platform for conversion of all biomass-derived fuels to energy as combined heat and electricity (CHP). Solid-oxide fuel cells have been shown to operate on nearly any fuel derivable from biomass, including hydrogen. Hence, one fuel conversion platform can easily integrate with multiple biomass conversion technologies to simplify operation and decrease capital and operating costs.

Recent mapping and inventory of Ohio's distributed biomass resources shows it to be available throughout the state in relative high density, and to include many sources of low-strength livestock wastes intermingled with high-strength food processing wastes, and positioned over abundant second-tier CRP lands or forests not used for crop production. This broad distribution of closely intermingled biomass sources and



types poses Ohio as an ideal test environment for a biomass to energy facility that integrates biological and thermochemical conversion technologies to convert diverse biomass types to fuels to be fed to a fuel-versatile SOFC for production of renewable and distributed electricity. The generic systems diagram below show that biomass-derived fuels can be converted directly to electricity or petroleum substitute fuels through Solid-Oxide Fuel Cells and Fuel Reforming.




The system described above is small scale but scalable. Such a system can operate on a family farm or be scaled up to serve a mega farm. If it works on the scale of a small farm, it can be moved closer to the urban center to power a supermarket or scaled up to power a hospital. Anywhere there is waste biomass, the small scale system can be deployed. Furthermore, and perhaps most importantly, because it can be scaled and designed to meet the power and fuel needs of its host site and host feedstock, all of the power generated onsite and fuels produced onsite will be consumed onsite, thus assuring highest value for the energy and fuels produced. Whenever an end user is generating and consuming 100 percent of its own energy, it is essentially replacing retail priced power and thus gaining the highest return. In this case of the system visioned in The Grand Challenge, it is 100 percent renewable power from agriculture waste or waste derived from agriculture operations such as food wastes.

**How the Role of the OARDC Will Contribute to Meeting the 25x'25 Goal Through Achievements in the Areas of: Increasing the production of renewable energy and alternative fuels; Delivering that energy to consumers; Meeting consumer demand; Enhancing sustainability, conservation and energy efficiency.**

In 1999 a landmark report[1] by The Kellogg Commission on the Future of State Land-Grant Universities challenged land-grant universities to consider "engagement" as a modern day interpretation of their original land-grant mission which redefines "…extension, conventional outreach, and even most conceptions of public service…" and questions "…inherited concepts (which) emphasize a one-way process in which the university transfers its expertise to key constituents…" The Commission suggests "engagement" should be "…a commitment to sharing and reciprocity…" involving "…partnerships, two-way streets defined by mutual respect among the partners for what each brings to the table…" and concludes by noting that an institution that responds to these imperatives can properly be called what the

[1] http://www.nasulgc.org/NetCommunity/Document.Doc?id=183

Kellogg Commission has come to think of as an "engaged institution." The vision to create and develop the Ohio Biomass to Energy program is an example the result of an engaged institutional policy[2].

The Ohio Experience

The Ohio Biomass to Energy Program (BTE), whose founding director is Dr. Floyd Schanbacher, is located at the Ohio Agricultural Research and Development Center in Wooster (OARDC), part of The Ohio State University College of Food, Agricultural and Environmental Sciences. The program focuses on biological and thermo-chemical processes to cost-effectively produce biofuels and bioenergy from biomass in an environmentally friendly way. Sources of biomass can include waste by-products from agriculture such as animal manure, the forestry and wood products industry, the food processing industry as well as from the municipal solid waste industry as found in landfills and municipal wastewater. Collectively, all hold great potential to provide renewable energy for America's future.

The genesis of the BTE program is based on a relationship between Dr. Schanbacher[3] and the commercialization objectives of Technology Management, Inc. (TMI) a small business based in Cleveland, developing a small scale fuel cell system with high value to small farms and rural businesses. Key to TMI's broad market appeal was the ability to operate on fuels which would be indigenous in rural markets and available to prospective customers, and specifically on biogas from small anaerobic digesters. Dr. Schanbacher had been seeking an industrial partnership to collaborate on the development of an advanced digester for the purpose of energy generation and had found little interest from the State of Ohio for biogas production alone, despite the fact that there was evidence of a very large latent demand for utilizing anaerobic digesters to convert animal and food-processing waste from Ohio's farms and food processing industry into biogas (primarily methane or natural gas). Numerous meeting took place in 2003 and 2004 discussing the use of biogas from small scale digesters suitable for conversion by TMI's fuel cell systems into electricity and heat. In 2005 BTE received a $1.5 million Wright Project award from Ohio's Third Frontier Program to assist in its development. This program has received much attention because of its practical emphasis on small-scale, kilowatt bioenergy systems which can be used by small farms and rural businesses, yet is scalable to any size. In addition, the BTE program received $1.6 million from the U.S. Department of Energy to find similar means to convert animal manure into renewable energy. Dr. Schanbacher believes that in theory the use of biomass produced in the state and the combined use of these two technologies alone "… could come up with a very significant part of the energy needs of Ohio."

Another crucial partner in the BTE program is NewBio E Systems providing novel anaerobic digestion technology optimized for high-strength biomass wastes as from the food processing industry, and uniquely designed to manage growth and retention of the bacterial mass independent of feed rates. This is supported by advanced control systems and software allowing local or remote monitoring and control. It is also highly scalable. This novel anaerobic digester provides an ideal research platform for optimization of anaerobic microbial growth, species balance, and testing of new sensors and controls to make anaerobic digesters robust and remotely monitorable and operable by third parties; addressing a well-known barrier to implementation of anaerobic digestion at small scale for farms and food processing industries. These digesters now operating at the OARDC BME facility will soon be partnered with conventional complete mix anaerobic digesters for livestock wastes for testing and optimization of augmentation of livestock wastes with high-strength food processing wastes for maximum economic return and reliability of digester systems. This is particularly relevant to a mixed biomass strategy as available in Ohio, and for taking advantage of Ohio's 5th ranked Food Processing industry whose biomass was estimated as able to provide 2/3 of the state's residential electrical need.

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[2] http://outreach.osu.edu/
[3] Professor in Animal Sciences in the OSU College of Food, Agricultural and Environmental Sciences located at the Ohio Agricultural Research and Development Campus in Wooster, Ohio

The biogas from anaerobic digestion will become fuel for the SOFC; Stage 1 of an integrated biomass to energy facility. Stage 2 will be acquisition and integration of a small-scale gasifier to run on anaerobically indigestible lignin-based or otherwise insoluble or intractable biomass such as dairy manure fibers or wood/bark. This will prove the carbon utilization efficiency of an integrated facility with both biological and thermochemical conversion systems and a fuel-common SOFC for converting bioderived fuels to electricity.

Additional partners attracted to the program include: Rockwell Automation (Mayfield Heights, OH), (focused on intelligent controls for remote operation of industrial processes and systems), the Ohio Third Frontier Wright Center for Sensor Systems Engineering at Case Western Reserve University with world-class development of novel sensors for process control, and the Edison Industrial Support Center and the Center for Innovative Food Technologies (Toledo, OH) who bring additional industrial partners or clients to the OARDC BME program.

This consortium of partners is key to the prospect of affordable and biomass versatile small scale biomass conversion systems that can be remotely deployed with centralized remote monitoring and control for distributed biomass utilization and power generation.

As the BTE program expands it will continue focus on small scale practical solutions which are also scalable, but broadened to include other clean thermo-chemical and biological conversion processes such as gasification or pyrolysis, in addition to anaerobic digestion, whereby biomass is processed to produce gaseous fuels. Existing technologies can accept biofuels; however, many are direct-firing and cofiring combustion devices such as engines and turbines, which produce air and noise pollution and require maintenance; but, because they are more efficient at larger sizes, are not suitable for use in residential or commercial scale buildings. Importantly and futuristically, the catalysis that is central to the SOFC sets the stage for development of small scale reforming of syngas to liquid hydrocarbon fuels in the Fischer-Tropsch Process. Eventual inclusion of a small-scale Fischer-Tropsch hydrocarbon reforming system into the Biological and Thermochemical Biomass Conversion process will provide two end products, electricity and heat (SOFC) or renewable carbon-based liquid fuels as petroleum replacements (Fischer-Tropsch reforming) able to shift with changes or seasonality of biomass resources and the economics of electrical energy vs. liquid hydrocarbon fuels.

<u>The Big Idea is “thinking small”</u>

State-of-the-art regarding technology surrounding biomass processing and fuel cells for power generation seems to be centered on medium to large scale facilities. In almost every case, this means that biomass must be transported to a central location for processing; then after conversion takes place, the electricity or fuel gas needs to be transmitted and distributed to end users. All of this is done at excessively high capital and operating costs. In addition, there are many hidden but increasingly important costs associated with traditional transportation not the least of which are air emissions, transport taxes and fossil fuel consumption just to move a raw material or product between points A and B. However, if the marriage of the fuel producing technology (e.g., anaerobic digesters) and electric generating technology (e.g., solid oxide fuel cell systems) were of a scale which could be deployed to where the biomass is located, then the significant economies of small scale start to become apparent, and the incentives to stimulate a new industry based on distributed biofuel and bioenergy production begin to align.

For example, imagine the family farm where manure and field waste could be fed into a small scale anaerobic digester, the biogas then directed to a small scale fuel cell to produce electricity and heat for the farm and the solids used for fertilizer. Imagine the benefits of reduced energy expenses, of less waste remediation expenses and the value of making the farm energy independent. The same concept can be applied to a home or subdivision, a grocery store, a food processing plant, a college, university or penal institution; anywhere that you have a need for energy and a solid stream of usable biomass.

Despite the clear logic and economics, there are reasons this vision has not gained traction within the confines of the traditional agri-business industry. This approach minimizes the capital needs of any one project, reduces risk and increases the possibility of success and technically, small scale processes; particularly chemical, can be scaled up, there are numerous reasons there has been low interest from big business:

- The structure and profitability of the agri-business industry is traditionally based on large investments in fixed assets for production, established channels to market, and branding. For those working with biomass as a feedstock, there are few incentives to explore, and much less to develop, systems which help small farms or rural businesses become on-site distributed producers of biofuels or bioenergy which might become competitive and result in huge "stranded investments" downstream.

- In addition, it is difficult and expensive to scale down large systems which are in production and either generating revenues or holding significant capital debt.

As this new industry – the distributed production of biofuels and bioenergy - is nurtured, it is logical and appropriate that until there is a critical mass of industrial support the BTE program continue to use its present structure <u>and expand</u> to include other practical business applications. The strength of the business model is based primarily on a two-way, ongoing exchange of tacit knowledge and only secondarily on traditional parameters such as access to academic research or technology transfer. Industry led commercial objectives without compromise to research independence is also a key factor. While interdependent, neither the university nor industry is dependent on the other. These unique features were recognized in 2005 when OARDC received the Nortech Innovation award for this model. In the presentation text[4]. This model would also meets the definition of the "engaged institution" called for by the Kellogg Commission.

<u>Where are we now?</u>

Given the abundance of biomass in the United States, the rising interest in distributed generation, and the investment and expertise within the State of Ohio on transforming biomass into a biogas that is processed in a fuel cell to generate electricity, it is natural that these technologies be merged into a larger vision with the potential to give birth to a new Ohio Biomass to Energy industry.

Placing unique demonstrations in carefully selected venues are a key shared objective to advancing the program. A mission critical challenge is to install the TMI fuel cell system which can operate unattended outside the lab for longer periods of time. While TMI has conducted successful, world-class

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[4] Text from the presentation: Our second category of award recognizes both an emerging and important trend—alternative sources of energy—and a unique business model for commercializing university research that serves as an example to be used more broadly, a cooperative business model that encourages simultaneous development of different innovations from the same source material. The award goes to the Ohio Agricultural Research and Development Center's Integrated Biomass to Electricity System. A 2005 Wright Project, OARDC's Biomass to Electricity project simultaneously addresses a world-wide energy problem by converting biomass (consisting of both food and animal waste) into a biofuel that can help alleviate our dependence on oil for energy production. The system creates a new product—biogas for fuel cells—from an "old" agricultural technology used throughout the world —anaerobic digestion.

But perhaps equally important as the technology itself is the "hub and spoke" model used by the university to commercialize this system. This approach allows for multiple collaborators focused on different market niches to work towards a common objective, while avoiding multi-party agreements and the risk that one collaborator's intellectual property or other assets crucial to the commercialization process will be exposed to competitors along the way. This ability to simultaneously pursue multiple independent commercial paths based on a single core technology will rapidly accelerate the development of innovative new products and services for our economy, and brings together in a unique way our state's agricultural and technology communities in what is just the beginning of a new trend in agricultural technology ventures. Accepting this award on behalf of the Ohio Agricultural Research and Development Center is the Project Director and lead researcher, Dr. Floyd Schanbacher. In addition to Dr. Schanbacher, we also want to recognize the significant contributions made by Dr. Bobby Moser and Dr. Steven Slack of The Ohio State University College of Food, Agricultural, and Environmental Sciences.

demonstrations in unique venues, their systems are laboratory demonstration systems and lack robustness. And, until the economic viability is demonstrated, there is only an early adopter demand for fuel cell systems. Ohio's regulatory landscape traditionally hasn't provided an incentive for farmers and food processors to generate renewable energy. According to Schanbacher, as a result of all of this, Ohio lags in renewable-energy projects.

Given the aggressive activities in other states to expand the biopower industry, clearly, something needs to be done soon to capitalize on the unique opportunity to create a new distributed Biomass to Energy Industry in Ohio and expand this vision nationwide in partnership with the USDA. The rapid deployment of the systems from this new industry will create and retain jobs in Ohio and across the nation, making our nation less dependent on others for energy production and protect and improve the environment.

<u>Concept of Ohio Biomass to Energy (BtoE) Center</u>

A Biomass to Energy Center is being created. The overarching objective of the Biomass to Energy (BtoE) Center will be technology commercialization for public benefit supported by research driven by the land-grant mission. In this context, the responsibility of the engaged land grant institution is to reduce research into practice as soon as is practical to realize its public benefits. As Ohio's land grant university, The Ohio State University will apply its research to ensure first public benefits impact Ohio's economy. The organizational structure will use a hub and spoke model constructed from individual working relationships in specific designated fields with individual companies. This is identical to the model now in place between TMI and the Ohio Biomass to Energy program. The land grant mission of The Ohio State University is to reduce theory to practice and extend this practice to all interested parties.

The focus of the BTOE Center will be on proprietary technologies which can contribute toward a new industry for our nation. A cornerstone will be the unique strategic advantages of distributed biomass and its on-site conversion to biofuels and bioenergy. The BtoE will be organized so as to foster the commercialization and growth of the BToE industry. This will be swimming upstream as most of the focus for renewable energy seems centered on wind, solar and crops to fuel. **There needs to be a strong voice for waste biomass to energy. The BToE Center will be this voice.**

The BToE will triage all research opportunities to ensure best fit with appropriate resources. Strong working ties will be made with related university research in biomass conversion and related areas, particularly with other Ohio universities (e.g., through the University Clean Energy Alliance of Ohio) and other land-grant universities with complementary expertise such as Cornell University and others in the N.E. SunGrant Initiative. In collaboration with its industry partners BtoE will seek funding through: Federal Farm Bill; federal grants from USDoE and USDoA; federal earmarks; Ohio Third Frontier Grants and other state sources; ODNR; solid waste districts and the private sector.

Commercial BtoE products will seek to use Ohio biomass and clean on-site technologies which are scalable and meet the following characteristics:

1. Focus on building a broad portfolio of demonstrations consisting of industry partnerships which embrace a range of small scale technologies, and where the demonstration can be scaled-up.
2. Place a priority on industry partnerships where there is a mutual commitment to commercial success and a business relationship. Today, this is in anaerobic digestion of biomass to biofuels integrated with small scale biofuel fuel cell technology for distributed electric power production. Other technologies are being added such as gasification and pyrolysis (which has some possible carbon negative attributes).
3. Use biomass sources which will benefit from on-site technology deployment. This will ensure minimization and/or elimination of collection and transportation expenses, environmental impacts of collection and transportation of biomass to central facilities, and investments in transmission and distribution lines. All of these expenses comprise unnecessarily high upfront capital costs and the potential for lower quality power.

4. Produce both gas and liquid fuels from the biomass conversion.
5. Allow for and synchronize system design with other forms of renewable energy (e.g. wind, solar, hydro). Biomass energy is firm energy. The wind does not always blow and the sun does not always shine, but there is an adequate steady supply of renewable waste biomass that can be used to base load renewable energy project. The ability to base load and provide firm renewable power that is built in conjunction with wind or solar may make a heretofore marginal project feasible.

The potential customer base for such small scale systems is limitless and includes family farms (energy is the number two production cost after labor, a goal would be to make a family farm in Ohio energy independent); waste to energy on large farms (i.e. CAFOs); food processing facilities; manufacturing plants, particularly those in rural areas operating with high energy costs; schools and institutions; rural homes and subdivisions; grocery stores, restaurants and commerce centers; critical loads for security and defense. Successful down-scaling could eventually produce practical and affordable residential energy systems fueled by biomass.

Commercialization will require extensive ongoing research into developing more efficient digesters, feedstock and the processing and preparation thereof, and testing of fuels for input to the fuel cells. In addition, ongoing research and development is necessary to improve the efficiency and reduce the size of the digesters and fuel cells for distributed commercial deployment.

Although part of the traditional definition of biomass, agricultural crops grown for food are **not** included as a part of the reach of this industry. The biomass used as feedstock will consist of: trees grown for energy production; wood waste and wood residues; non-food producing plants; residues; fibers; animal wastes; fats, oils and grease; and the biomass portion of municipal solid waste that have had recyclables of metals and glass removed. With the addition of gasification to the system it is very possible to process plastics into fuels and power.

The BtoE Center will work with its partners to match industry research requirements with faculty expertise or facilities in the fields of food and agriculture, drawing first on the resources of The Ohio State University College of Food, Agricultural, and Environmental Sciences. The extension service arm of the College will provide entry into the rural and urban sectors of Ohio to deliver the benefits of this new system. Benefits will include the creation and retention of jobs in Ohio, making Ohio less dependent on others for energy production and protect, and improving the environment. But, we don't stop there as this model can be replicated to similar agricultural activities across our nation and across the globe.

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