Wisconsin Department of

Agriculture,

Trade and Consumer Protection

Biobased Industry Opportunity (BIO) and
Agriculture Development and Diversification (ADD)
Grant Programs

FINAL REPORT

"Market Feasibility for Products Developed at the Cashton Greens Energy Park"

Cashton Area Development Corporation

March 15, 2006

Overall Project Introduction
Wisconsin's dairy industry has a $20.6 billion impact on the state's economy. The growth in dairy is directly related to the industry's ability to manage growth. This ability to grow is tremendously hampered by the ability to manage manure safely and efficiently using the inherent nutrient value of the manure for growing crops while not engaging in practices that contaminate the ground water, surface water and drinking water. Unfortunately, the current manure management condition in Wisconsin is more of a land disposal practice than it is a nutrient management activity.

In 2005 there were 52 major manure spills in Wisconsin that contaminated wells, poisoned streams and threatened the health of people living in the countryside. Today, in the small community of Wayside, WI there are 43 private wells contaminated with nitrates and fecal bacteria; the direct result of poor manure management practices. There simply is not a management technology that will allow the dairy men and women to manage their manure in ways that preserve and reform the nutrients into a usable form without contaminating the environment. The current manure management condition in Wisconsin then is that dairy farmers cannot grow unless they purchase or rent more land to spread their manure and even then, they have to apply manure at times of the year when there is significant opportunity for manure runoff into the drainage ways, surface waters and infiltration into the groundwater or on land that is saturated with phosphorus.

The State of Wisconsin through its agricultural and environmental agencies (DATCP and WDNR, respectively) has taken a proactive approach to stemming the environmental damage that manure runoff causes. The **Manure Management Task Force** recently came forward with their recommendations to the Wisconsin Legislature and the recommendations passed unanimously (March 1, 2006). Some of the more salient recommendations are that the DATCP and WDNR should focus on actions that take advantage of the sustainable practice of land application of manure by implementing of phosphorous-based nutrient management plans. And, that Research efforts should continue to examine the environmental impacts of manure runoff events (including impacts from phosphorous and other nutrients, pathogens, ammonia, biochemical oxygen demand, and effects on groundwater) and should study the effectiveness of practices in protecting water quality. And finally, the recommendation to develop a regional **pilot** program to test the effectiveness of limited enforcement protection and other incentives for farmers who meet standards for superior environmental performance.

These recommendations all direct DATCP and WDNR to work with the private sector to support and expand the use of environmental management systems and other comprehensive planning tools through the ***Green Tier*** Program or other market incentive-based approaches for manure management in Wisconsin.

Creating Wisconsin's Cellulosic- Based Biomass Economy
The convergence of an excess supply of manure, the need for Wisconsin's farms to grow, the application of nutrients that are beneficial to the soil, the need for renewable energy and the urgency for a new regionally-based environmental management system that uses the qualities of the manure biomass as an opportunity, serves as the basis for the following overall project to develop the cellulosic-based bioindustry in Wisconsin.

Governor's Bio-Industry Consortium
Also in 2005, the Governor appointed a **"Bio-Industry Consortium"** working group that is charged to develop the following six subject areas, expressed here as goals:

1. Expand markets for biobased energy, fuels, and products,
2. Facilitate development of biobased businesses,
3. Meet technology needs,
4. Manage financial risk and attract investment,
5. Develop innovative public policies, and
6. Reach out to – and educate – the public, government officials, and businesspersons.

A seventh and more technical subject – available raw materials, conversion processes, and products– is being addressed in phase I of an external study of Wisconsin's opportunities and competitive advantages in the bioeconomy. The study is being performed by a group of research organizations under the direction of the Energy Center of Wisconsin and is being funded by the Department of Agriculture, Trade and Consumer Protection, Department of Administration, and Department of Natural Resources. The study will identify Wisconsin's competitive advantage in biofuels and biobased products and will be coordinated with, and support, the work of the consortium. A technical projects team has been appointed to oversee the work of the opportunities and advantages study and serve as liaison between the study group and the consortium.

This seventh subject area is where our current efforts add increasing value to Wisconsin's emerging cellulosic-based economy. Our effort is led by a private group of entrepreneurial individuals and businesses rather than the Energy Center of Wisconsin and the State Agencies of DATCP and WDNR. We are grateful for funding from DATCP and the State of Wisconsin to provide a second, more market-driven approach to discovering opportunities for the emerging bioindustry in Wisconsin. **The goal of our effort is to demonstrate the technology of slow pyrolysis of bovine manure to solve the multiple problems manure management has created in Wisconsin.**

We are focused to accomplish the following objectives that have direct application to the needs of the State of Wisconsin as identified by both the **Manure Management Task Force** and the **Governor's Bio-Industry Consortium** working group:

- Demonstrate that the novel pyrolysis technology is capable of removing at least 75% of the nutrients from the waste stream generated by a dairy operation.
    - A critical barrier to attaining widespread adoption of nutrient control for concentrated animal feeding operations is the lack of a proven technology offering clear economic advantages. As animal feeding operations have become larger, land application practices have become unacceptable because the nutrients imported to the farm have grown out of balance with the fertilizer needs of the local land.
    - Developing a regional solution to manure management allows farms of all sizes to participate in advances manure management. Recent anecdotal evidence suggests that smaller operators are many times a larger problem than large operators in land disposing of manure.

- The pyrolysis technology to be demonstrated in this project offers a means to reduce odor emissions, reduce the loading of nitrogen, phosphorus and pathogens to ground and surface water, reduce greenhouse emissions, reduce manure volume and mass, degrade pharmaceuticals contained in the manure, reduce the dependency of the livestock producer on the local land base, improve the quality of soils, and meet regulatory requirements with a cost-effective process.
    - These potential advantages rely on the creation of a product from the slow pyrolysis process that has specific characteristics that can provide the above benefits safely, odorlessly, in a commercially sustainable manner and one that yields a "Carbon Neutral Footprint" in the process.

- Create an industrial park setting whereby we can demonstrate the biomass conversion process, create the end products of value and allow for economic growth by having tenants of the park use the renewable energy created by the process in their manufacturing or distribution activities.

Overview of the Literature

Significant research and development has been done by our team to determine if the products of slow pyrolysis: bio-oil, synthesis gas, and char, have specific attributes and values that allow for placement into existing or new markets. This ADD grant was solicited "to evaluate the market feasibility of end products and the operating characteristics of the bio-refinery component of the Cashton Greens Energy Park Development Project". In order to fully understand the "hoped for" application of by-products from the conversion of manure biomass, we had to understand the potential characteristics of the by-products and the research that has been unfolding over the past several years. One of the most exciting opportunities is the development of the char material derived from the pyrolysis of bovine manure.

Char

Dr. Johannes Lehmann, Department of Crop and Soil Sciences, Cornell University, Ithaca, New York, recently edited a text entitled, *"Amazonian Dark Earths: Origins, Properties and Management",* Kluwer Academic Publishers, 2003. This text is a compendium of various research studies on extremely fertile soils discovered in the Amazon basin that are now known to be the result of human habitation and domestic activities. One of the features of these extremely fertile soils is that they are high in organic material especially charred plant material (page 4). Lehmann et al. go on to explain that "the occurrence of ceramics and charcoal indicates that the genesis of these soils is strongly linked to anthropogenic processes" (page 141) and that the "available data indicate that black carbon indeed influences total nitrogen release either by microbial immobilization due to the high carbon/nitrogen ratios of the black carbon or by catalytic effects of the high surface area of the black carbon" (page 109). This increase in organic matter, nutrient release, high surface area and microbial interactions translate into increased yields of some crops with "bean yields being generally higher on Amazonian Dark Earths (ADE) than on enriched soils (those with standard NPK applications)" (page 117).

Our team of scientists, chemists, engineers and researchers are working closely with Dr. Lehmann and others to characterize the char material we create in our demonstration-scale pyrolysis unit in the spring of 2006. The char material created were from paper waste and woodchip feedstocks. Further testing in spring 2006 will use manure as feedstock. We will report our findings in the Bio-Industry Grant report at the end of our effort.

Importance to Wisconsin

Conforming the research on char to the needs of Wisconsin, we see a very strong correlation among the various conditions that need improvement and materials that could help bring about that improvement. Again, some of the conditions that exist in Wisconsin's dairy agriculture is that manure is land applied in either a liquid form (from lagoons and holding tanks) or as a dry material (as post-digested bedding material as a result of anaerobic digestion). In both of these disposal methods, the nutrients of the manure may or may not be applied at an agronomic rate, or in a form that is bio-available to the plant. Also, depending upon the physical nature of the manure, if applied wet it has a significant opportunity to runoff into surrounding drainage ways and streams. Or, if applied dry as post-digested bedding, it has most of the phosphorus still in place contributing to additional runoff if applied to phosphorus-saturated soils. In all cases, the current condition in Wisconsin is leading to the demise of dairy farms that can be operated for growth and for sustaining environmental quality.

A char material, if developed through a process that was commercially viable (net energy balance and strong business *pro forma*), environmentally sustainable (would add value to the soil and not be another disposal practice), could solve the odor issue and would allow for economic growth by re-forming agriculturally important nutrients into a form that could be removed from their watershed of origin, could help solve the dilemma of land disposal of manure in Wisconsin by the dairy industry and could provide a reasonable method for deriving value from an abundant biomass resource.

Our Approach

The Cashton Area Development Corporation (CADC) has spawned the creation of a multi-disciplined place-based technology services company named Generation International, LLC (Generation). Generation purchased Biomass Energy Services & Technology (BEST) of Australia in 2005 and has been working with BEST to develop Wisconsin-specific technology to solve the problem of biomass management of manure rather than just moving the problem around. BEST is a multi-disciplined biomass energy company with 30+ years of experience in biomass conversion in Australia. The BEST/Generation Team also has access to additional industrial sector experience in chemical production, process engineering and design, and process control. Our team is further rounded out with dairy and agricultural economists, financial analysts, real estate development specialists and agricultural watershed experts. In short, we represent a holistic, well-rounded team of experts, poised to push the understanding of biomass conversion of already existing dairy wastes to build the economies of our rural communities while improving the energy future and environmental present for this generation and for generations to come.

Our approach to developing new technology is relatively simple: learn from those who have gone before us and then "prove it". We are in the process of "proving the reliability of thermo-chemical conversion as it applies to agricultural biomass". The advanced pyrolysis technology to be used in this pilot project has been developed and tested for various organic feedstocks by BEST in Australia. Information from those previous tests provides an important background for the work to be done in this pilot project. BEST has successfully converted paper waste, woody waste, rice hulls, chicken manure, cow manure and other materials by the slow pyrolysis process used in this effort. We have significant reason to believe that we can create a valuable suite of end-products including synthesis gas to be used to fuel a genset, char material with properties that will add value to the soils of Wisconsin and bio-oil that will be consumed in the slow pyrolysis process as a fuel in a manner that will be efficient, safe, odorless and commercially viable.

The process to be demonstrated in this project has exceptional environmental benefits beyond improved air and water quality. Renewable raw materials are used for energy and to form char, a valuable product with uses in filtering, adsorption, and as an excellent soil amendment. An additional environmental benefit is unique to this manure treatment process. Pyrolysis char is very resistant to environmental degradation and microbial decay. This carbon persists in the soil for centuries and is therefore a long-term sink for environmental CO_2. Therefore, this biomass-fueled process is not just carbon-neutral, but actually removes carbon from the atmosphere and sequesters the carbon into the soil on a net basis.

Specifics of the Project

Specifically, this project seeks to prove the efficacy of a demonstration-scale biomass conversion unit in converting dairy and bull manure to produce valuable products (synthesis gas and char material) while preserving the agronomic nutrients. Operating results from the pilot unit will be used in the final design of an industrial-scale manure pyrolysis plant to be located in the Cashton Greens Energy Park in Cashton, WI. Engineering design and construction plans, site development, development of a business plan and implementation of the industrial-scale plant will be the product deliverables of this development and will begin under the "Bio-Industry Grant- Implementation Phase to begin in Summer, 2006. The Bio-Industry Grant- Implementation Plan will be submitted under separate cover.

Introduction to the ADD Grant Project

The purpose of the Agriculture Development and Diversification (ADD) Grant was to evaluate the market feasibility of end products and the operating characteristics of the bio-refinery component of the Cashton Greens Energy Park Development Project. The major components of this project then were:

- to delineate the operating characteristics of a demonstration scale biomass conversion unit (formerly referred to as a bio-refinery)
- to understand and characterize the potential value of the various end products resulting from the pyrolysis of manure feedstock
- to explain the relationships of the value of the end products of biomass conversion in a context that provides a platform for the creation of usable renewable energy by tenants of the industrial park and the surrounding community.

The ADD grant enabled the Cashton Area Development Corporation (CADC) to focus on the above elements beginning with defining the operating characteristics of the biomass conversion facility.

Defining the Operating Characteristics of the Biomass Conversion Facility

In general terms, the thermo-chemical conversion process of slow pyrolysis is illustrated in discussed below. The feed material is dried to a moisture content of between 10-15% and fed into the pyrolysis kiln where it is heated in the absence of oxygen to produce synthesis gas, bio-oil and char. As mentioned earlier, the bio-oil is consumed by the process as fuel and is not the focus of this current project phase. The demonstration scale biomass conversion unit used in this project is capable of handling dried feed material at a rate of 50 lb/hr. This feedstock material is dried separately and placed in the feed bin, which holds 400 lb of dried feed. Each 400 lb batch of material produces approximately 140 lb of char. In this demonstration unit, the syngas is not recycled and it is all fully combusted in a flare after necessary treatment and cleaning to ensure a clean exhaust stream. Natural gas is used as a fuel for drying the material and also heating the pyrolysis kiln. The general design of the pilot plant is shown in Figure 1, and a photo of the unit is presented in Figure 2.

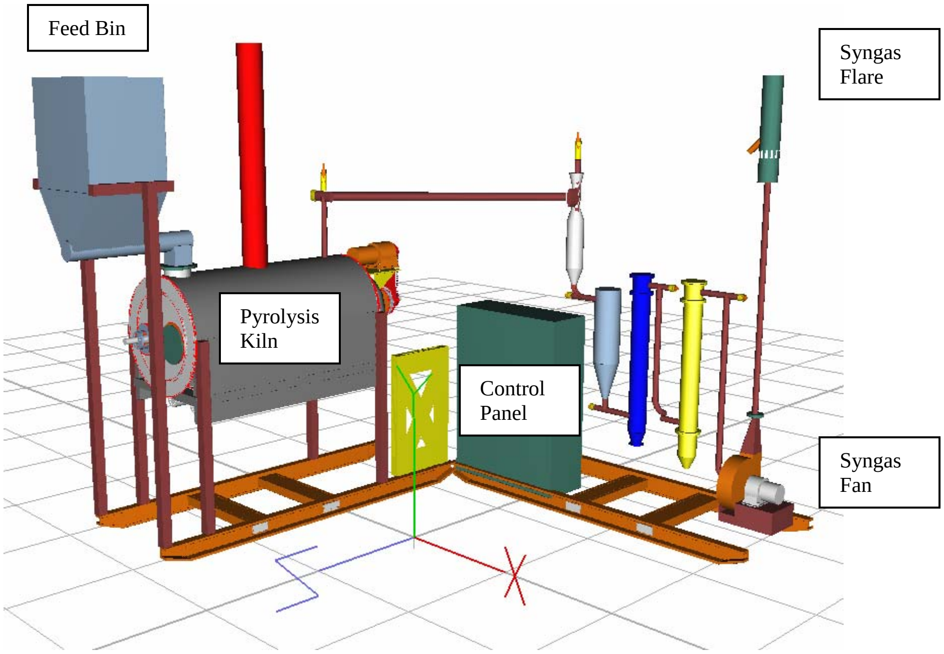


Figure 1. Layout of the pilot plant with unit operations identified.

Figure 2. Photograph of the pilot plant.

The commercial pyrolysis plant that will be designed based on the pilot scale testing is a fully continuous system with an integrated drying plant. Figure 3 shows the general layout of the commercial scale plant. A preliminary process flow diagram of the commercial plant is presented in Figure 4. As is indicated, the syngas that is generated in the pyrolysis of the feed material is recycled back to the kiln and dryer to fulfill the energy requirements of the plant. The excess syngas can be utilized for energy generation (not shown.)

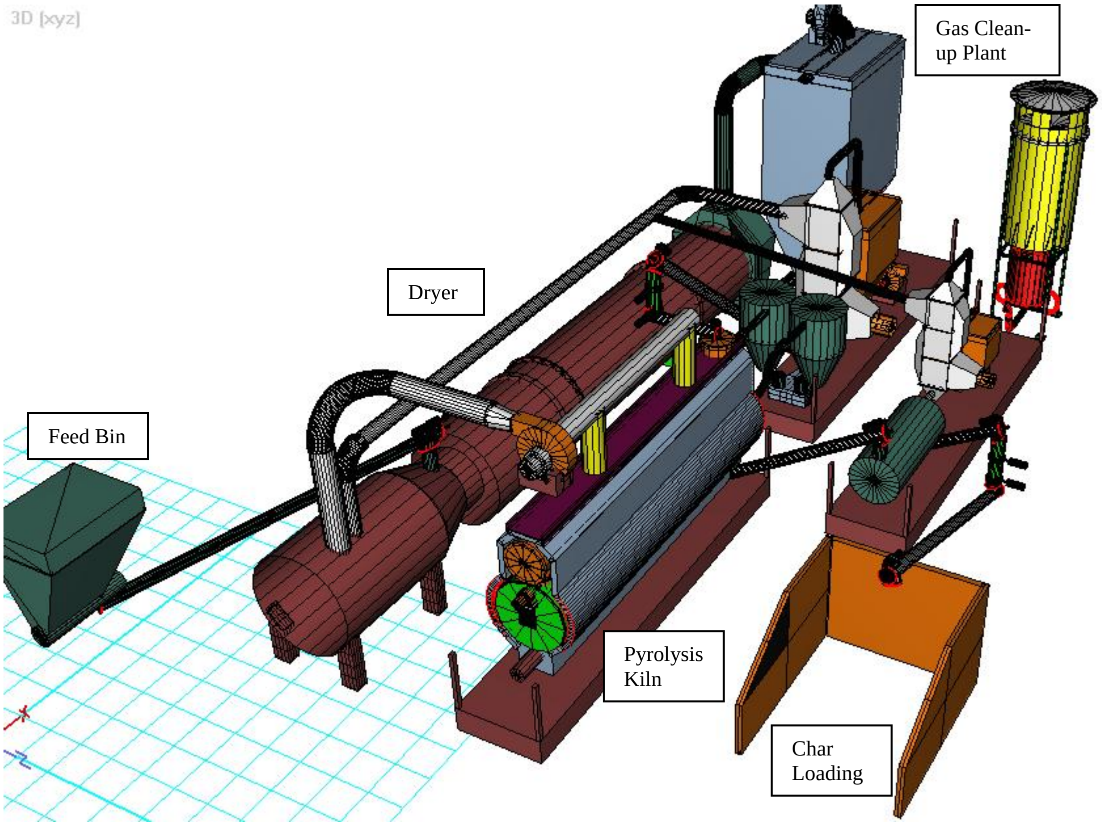


Figure 3. Layout of the commercial scale pyrolysis plant.

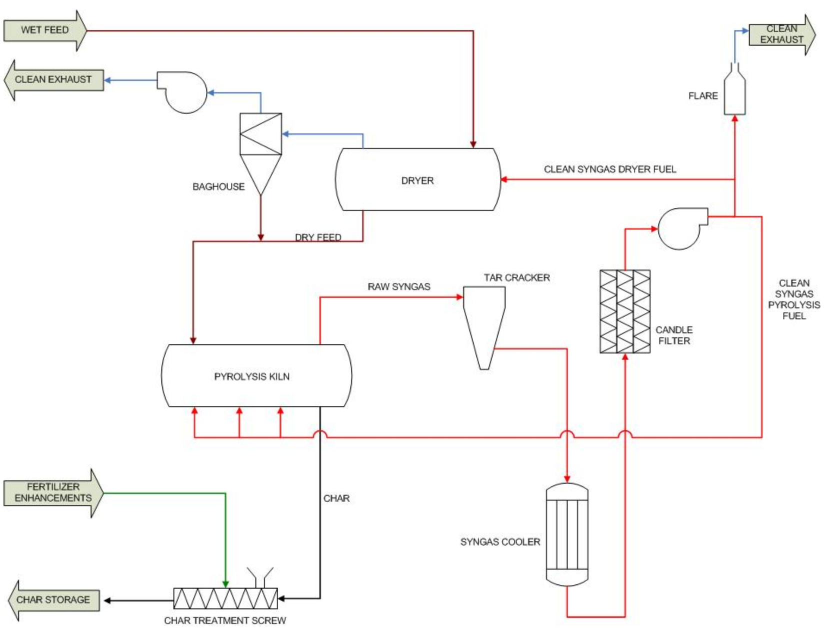


Figure 4. Preliminary design scheme of the commercial pyrolysis plant.

Characterize the Potential Value of the Various End Products

As explained above, the thermo-chemical conversion process of slow pyrolysis yields three distinct end products: synthesis gas (syngas), bio-oil and char. The bio-oil portion of the process was consumed within the pyrolysis event as fuel for the process and therefore is not considered a by-product external to the process.

Testing the Process

BEST has engaged in a number of pilot scale pyrolysis trials on paper waste sludge using a 25kg/hr (~50 lb/hr) semi-continuous paddle pyrolyser (named El Toro). The specific testing event referenced below was done by BEST in Australia at their research facility and was completed in November, 2005. The main aims of these trials were to:

- Produce 100kgs of char from each of the two feed materials (Mix 1 is 50% paper sludge and wood chips; Mix 2 is 30% paper sludge and wood chips) for agricultural trials,
- Analyze the char product including Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD) and analysis of surface area,
- Measure Syngas Composition, and
- Produce a preliminary Mass and Energy Balance.

A total of 10 runs were undertaken. 100 kgs of char was produced. Once all of the operating issues were resolved the unit operated stably and a high quality char and medium calorific value gas was produced.

Operating Procedure

The feed for the test run was loaded into the feed bin, which was then sealed and purged with nitrogen to remove any oxygen. A screw conveyor, driven by a variable speed motor, was used to add the biomass feed to the kiln. The biomass is heated up inside the kiln where the pyrolysis reactions take place. Stirrers inside the kiln move the biomass/char along to the end where it drops into a product bin (not shown). The syngas produced in the kiln was conveyed by means of a gas fan providing the suction needed to overcome the pressure drops. The speed of the gas fan was manually controlled to keep the pressure in the kiln neutral or slightly positive during gas analysis to avoid air entrainment. The air and the gas enter an externally heated reaction chamber which is heated to above 800 °C. The exothermic partial oxidation reactions also provide some of the energy required for the endothermic tar cracking reactions through the use of the bio-oil as fuel for the process. The very hot gas then passes through a cooler and filter to remove particulates. The gas is then further cooled before passing through another fan. The gas then passes to a flare were it is ignited using an external gas burner. Before any feed is added to El Toro, the whole gas cleanup system needs to be close to running temperatures to ensure minimal problems are encountered. A steam purge is carried out just before starting the feed – this removes any oxygen and assists in carrying the heat through the system.

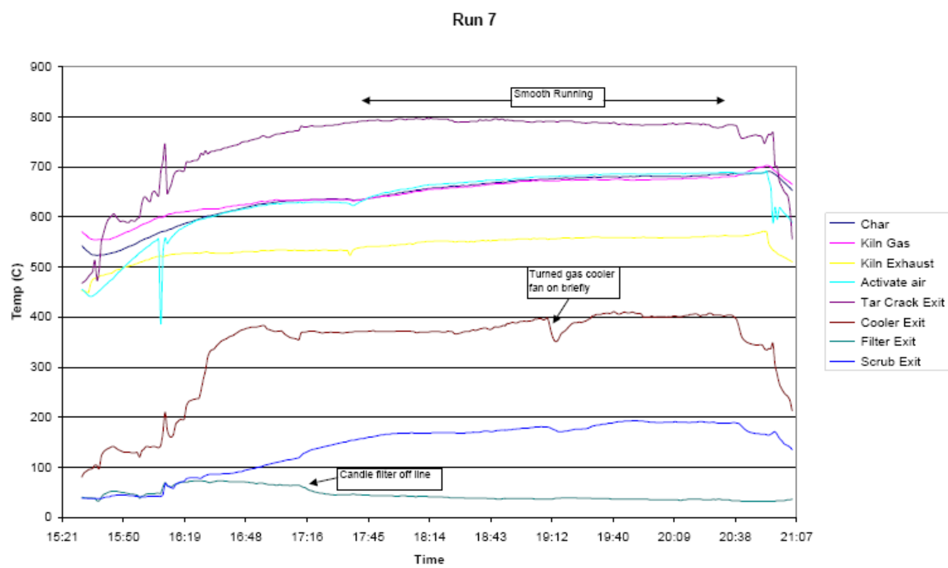
Analysis of the Outputs

The synthesis gas produced from the pyrolysis of the paper sludge /wood fines mix was measured and found to have a calorific value (CV) on a dry basis of approximately 9.7 MJ/kg for Mix 1 feed, and 8.7 MJ/kg for Mix 2 feed. The lower CV for Mix 2 is due to the greater amount of air injected to crack the tars, diluting an initially more energy rich stream. A basic mass and energy balance on Mix 1 and Mix 2 was carried out. Table 1 below is a summary of the test results for three runs where the unit was stable and producing char and syngas, and was carried out after commissioning was completed.

Table 1. Results of pyrolyzing a paper sludge/wood chip mixture in the demonstration unit.

Run Number	Feed Type	Mass of Feed (kg)	Mass of Char Produced (kg)	Char Yield	Calculated Mass of Syngas Produced (kg)	Syngas Yield
6*	2	97.55	41.85	42.9%	50.8	57.1%
7	2	111.3	32.6	29.3%	73.1	70.7%
11	1	35.1	11.17	31.8%	21.95	68.2%

* **No activating air**



The above test results for Run #7 were typical of the parameters monitored during the test events. This chart conforms to the following results for the run in Table 1 below.

Synthesis Gas

The major difference between the two feed materials appears to be the proportion of hydrogen and methane produced in the syngas. Mix 1 with the greater proportion of sludge produced a syngas with high methane content and a relatively high calorific value of 9.7MJ/kg. Mixture 2 produces a lower calorific value gas but produces more hydrogen. The syngas analysis of Mix 1 reveals a higher portion of higher hydrocarbons and methane.

Table x. Syngas analysis of paper sludge/wood chip feed.

			Gas Analysis Average Values (%)									
Date	Run No.	Feed Type	CV (MJ/kg)	H2	CO %	CO2 %	HC (ppm)	Methane	Eth.	Prop.	Ethyl.	Acety.
27/09	7	2	8.7	20.4	15.8	18.6	3755	8.30	0.48	0.37	2.62	0.15
17/10	11	1	9.7	13.7	17	22.5	5650	12.2	0.72	0.54	3.89	0.23

Char

The solids portion of the pyrolysis conversion is char. Listed in Table y are the calorific contents of char produced in experiments with the wood waste material, and Table z presents a series of analytical results carried out on the char material derived from these tests. Surface area, pore volume and pore diameter are found to be applicable for filtration and soil amendment properties. The char created from the processing of paper sludge with wood chips was highly porous and suitable for further testing. The SEM of the material further illustrated the creation of highly porous char through activation.

Interpretation of Results

The char material created by the pyrolysis process demonstrated characteristics that would be beneficial if the material were introduced into a soil profile. While more research is certainly warranted, the benefits from addition of char in organic fertilizer can be listed as follows:

- It is an absorbent for soil-damaging herbicides and pesticides,
- It absorbs and neutralises the natural toxins in decomposing organic materials,
- It absorbs at least some of the harmful chloride and fluoride found in tap water,
- It removes the germination-inhibiting chemical from the seed surface,
- It decreases NH4 leaching and increases the nutrient-use efficiency, and
- It helps retain soil moisture due to its high porosity.

These results provide a great deal of confidence that the pyrolysis technology being proposed for the commercial biomass conversion facility will be successful for the conversion of dairy manure to a syngas suitable for energy production and a char that will have valuable soil amendment properties.

Table y. Calorific content of char produced from paper sludge/wood chip feed.

		Mix 1 (MJ/kg)	Mix 2 (MJ/kg)
Feed	Weighted Total	13.10	14.59
Char	Paper Sludge Component	11.63	11.63
	Wood Chips Component	33.49	33.49
	Weighted Total	**22.56**	**26.93**
	Combined Sample	**21.82**	**18.37**

Table y. Char testing results for paper sludge/wood chips.

Testing Procedure	***Value***
BET Surface Area	115.0 m^2/g
Langmuir Surface Area	153.3 m^2/g
Micropore Area	100.1 m^2/g
External Surface Area	14.8 m^2/g
Micropore Volume	0.0465 cm3/g
Adsorption Average Pore Diameter	22.9 Å

Additional Char Characteristics

Additional characteristics of char were defined by plant growth studies undertaken to determine the value of char as a soil improvement product. Cow manure was used as the feedstock in a slow pyrolysis unit to create two (2) char samples. One sample was the outcome of pyrolysis at 250 degrees centigrade while the second sample was created at 550 degrees centigrade. Both samples of char were added in varying degrees to soil with a control soil mix also planted. In all, five (5) soil additives of NPK were investigated at three (3) concentrations in the soil with eight (8) pots planted. In total, 128 seedling pots were planted with Sparkler Radish seeds and were placed at random in a hot house.

Market Specific Issues

The overall conclusions for slow pyrolysis and its ability to create meaningful products are as follows:

- The process does yield marketable quantities of char and syngas from several different feedstocks. Future work needs to focus on the types of feedstock and its impact on the quantity and quality of syngas and char yields.
- The char material can be created to fit into three (3) very different and distinct markets: fuel, filtering media and fertilizer. The use of char for fuel was determined to be a viable market as evidenced by the char yield and its moderate calorific value. The filtering opportunity for the char material is also potentially viable since the porosity of the char was high and hence, its filtering capacity would also be high. And the fertilizer capabilities of the char are also hopeful since the char's porosity could contribute to the what the char literature suggests which is that the highly porous char material could act as a haven for microbes that would allow for the slow release of nutrients into the root zone of the plant.
- The synthesis gas was also determined to have sufficient calorific value as a fuel and would be a promising source of BTU's for driving a genset or similar engine.
- All results indicate a need for further testing and creating of both the syngas and char for further analysis and to identify end markets for these by-products of pyrolysis.

Key Personnel

- Dr. Stephen Joseph, Managing Director of BEST, PhD, Department Architecture and Anthropology, University of NSW and BSc (Hons), Metallurgical Engineering
- Mr. Jason Smith, Minerals Processing Engineering BE (MinProc)
- Ms. Adriana Eliza Thomson, Bachelor of Engineering (Chemical) and Bachelor of Science (Drug Design and Development)

Cashton Greens Renewable Energy Park and Biomass Conversion

The Cashton Greens Renewable Energy Park is a 121.75 acre industrial park located in the Village of Cashton, Wisconsin. The concept of the renewable energy park was developed by the CADC in response to the need from local dairy producers to manage their manure in a manner that would allow for growth in their herds without increasing either the lagoon storage capacity for manure or acreage necessary for land spreading manure. The main feature of the energy park is the biomass conversion facility (formerly referred to as the bio-refinery). The biomass conversion facility is intended to be a slow pyrolysis processing plant that will use bull and cow manure as feedstock to create syngas and char while significantly reducing the volume of the manure through thermo-chemical conversion.

Summary and Conclusions

Syngas

The composition of the synthesis gas derived from the pyrolysis of manure holds significant promise as a fuel for energy generation. Further research on the mass of syngas produced and its composition need to be continued using manure as feedstock. An important element of this analysis will be the effectiveness of the hot gas clean up system in series with the pyrolysis unit.

Char

Initial pot trials as well as the existing literature on char as a soil amendment and conditioner hold significant potential for the development of a NPK infused char material. Further research will identify the specific regimen for creating valuable agricultural char material through the pyrolysis process.

Feedstock Requirements

Organic feedstock must be conditioned to a uniform size (ideally not more than 4 square inches) and have reduced moisture content prior to being introduced to the pyrolysis process. Optimum size will vary but the moisture content must be no higher than 15% moisture in order to meet the energy requirements for the operation. Feedstock sources can be many and varied with bull, cow, chicken and turkey manure being a prime consideration. Other feedstock includes paper sludge, woody waste, mixed solid waste and potentially Biosolids.

Connecting the Dots: How is this Project can Benefit Wisconsin Agriculture

Dairy farms import very large quantities of nutrients by the purchase of fertilizers and feeds. A significant fraction (50-80%) of the nitrogen, phosphorus and potassium in the feed passes through to the manure. Current manure management systems for large dairy farms typically collect the waste in a lagoon, from which the liquid effluent is taken for recycle of nutrients to the land. Anaerobic lagoons are much more common than aerobic lagoons, because of their smaller size. Anaerobic digestion in lagoons reduces the organic content, and a significant amount of the nitrogen is lost as ammonia. Much of the phosphorus content settles to the bottom in a sludge, which must be periodically removed for application to the land.

This practice is unacceptable for larger operations because the nutrient levels involved are too large for the farm land available nearby. Application of the large waste stream leads to excessive quantities of the nutrients in the soil and to surface and subsurface nutrient run-off.

The dairy farms in the Cashton area to be served by the regional waste management system rely predominantly on land spreading to dispose of their manure. Since the area now has excess nutrient loadings, this practice does not allow expansion of dairy operations in the region. The regional biomass conversion system using pyrolysis technology will allow these farms to continue operating and to increase herd sizes by decoupling nutrient production from local land application.

Figures 5 and 6 illustrate the comparison between a traditional land-based manure handling system and an alternative regionalized manure management facility.

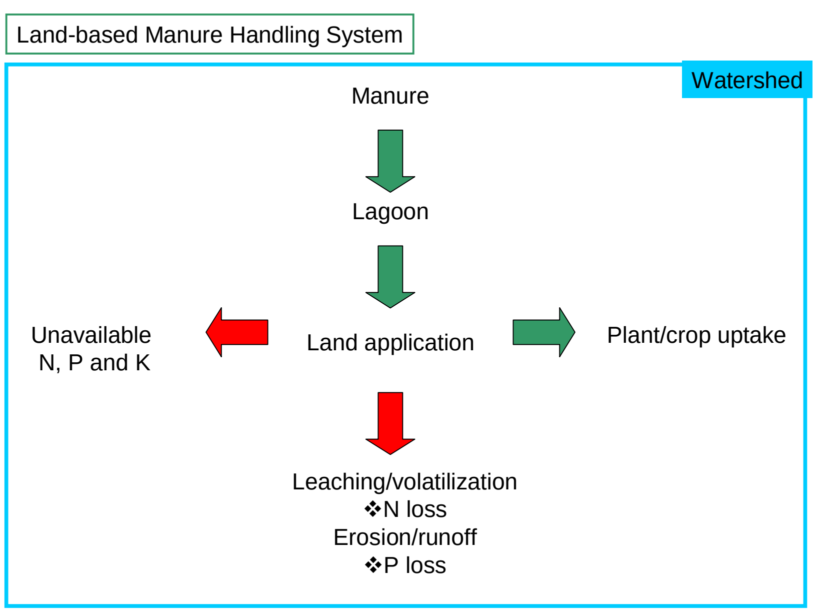


Figure 5. Nutrients in a land-based manure management system are returned to the local land and losses are sustained, leading to water and air pollution.

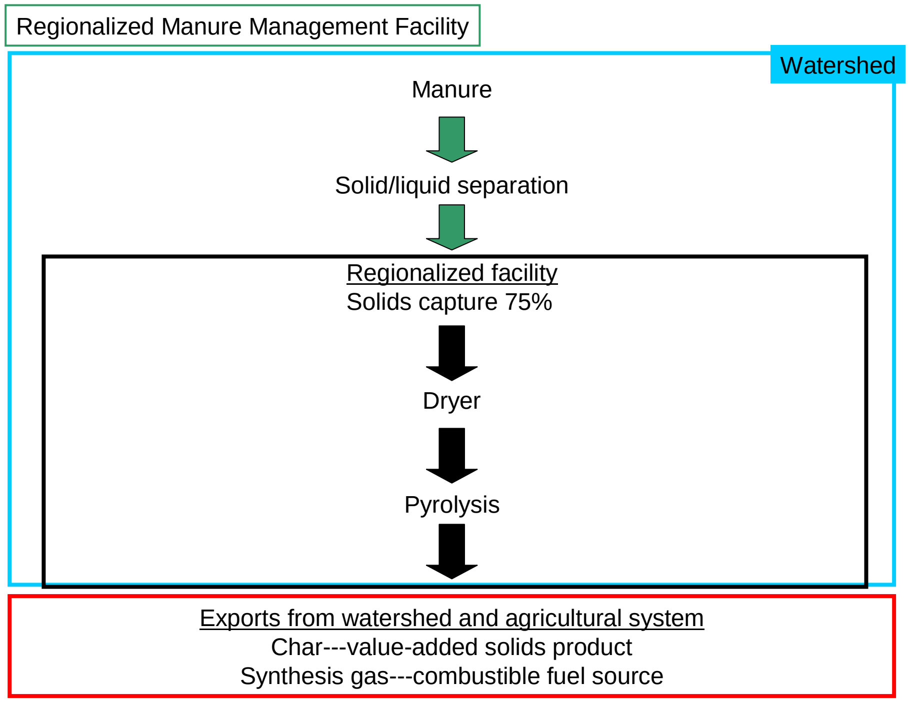


Figure 6. Nutrients in a regional manure management system based on pyrolysis can be efficiently captured and exported from the watershed and agricultural system.

If proven effective and economical, the regional treatment of dairy manure from several farms could liberate the producers to grow their herds, increase economic activity (estimates from the Milk Marketing Board attribute $17,000 in economic activity for each dairy cow in Wisconsin) and not have to purchase or rent additional crop land specific for manure application.

This current project is significant since it represents a substantial decoupling of dairy growth from manure disposal.

Important Steps in the Process
The current ADD Grant was helpful in that it catalyzed significant char and syngas characterization studies to help determine the marketability of each of these by-products of commercial pyrolysis. Once we determined that manure could be safely converted through the pyrolysis process, we then began to characterize the by-products of the conversion process to ascertain value. We continue to pursue this determination of value of the char and syngas through ongoing demonstrations of pyrolysis of bull and dairy manure. Once the syngas and char are thoroughly analyzed and tested for suitability in various uses, we can then scale up the design to a commercially viable biomass processing facility and locate the nation's first Manure Management District in Cashton, Wisconsin.

Challenges
Significant challenges exist in the demonstration of pyrolysis using manure as feedstock. We continue to refine the pyrolysis processing unit especially the hot gas clean up function. Additional work needs to be done on the pre-treatment and conditioning of raw dairy manure prior to pyrolysis including identifying successful de-watering and drying technology. And additional challenges exist in meeting the energy requirements of the biomass conversion facility.