Initiative – Investigating Drying Technologies for Post-Digester Solids

Summary Report
Project AIC 097
April 7, 2011

Kevin Hennessy
Associate Scientist – Co-Products
Agricultural Utilization Research Institute
P.O. Box 251
Waseca, MN 56093
Email: khennessy@auri.org

Purpose

Post-digester manure solids refer to the material left after manure has been processed in an anaerobic digester and passed through a separation process to physically remove part of the water fraction. The Vincent Press or the Fan Separator is often, but not always, used to accomplish this step. However, this still leaves the remaining product at around 65-70% moisture, making it costly to dry down to pelleting or combustion/gasification moisture ranges (in the case of pelleting this is below 18%). The purpose of this initiative is to investigate drying technologies that might make the drying process more economical, and make the use of post-digester manure solids for a fuel or fertilizer viable. The drying of any high-moisture substrate could be substituted for manure solids in many of the dryers that are about to be profiled.

Goal

When drying a material thermally, a theoretical minimum of ~ 980 Btu/lb is perfect efficiency. Various drying technologies claim less than this per pound of moisture removed – all of these methods involve some sort of mechanical removal of water. There are methods also that would use the manure itself as fuel once dried to power the dryer, thus saving on cost of fossil fuel by using what was the low value manure product. The goal of this initiative is to profile these drying systems and accumulate as much information as possible to guide the reader's decision-making if considering use and purchase of these systems.

Investigation into Non-traditional Drying Technologies

Background:

An AURI client who works in the field of biogas called the AURI office in Waseca to inquire about ideas for what could be done with the post-digester manure solids which were accumulating at one of their projects. Earlier in the year the Co-Products lab had successfully pelleted manure solids supplied by a different client. After this discussion, a little brainstorming, and some internet research, a few options appeared to exist that could possibly dry post-digester manure solids in such a way that the economics could be more favorable than previously thought.

Considerations:

Efficiency: whether or not a drying system is practical depends in large part on efficiency. Whether or not a drying system will save the user money in the long run will depend on its cost to use and maintain. Drying systems that claim half the Btu/lb of water removed of traditional drying systems, which average 1,600-2,200 at best, show promise of improved efficiency.

Throughput: efficiency aside, not every drying system will be able to keep up with the throughput of a system with which it needs to be integrated. Should manure solids be produced at a rate that exceeds the capacity of the dryer the wet solids would have to be stored until they can be fed to the dryer, which is often not practical. Throughput will often be a necessary consideration in choosing a drying system for a particular application.

Capital Investment: how much a system costs will determine the payback that can be predicted due to increased efficiency. The investment cost and payback time can often be the limiting factor, especially when taking the chance with newer, untested equipment that has yet to become widespread commercially.

Total Power Requirements: the need for electricity to run a system can be a limiting factor for a drying project. Total electricity needs can also increase the cost of a project when it is replacing an otherwise cheaper energy source, such as natural gas.

The author will make an attempt to address these three concerns as the various drying technologies are discussed below. The only exception to this is pricing on the dryers, which will need to be obtained from the dryer manufacturer.

The Dryers

Dryers that Participated in AURI Dryer Demo Days:

Tempest Air Dryer, Marion Mixers, Marion, Iowa

Dryer Name:	Tempest	**Dryer Type:**	High speed air
Company:	Marion Mixers, Greg Stover		
Company Address:	3575 - 3rd Avenue, Marion, IA 52302		
Company Website:	www.marionmixers.com		
Company Phone:	(319) 377-6371		

Efficiency:	
Btu/lb water removed tested:	800
Btu/lb water removed claimed:	310.62 (with new 1 ton electrical unit with eductor)
	764.10 (with Big Blue unit)

Power requirements:	
Total horsepower:	600 (Big Blue unit; powered by diesel)
Horsepower notes:	

Maximum throughput (wet tons):	1 per unit
Biomass tested:	Pulp and paper, biosolids, animal manure, DDG's, others.

In June of 2009, I visited Eldora, Iowa, with a group interested in drying post-digester solids. A number of barrels of solids from a Fan Separator located at Jer-Lindy Dairy in Brooten, Minnesota, were brought along for testing.

Testing was done on what GRRO Technologies refers to as their "Big Blue" unit. Big Blue is run with diesel fuel and a Caterpillar engine. No energy numbers were collected as part of the demonstration. Manure was fed into the unit via a conveyor belt at around 65% moisture and returned out of the unit at around 11% moisture – this being done in one pass. See pictures 1,2 and 3.

Picture 1: ~65% moisture post-digester solids being fed into Big Blue unit using conveyor

Picture 2: ~11% dried product exiting Big Blue unit.

Picture 3: Global Resource Recovery Organization's "Big Blue" dryer, June 9, 2009.

GRRO also has a unit installed at Johnson Gas Appliance Company, Cedar Rapids, Iowa. This unit has undergone extensive testing, with the energy consumption averaging about 800 Btu/lb of water removed, according to company officials reporting at AURI's Dryer Demo II. This unit is not mobile and runs exclusively on electricity (see picture 4).

Picture 4: GRRO's Tempest Drying System installation at Johnson Gas and Appliance Company, Cedar Rapids, Iowa.

In the case of the Big Blue unit, drying is achieved by use of high speed air only, with no supplemental thermal energy added. Material tested in June, 2009, exited the dryer at ambient temperature, if not a bit cooler to the touch.

In subsequent work with the unit at Johnson Gas, thermal energy has been used as part of the process to further facilitate drying speed. In tests run with paper sludge in September, 2010, 26 points of moisture were removed in one pass run at a rate of 1,250 wet lbs/hour. At a rate of 2,508 wet lbs/hour 13 points of moisture were removed from the same original wet material.

The unit consists of two chambers, each with its own cyclone. Average throughput for a biomass material using this unit is listed at around 1 wet ton/hour, but depends on the degree of drying which is desired, as well as the material being dried. Additional throughput is achieved by adding additional units. An added benefit or detraction, depending on the desired state of the dried product, is that the dryer mills the material to a

smaller particle size due to the high speed collision of particles which the system subjects material.

In November of 2009, GRRO entered into an agreement with Marion Mixers in Marion, Iowa (near Cedar Rapids, www.marionmixers.com). Marion Mixers is working aggressively in supporting technical improvements to the Tempest. Marion is now in charge of worldwide sales and marketing of the dryer, with a goal of releasing a dryer capable of processing 2-5 wet tons of product per hour. Interested persons can contact Director of Sales and Marketing Development Greg Stover with any questions about new advances to this technology.

Industrial Microwave Drying System, Cellencor Corporation, Ames, Iowa

Dryer Name/Type:	Industrial microwave, 915 Hz
Company:	Cellencor Corporation
Company Address:	Iowa State University Research Park, 2325 North Loop Drive, Suite 6124, Ames, IA 50010
Company Website:	www.cellencor.com
Company Phone:	(515) 296-4213

Efficiency:	
Btu/lb water removed tested:	1377
Btu/lb water removed claimed:	900-1100 depending on product dried.

Power requirements:	
Total Kw:	1,100 for 1 MW unit.
Power requirement notes:	Almost all of the MW energy is transferred to the product.

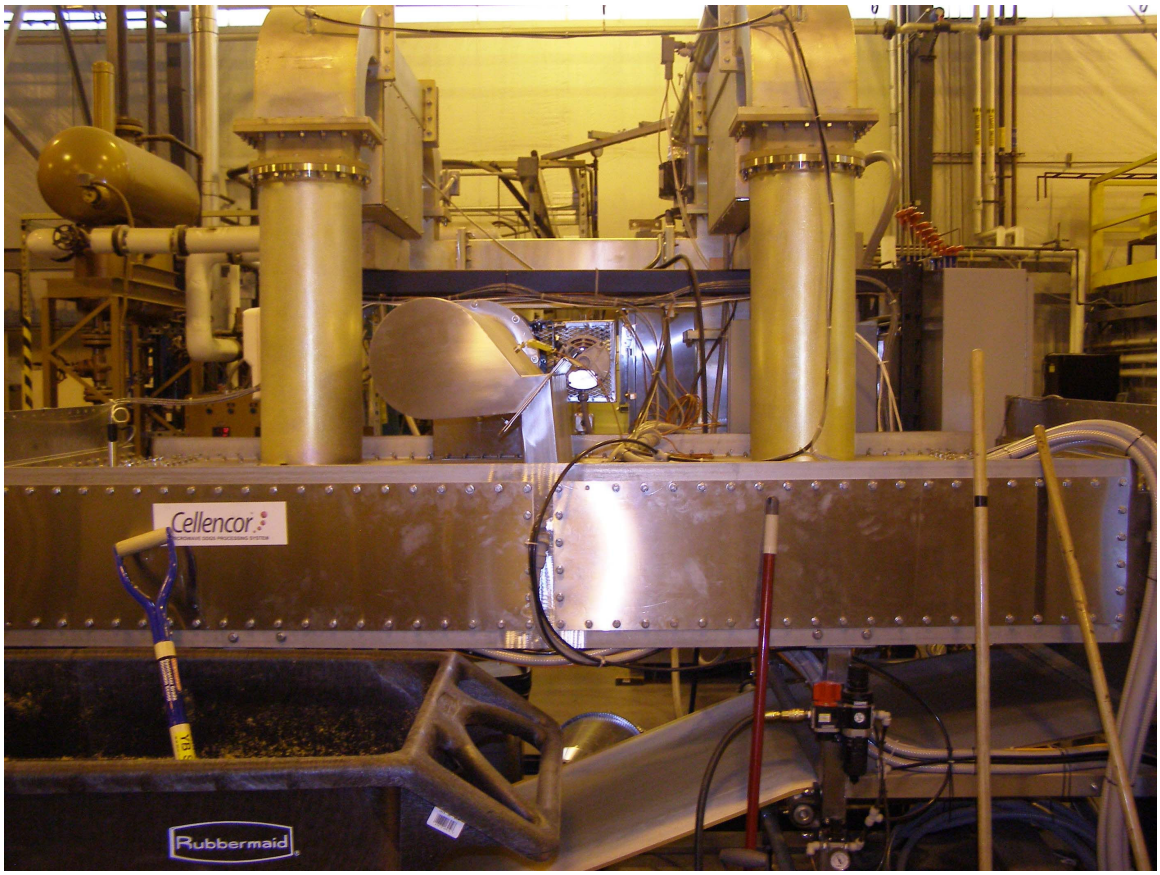
Maximum throughput (wet tons):	75 tons/day DDGS, from 65% to 10% MC using 1 MW system.
Biomass tested:	DDGS, sugar beet pulp, wood byproducts, ethanol solubles.

AURI has previously researched the microwave drying systems of Cellencor Corporation in its 2009 initiative Microwave Drying of Beet Pulp: (http://www.auri.org/research/Microwave%20Drying%20of%20Wet%20Beet%20Pulp%20Initiative%20Final%20Report%20%206-4-09.pdf).

In this initiative beet pulp was dried and the system was evaluated for efficiency and for the improvement in feed value resulting from drying in a system that is less harsh than thermal drying would be.

Post-digester manure solids were not tested on the microwave unit, but the use of the microwave system on such material would be straightforward and similar to the testing of wet beet pulp. In our beet pulp tests the best run produced a number of 1,377 Btu/lb of water removed, with an overall average of 1,581 for all runs. Cellencor claims efficiency can be as low as 1000 Btu/lb of water removed and that this has been achieved with testing of DDGS in a larger pilot-scale unit. As relates directly to this initiative, the feed

value of post-digester solids is not an issue – rather efficiency and throughput rates would be key factors.



Picture 5: Cellencor Corporation's 75 kW test unit at the Becon Center in Nevada, Iowa. Testing with this unit was performed for AURI on wet beet pulp and results of that initiative "Microwave Drying of Wet Beet Pulp" can be found in the research section at www.auri.org.

Cellencor Vice-President Ken Kaplan presented at AURI's Dryer Demo I in Benson, Minnesota on May 13, 2010. In that presentation, using DDGS as its example, Kaplan said a microwave system would generally use 900 – 1,100 Btu/lb of water removed depending on the product characteristics, and that a 1,000 KW system could dry 75 wet tons/day of DDGS from 67% to 10% moisture content in a 24-hour period.

Cellencor prefers to consult with clients on requirements and goals before specifying and pricing out systems for specific applications.

In the interest of fairness, I must add that Cellencor's technology is the only technology in this document where efficiency numbers were verified directly. The numbers list here, collected during the previous initiative, were obtained using the test unit pictured above.

Manure Burning Drum Dryer, Van der Geest Dairy, Merrill, Wisconsin

Dryer Name/Type:	Manure Fired Drum Dryer
Company:	Energy Unlimited, Inc./Installation at Van der Geest Dairy, Merrill, WI
Company Address:	P.O. Box 7, 4881 Highway YZ, Dodgeville, WI 53533
Company Website:	www.energyunlimitedinc.com
Company Phone:	(608) 935-9119

Efficiency:	
Btu/lb water removed:	1800 (standard for triple-pass rotary drum dryer)

Power requirements:	
Btu to power system:	15M for Van der Geest system at 4 wet ton/hour
Power requirement notes:	10hp motor rotates drum; 50 hp fan - both from Van der Geest installation.

Maximum throughput (wet tons):	4 at Van der Geest installation.
Biomass tested:	Animal manure, wood by-products

I visited Van der Geest Dairy, Merrill, Wisconsin, on August 21, 2009. Van der Geest Dairy does not operate an anaerobic digester, but does use and sell its manure solids for bedding with the solids dried to about 20% moisture for the bedding stream. Pictures 6 and 7 were taken during the visit that day.

Van der Geest's process begins with water removal using two Vincent presses that have been installed at the facility. The resulting material at the typical 65-70% moisture level, is dried to 10%, then used as fuel in the drying system. The water removed with the Vincent Presses is piped into the soil to fertilize the fields.

Estimates from Energy Unlimited, Dodgeville, Wisconsin, the company that installed the equipment at Van der Geest, is that two parts manure are dried for every one part used as fuel. Using the 65% moisture number and a wet ton as our beginning weight, then there would be 700 pounds of manure solids in the wet ton, or 778 pounds of material when dried to 10% moisture. One-third of that is 259 pounds, leaving the other two-thirds dried to 20% as 583 lbs. to be used as bedding.

Van der Geest Dairy Cattle, Inc.'s Fall 2008 Newsletter sums up their investment in the drying system:

The dryer is very important to our business. It saves over 4000 loads of treated waste that would have to be transported on town roads also while saving 14,000 gallons of diesel fuel per year. It also saves our operation from purchasing over 300 semi loads of bedding per year which cost approximately $1800 per load. The bedding product is a sterile dry product which we have found that our cattle prefer over any other bedding product supplied. Once again we are trying to keep our cattle comfortable at all times.

Picture 6: Van der Geest Dairy's installation of a Heil triple-pass rotary drum dryer fueled with ~10% moisture dried manure product. The burning chamber is the upright cylinder to the left; the rotary drum dryer is orange and center; the hopper feeding dried manure is grey and right; upright cyclone and structure to the right/back are part of the processes for storing manure solids to be used for bedding, dried to ~ 20% moisture.

Picture 7: Van der Geest Dairy: a baghouse with 376 polyester bags is needed to control particulate levels well enough to meet DNR requirements for the dryer's emissions.

Kinetic Disintegration System (KDS), Minnesota Valley Alfalfa Producers, Priam, Minnesota

Dryer Name:	Kinetic Disintegration System	**Dryer Type:**	Grinder
Company:	First American Scientific Corporation		
Company Address:	201-30758 South Fraser Way, Abbotsford, BC CANADA V2T6L4		
Company Website:	www.fasc.net/		
Company Phone:	(604) 850-8959		

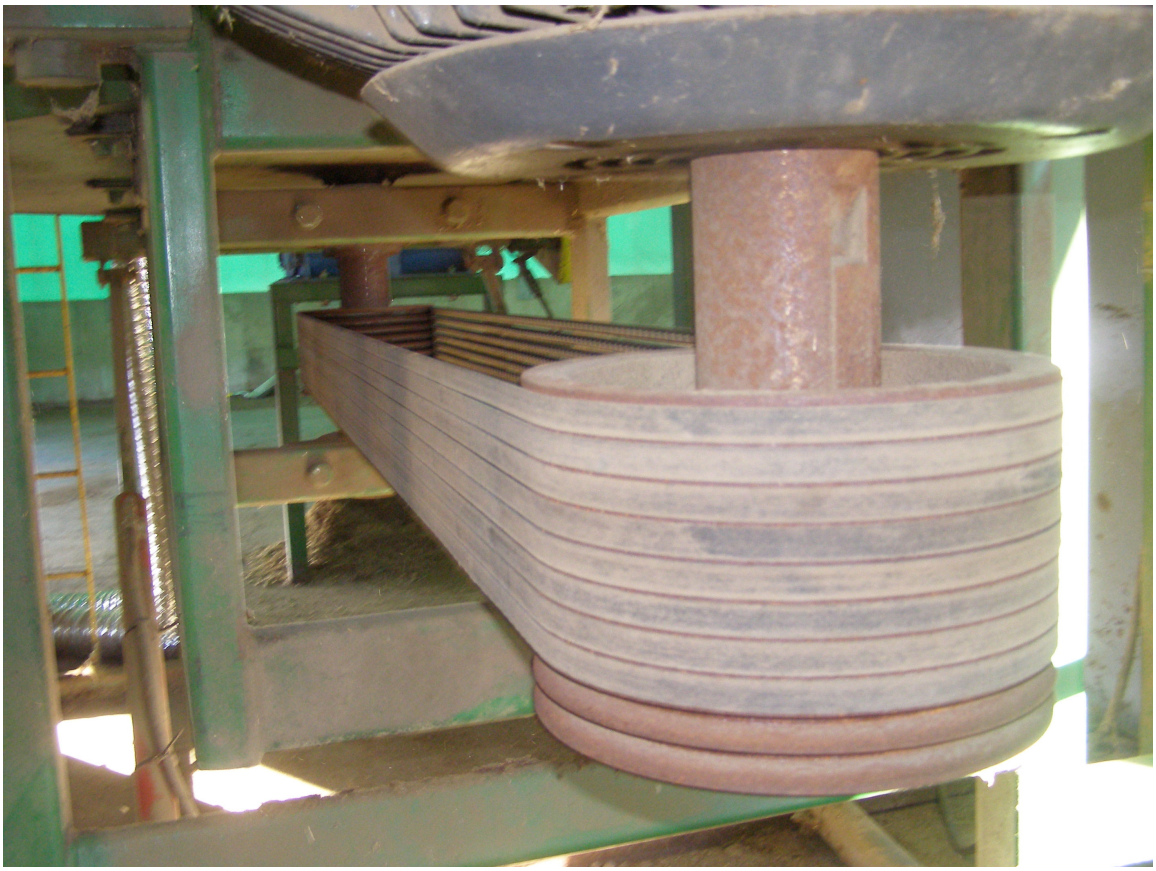
Efficiency:	
Btu/lb water removed tested:	Not tested at MnVAP.
Btu/lb water removed claimed:	See chart in text.

Power requirements:	
Total horsepower:	407 for 6 drive motors including 350 hp main motor (per company representative, single unit)
Horsepower notes:	350 hp motor with 75 hp blower at MNVAP

Maximum throughput (wet tons):	2 with 500 hp motor starting at 20% moisture content
Biomass tested:	Bagasse, animal manure, wood chips/bark, biosolids

Pictures on the following pages (pictures 8 and 9) are from the tour during AURI's Dryer Demo II on November 4, 2011, in Willmar, Minnesota. The KDS is a product of First American Scientific Corporation (FASC), with corporate headquarters in Abbotsford, British Columbia, Canada. The machine is actually a grinder, which through kinetic energy of high speed particle collisions, and the heat produced by the friction of grinding material, dries the material as it grinds.

Picture 8: KDS Machine at MNVAP, Raymond, Minnesota.



Picture 9: KDS from underneath.

The KDS internal chamber has a diameter of 1.3 meters and encloses a set of 8 spinning chains with a stationary torus above it. The motion of the chains, moving at a speed at the tips of up to 200 meters/second, not only serves to pulverize material but also heats up the air in the chamber.

The unit at MNVAP has a main motor with 350 hp. A 440 volt line is needed to power the KDS. In addition to the motor there is a 75 hp blower fan motor. At a starting value of 20% moisture they have been able to get approximately 1.5 ton/hour throughput. They have been told that installing a 500 hp motor on the unit would increase throughput by 0.5 ton/hour. The KDS is currently the bottleneck in the overall process throughput. Material up to 2 feet long has been run through the KDS with no ill-effects.

Speaking with a FASC representative, it was disclosed that the KDS uses less energy when reducing the moisture content in a material that starts with lower moisture. The numbers presented to us are listed in table 1.

KDS Energy Numbers	
Range (% moisture)	btu/lb
50-10	683.1
40-10	512.3
30-10	341.5
20-10	256.1

Table 1: KDS energy numbers based on starting moisture and intended drying range.

The company website claims the KDS can dry material up to 70% in moisture and reduce it to as low as 5%. Production rate is listed at 1-4 tons per hour (depending on material characteristics). Particle size can be controlled from less than 45 micron up to 1000 micron (2 mm).

Tri-Phase Drying Technologies, LLC, Norwalk, Iowa

Dryer Name:	Tri-Phase II	**Dryer Type:**	Air circulating
Company:	Tri-Phase Drying Technologies, LLC		
Company Address:	340 Wright Rd., Suite H, Norwalk, IA 50211		
Company Website:	www.triphasedrying.com		
Company Phone:	(515) 468-3923		

Efficiency:	
Btu/lb water removed tested:	No data; testing of first install to begin soon.
Btu/lb water removed claimed:	500-600

Power requirements:	
Total electric:	Dependent on air convection dryer used; size of system.
Electric notes:	Input needs are for heat pump, blowers.

Maximum throughput (wet lbs.):	System is sized to needs.
Biomass tested:	Limited testing – will work with a wide variety of materials.

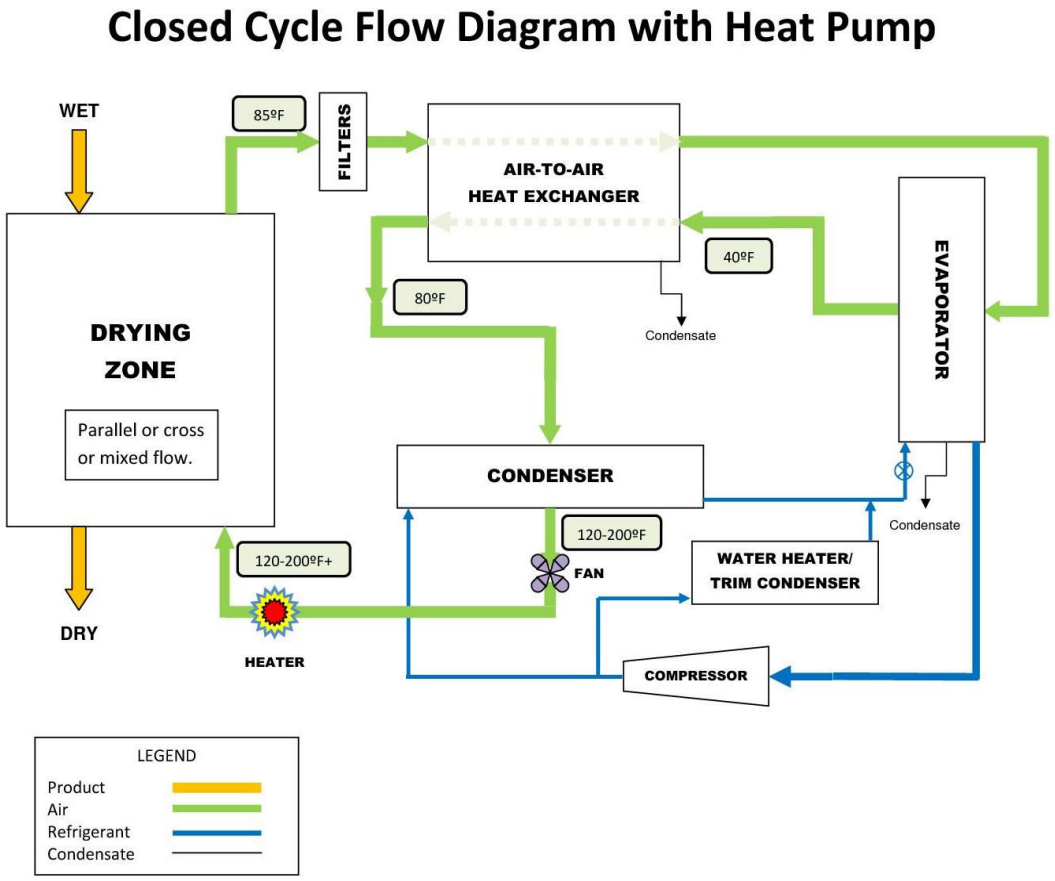
Tri-Phase Drying Technologies' President Steve Shivvers was one of the four presenters at AURI's Dryer Demo I on May 13, 2010 in Benson, Minnesota. His company's system uses existing air circulating dryer technology, and is innovative in the sense that it utilizes a heat pump to reduce the use of input energy (in this case electrical energy primarily for blowers and a heat pump). The heat pump's fluid is used in a heat exchanger to warm circulating air up to 200°F (see diagram in picture 10). The system can be retrofitted to many types of existing dryers (the current brochure has listed rotary drum, belt conveyor, fluidized bed and vertical cascade as examples).

The heat pump is run by a compressor, moving a refrigerant between two sides of the process. On one side is the condenser coil, where the refrigerant condenses and gives up heat to the surroundings. This energy is used to heat circulating air entering the dryer. On the other side is the evaporator coil, which evaporates the heat pump's liquid

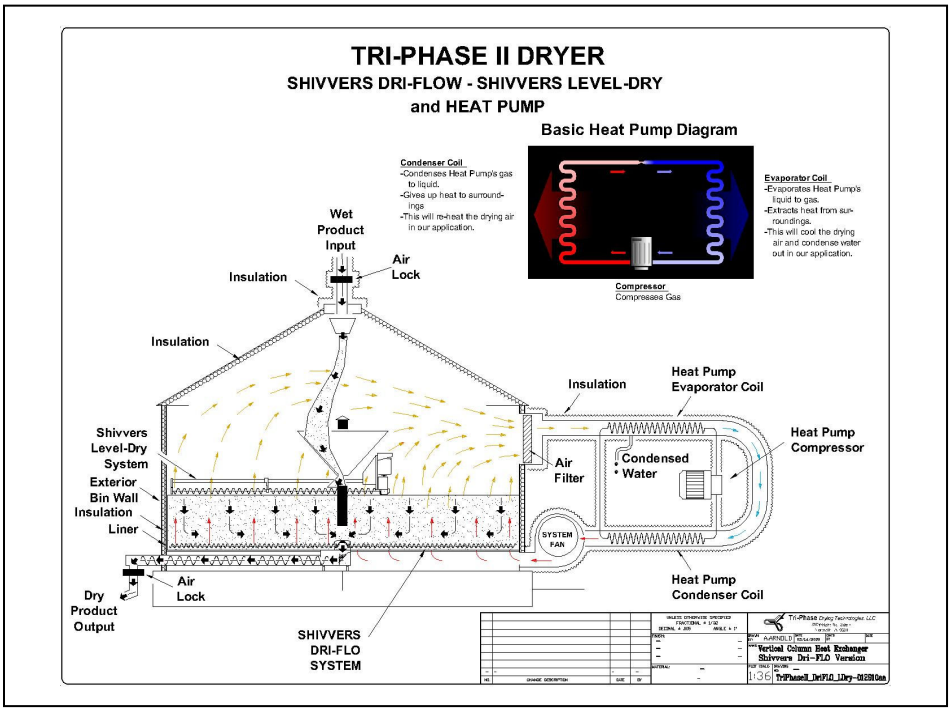
returning from the condenser coil to a gas. The evaporator coil extracts heat from its surroundings. This cool liquid will cool exhaust drying air and condense water from the material. The refrigerant then moves back to the compressor to begin the cycle again. Electric energy is needed to run the refrigerant pumps, the fans used to circulate air through the system, and any other mechanisms requiring electricity, such as feeding augers. The input energy required equates to an estimated 500-600 Btu/lb. of water removed from product.

Besides retrofitting systems the company also is marketing their own system, the Tri-Phase II. The Tri-Phase II system uses a Shivvers Grain Dryer Level-Dry system (see picture 11 for a diagram of this system). A unit at American Natural Soy in Cherokee, Iowa, is the first commercial installation of this system. Any material that can be augered, which includes most biomass materials, including post-digester manure solids, could be dried in such a system.

Mr. Shivvers has many years experience in the grain drying business, with his family's business being Shivvers Grain Dryers (http:\www.shivvers.com). The company has over 40 years experience in the grain drying business, and was first to introduce in-bin counter-flow drying and computer controls for grain drying.



Picture 10: The Tri-Phase drying process (diagram courtesy of Steve Shivvers).



Picture 11: Shivvers Level-Dry System using heat pump technology (diagram courtesy of Steve Shivvers).

Algaeventure Systems, Marysville, Ohio

Dryer Name:	AVS SLS (solid-liquid separation)	**Dryer Type:**	Belt
Company:	Algaeventures Systems		
Company Address:	13311 Industrial Parkway, Marysville, OH 43040		
Company Website:	www.algaevs.com		
Company Phone:	(937) 645-4604		

Efficiency:	
Btu/lb water removed tested:	No data
Btu/lb water removed claimed:	0.12 per calculations on website (for motor that drives belt)

Power requirements:	
Total electrical:	30 inch wide industrial model in production uses 115V, 15A
Electrical notes:	Electricity for pneumatics (blow off flakes, drive belt) to be added

Maximum throughput (wet tons):	No data at this time
Biomass tested:	Algae, ethanol solubles, manure slurries, other dilute slurries

Although not directly applicable to a feedstock like post-digester manure solids after running through a Vincent Press or Fan Separator, the SLS (solid-liquid separation) from Algaventure Systems (AVS) is a unique dewatering/drying system. Ideal for very dilute slurries such as algae solutions (which can be as low as 0.5% solids), this belt drying system could be a very low-energy consuming answer for water removal from many potentially difficult products.

The author had occasion to visit Marysville, Ohio, in November, 2009. AURI shipped a bucket of thin stillage starting at around 12% solids. Picture 12 below shows a test run on what was then AVS' benchtop unit (at that time the HDD – Harvest, Dewater and Dry platform) as the material moved up the belt from below (wet material in well, background) toward the foreground (dry material beginning to flake).

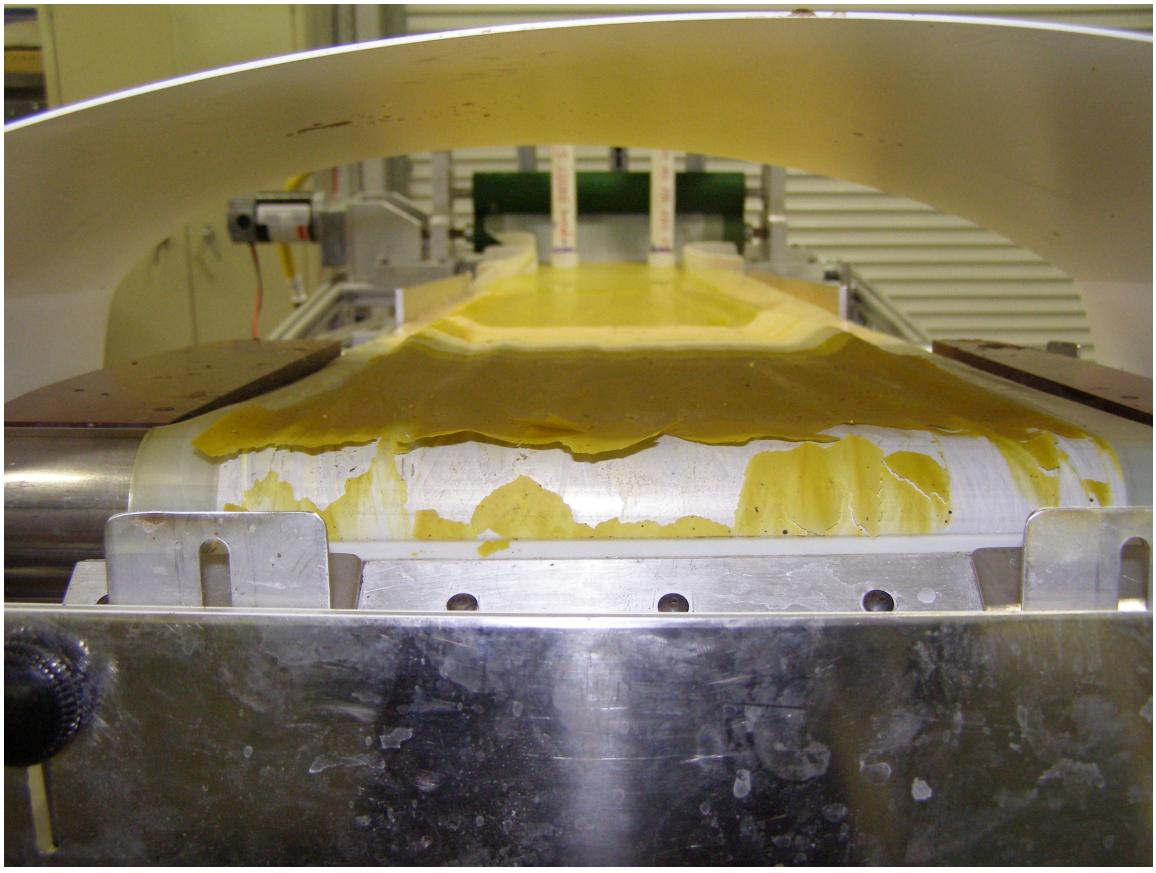
The device removes water primarily via capillary action. The system is composed of two belts – a lower belt is a wicking belt (see picture 13 below), which is colored orange and is made from a commercially-available absorbent material; on top is a belt made of a filter material with a defined pore size. The filter belt needs to have opening small enough to hold solid material, but large enough to allow water to be wicked by the absorbent belt below. The two belts are run in opposite directions – the filter belt toward the top and the absorbent belt toward the bottom. Water is squeezed from the absorbent belt as it makes its loop around the system (see picture 13).

For the testing done with the thin stillage, the material started at 88% moisture. Material travelling up the belt and flaking off was dried to 2.4% moisture in the single pass. No external heat source was used for this test. The resulting dried product was a bright yellow color (see picture 14).

Much progress has been made with the unit since my visit to Marysville, and also since CEO Ross Youngs presented in Benson at Dryer Demo I. An AlterE (DBA of AVS) SLS

Lab model and a Production-Scale SLS System are both currently listed on the company's website. The Production model claims to be able to process hundreds of gallons per day of dilute algal solutions (3-20 g/l) and dewater to 25-30% solids. Filter belt size is available in a range from 1 to 700 micron.

An additional advantage of SLS dewatering is the manner in which the system applies the solid "cake" for drying. The SLS dewatering process results in a very thin cake spread evenly across the belt, significantly increasing the ratio of surface area to cake weight. This adds value by taking advantage of natural evaporation and reduces the dependence on external heat required for vaporization.



Picture 12: Thin stillage from Al-Corn ethanol plant in Claremont, Minnesota, as it moves up the dewatering belt of AVS' early prototype of the SLS.

Picture 13: The underside of the former AVS SLS model, where the adsorbent belt (orange) is wrung out after wicking water from the bottom of the filter belt.

Picture 14: Dried ethanol soluble with bright yellow color fail to show darken color associated with scorching.

Dryers viewed by author, but not part of Dryer Days or seen in operation:

Rotary Biomass Dryer, Lynnwood, Washington

Dryer Name/Type:	Rotary Biomass Dryer	**Dryer Type:**	Compression
Company:	Biogas Technologies, LLC		
Company Address:	1031 - 200th Street SW, Lynnwood, WA 98036		
Company Website:	www.bio-gastech.com		
Company Phone:	(206) 963-6775		

Efficiency:	
Btu/lb water removed tested:	350-750 (per Colorado engineering firm)
Btu/lb water removed claimed:	~ 400 with dairy manure solids

Power requirements:	
Total hp:	Units installed vary now from 150-350 hp depending on throughput desired.
Power requirement notes:	Hp-throughput examples: 1.5-2 tons/150 hp; 4 tons/350 hp

Maximum throughput (wet tons):	1-10 per hour presently, scaled to application.
Biomass tested:	Animal manures, sawdust, municipal solid waste (minus glass, metals), multiple crop residues including bagasse.

My firsthand contact with the Rotary Biomass Dryer was at an installation in Emily, Minnesota (see picture 15 and 16). The dryer was installed at the site of Pallet Minnesota, owned and operated by Dan Heggerston. At Heggerston's site, the dryer was to dewater "heritage sawdust" – sawdust on the site from an old saw mill that has been piled up for years but still retains its properties for energy, with little to no microbial deterioration. On the site also was a ram briquetter manufactured by C.F. Nielson (http://www.cfnielsen.com/) and owned and operated by Renew Energy Systems, St. Ansgar, Iowa that was to densify the dried product (see picture 17 and 18). Besides the sawdust there were plans to dry and briquette dairy solids and corn stover at the Emily site. Corn stover was briquetted for the University of Minnesota Morris gasifier but did not require drying.

According to Craig Ferrell, Biogas Technologies' President, the dryer is being tried in a number of sites on various products and installed in others. These projects include:

Picture 15: The exit point of the Rotary Biomass Dryer.

Picture 16: The other side the Rotary Biomass Dryer. On the left is where material feed into the dryer.

Picture 17: The twin-screw ram briquetter, manufactured by C.F. Nielson, that was located on the site of Pallet Minnesota in Emily, Minnesota.

Picture 18: The C.F. Nielson ram briquetter was located in the gray shed to the right, rear. Briquettes travel the entire yellow line into the foreground left. Material that feeds the briquetter enters through the orange conveyor to the rear over the gray shed.

- Crave Brothers farm, Waterloo, Wisconsin, is using the Rotary Biomass Dryer to dewater post-digester manure solids from 65-70% moisture down to around 50% to use for bedding. Throughput is 1.5 - 2.0 tons per hour using a dryer equipped with a 150 hp motor.
- Dane County, Wisconin, operates a manure processing facility. At that site they use a dryer with a 350 hp motor to dewater four wet tons per hour to 50% moisture. The solids from that facility are used as bedding for local farmers and also upgraded and sold as a premium potting soil.
- Sealander Waterworks, Rock Island, Quebec, Canada, has a dryer installed that is part of a renewable energy demonstration site.

- Renew Energy Systems, St. Ansgar, Iowa (www.renewenergysystems.com), has a dryer they are using with fresh cut sawdust, taking it from 45% moisture down to 10/15%. Their dryer uses a 250 hp motor and they are expecting throughputs of 1.5 to 2.0 wet tons per hour – enough to feed two ram briquetters.

This dryer works by compressing the material against a unique compression ring that allows the steam and biomass to leave under pressure. Tension on the compression ring can be adjusted for different biomass moisture contents.

Other Dryers Researched:

Other High Speed Air Dryers

Two other high speed air dryers were discovered over the span of this initiative.

Whirl-Away Drying Systems, LLC, RR1, Box 745, Marietta, OK 73448, Phone: (580) 826-6019 (www.whirlawaypad.com).

Originally referred to as the PAD (pulverizing air dryer) by Gulftex, WhirlAway's PAD is a dryer similar to the Tempest described earlier in this report. While operated under the name Gulftex, this dryer had a trial at Chippewa Valley Ethanol Company between July 1, 2002 and June 30, 2003. Many improvements have been made since that time according to company spokesperson Clay Dingee (who I was able to speak with by phone). The demonstration work with this dryer is being done primarily in the south and we were not able to schedule another trial in Minnesota while working on this initiative. Biomass that has been processed, in addition to animal manures include municipal waste, paper sludge and crustacean (per the company's website).

The PAD consists of two blowers and 4-8 cyclones, according to information published by Biovalor, the PAD licensee for Europe. Impressive examples include the drying of paper sludge, starting at 68% moisture, down to 11% and chicken manure from 76% MC to 24%, both using only 152 Btu/lb of water removed (translating from 89 kW-hr per ton). Input moisture content is listed as high as 85% with end MC feasible below 10%. Size reduction, thus saving on milling of biomass should it be necessary, is also touted as a secondary benefit of the PAD.

PulverDryer USA, Inc., 5541 King Highway, Kalamazoo, MI 49058 (mail to P.O. Box 6, Comstock, MI 49041) (www.pulverdryerusa.com).

I was unable to contact a representative from this company. The website is fairly complete (minus a contact phone number) with animations of a three-stage and a batch unit.

Air Flow Dryers

Turbo-Dryer, Wyssmont Company, Inc., 1470 Bergen Boulevard, Fort Lee, NJ 07024, Phone: (201) 947-4600 (www.wyssmont.com).

The Turbo-Dryer gets its name from the stacked trays, which slowly rotate and allow material to be in a thin layer on a tray, and then drop from top to bottom trays while air flows over the layer of material being dried. The company website lists a wide variety of materials as having been tested, quite a number being specialty chemical applications but biomass is mentioned including corn cob and manure.

Farmer Automatic of America, P.O. Box 39, Register, GA 30452, Phone: (912) 681-2763 (www.farmerautomatic.com).

Although this German-based company appears to be primarily focused on poultry farming, the brochure on their website for the belt drying system states the drying systems can be adjusted to any "type of the wet organic biomass." A belt dryer and an overhead dryer have brochures on the website – the overhead dryer appearing to be part of a chicken housing system, and the belt dryer being flexible to various biomass types, with a unique belt system used to maximize air flow around the material being dried.

The website also lists pelletizing systems and egg moving systems.

Feedstock Powered Combustion System for Dryer Hot Air Source

King Coal Furnace Corporation, 1270 Beech Street, IGOE Industrial Park BLDG #5, Bismarck, ND 58504, Phone: (701) 255-6406 (www.kingcoal.com).

Late last summer Agweek published an article detailing King Coal's biomass powered combustion system (www.agweek.com/event/article/id/16956/). The system can take any biomass material as long as its particle size is less than one inch. The article tells of two installations – one to be built in Canada; the other in Mentor, Minnesota.

In speaking with company president Mike Robb, I found another installation to be American Peat Technology in Aitken, Minnesota. American Peat has a 24 million BTU system in place they are used to dry peat – a material known to hold onto water. Robb also related other partnerships in the works which will hopefully be detailed at AURI's Biomass Dryer Discussion Group on Yahoo, to be addressed later in this paper. Another unit has been shipped to a brewery in Alaska, where the heat will be used to produce process steam from distiller's grains produced by the brewery.

The unique feature of King Coal's combustion system is the self-cleaning stoker. This allows any biomass material to be used – so long as the particle size is 1" or less. The system is also computer controlled with the feed rate being adjusted to the number of BTU output needed from the furnace. King Coal makes the entire system including the

heat exchanger used to heat the air for drying purposes in an indirect heating system. Their unit can also be used for direct heat, depending on the nature of the application.

AURI's Dryer Demo Days

AURI held two events centered around this initiative, both going under the title of Dryer Demo Day. A summary of each is listed below.

Dryer Demo Day, Thursday, May 13, 2010, McKinney's Restaurant, Benson, MN

Drying companies represented:

Global Resource Recovery Organization (original manufacturer of the Tempest dryer); Presenter: Bill DeJong
Algaventure Systems; Presenter: Ross Youngs
Cellencor Corporation; Presenter: Ken Kaplan
Tri-Phase Drying Technologies LLC; Presenter: Steve Shivvers

The dryer demonstration in the afternoon was of the diesel-powered Tempest dryer mobile unit (Big Blue), tested with Chippewa Valley Ethanol Company's corn cobs and Riverview Dairy's post-digester manure solids.

Dryer Demo Day II, Thursday, November 4, 2010, 14th Avenue Grill and Lounge, Willmar, MN.

Drying companies represented:

Marion Mixers; Presenters: Greg Stover and Bill DeJong
Energy Unlimited; Presenter: John Lundell
Minnesota Valley Alfalfa Producers (and the KDS): Presenter: Keith Poier

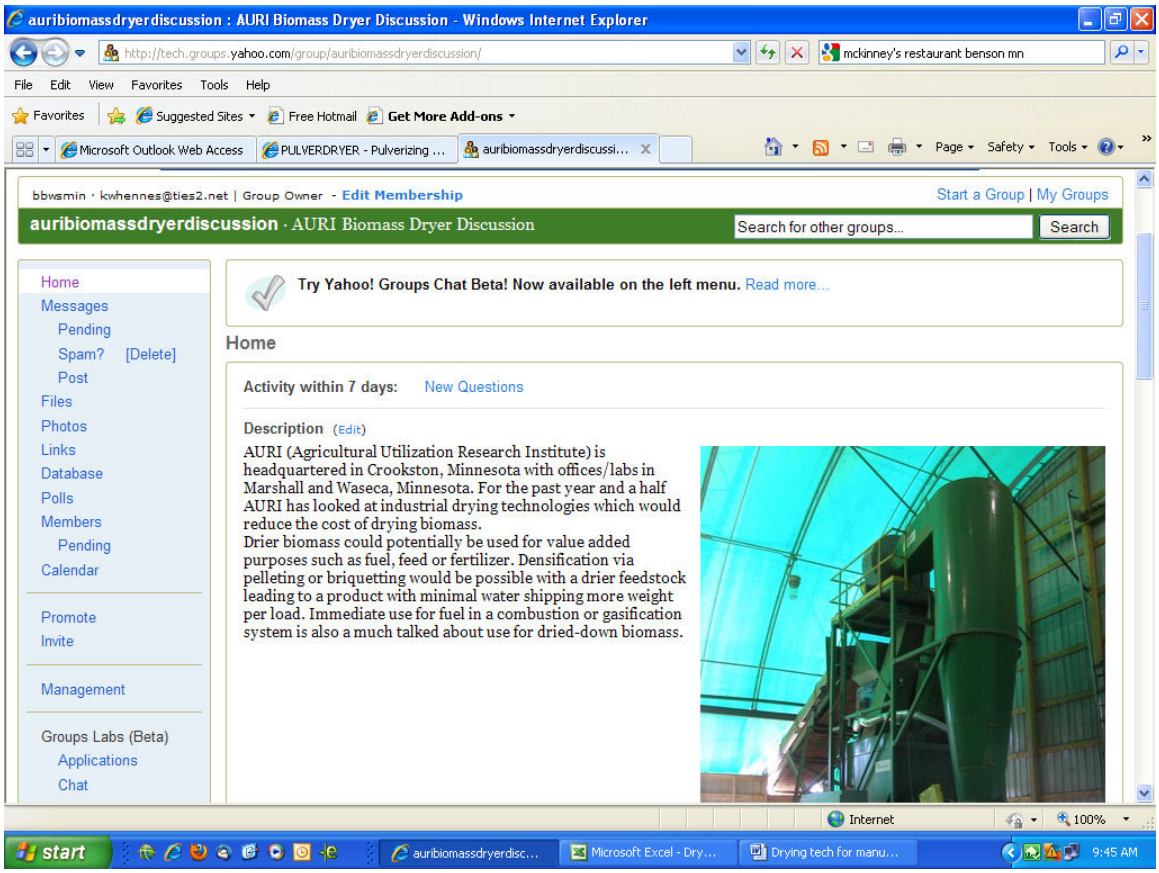
The dryer demonstration in the afternoon was of the Kinetic Disintegration System (KDS) installed at Minnesota Valley Alfalfa Producers in Raymond, Minnesota.

The dryer demo days were used to pilot AURI's new Innovation Launching Pad process (ILP), which in this case was used to allow equipment users and dryer companies an opportunity to get together to facilitate technology adaptation.

Yahoo Group: AURI Biomass Dryer Discussion

As a follow-up to the two AURI Dryer Demo Days, a Yahoo Group was initiated to allow the discussion to continue that was the topic of this report. You can find the group on the Worldwide Web here:

http://tech.groups.yahoo.com/group/auribiomassdryerdiscussion/



You must sign up with Yahoo to get access to the group, but the Yahoo process and the group usage is free. It is hoped that the group will help facilitate further interest in efficient biomass drying. Future updates and discussion of biomass drying technologies will occur here.