University of Maine Orono Forest Bioproducts Research Institute

An Overview of Cellulose Based Technologies to Recycle/Reduce Solid Waste

April 9, 2015

Toxics Use Reduction Institute (TURI) Planner's Conference

Doubletree Inn, Bedford, MA

Presenter: Sandra J. Wyman, P.E.

sandra@p2star.com

www.linkedin.com/in/p2consulting

Technology Research Center

Pulp Mill

1865 THE UNIVERSITY OF MAINE

Forest Bioproducts Research Institute

Technology Research Center

the city of Old Town, Maine

FBRI

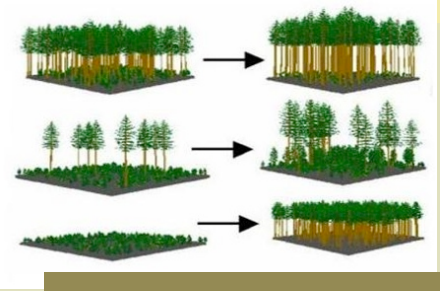
Mission

- To advance understanding of the scientific underpinnings, system behavior and policy implications for the production of forest-based bioproducts.
- To provide and promote technology validation and partnerships that will meet societal needs for materials, chemicals and fuels in an economically and ecologically sustainable manner.

FBRI – "Serving societal needs by bringing sound science to commercial viability"

FBRI
FOREST BIOPRODUCTS

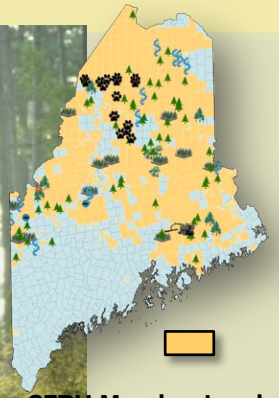
Ensuring Sustainability of Forest Bioproducts



Better Models for Predicting Biomass Supplies

Improving Biomass Harvesting & Transportation Systems

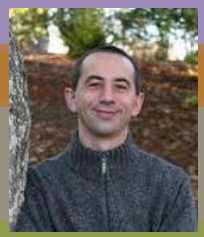
Partnership With Maine's Commercial Forest Landowners (8.5 million acres)



CFRU Member Lands

Assessing Life Cycle Impacts

Understanding Public Perceptions



THE UNIVERSITY OF MAINE

FOREST BIOPRODUCTS RESEARCH INSTITUTE

University of Maine (UMO) Forest Bioproducts Institute (FBRI)

http://forestbioproducts.umaine.edu/

- Contact : *Mike Bilodeau*, Director of Process Development Center and FBRI
  - Tel: 207-581-2387
  - Email: mbilodeau@maine.edu
- Founded April 2013 at University of Maine, Orono Campus
- Funded with $1.5 million grant from U.S. Forest Service
- Pilot Plant with 1 ton per day capacity of nanofiber; a bio-based, sustainable raw material
  - For businesses and universities doing R&D with nanocellulose
  - Cellulose nanofibrils are produced via mechanical refining process
  - Crystalline nanocellulose produced via chemical process and spray dried for shipping
  - Produce and sell at cost for R&D trials in various industries [order form on website]
- Possible uses of nanofiber
  - PET Replacement
  - Release substrate
  - Coating/comosite additive for strength
  - Automobiles
  - High end papers; filtration substrates

Source: http://www.mainebiz.biz/article/20130429/CURRENTEDITION/304259999/umaine-project-unlocks-nanofiber-potential

University of Maine (UMO) Forest Bioproducts Institute (FBRI)

http://forestbioproducts.umaine.edu/technology-research-center

- Contact: *Amy Luce,* Technology Research Center (TRC) Manager

  aluce@umche.maine.edu

  ***Phone**: 207-944-5674*

- The University of Maine's Forest Bioproducts Research Institute's new TRC, located in Old Town, ME, validates, demonstrates, and helps commercialize developing fuel, chemical and advanced material technologies from forest bioproducts at an industrially relevant scale.
- **About TRC**
  - Is a fee-for-service operation
  - Provides objective, independent testing
  - Protects intellectual property and shares precompetitive best practices
  - Meets all necessary approved environmental permitting standards
  - Accepts any cellulosic feedstock
  - Offers clients access to University of Maine faculty and visiting researchers
  - Provides research opportunities for graduate students and hands-on experience for undergraduates

UMO Forest Bioproducts Institute (FBRI)

http://forestbioproducts.umaine.edu/technology-research-center

Technology Research Center Processing Capability

Many unit operations; floor scale units can be combined to demonstrate various production scenarios

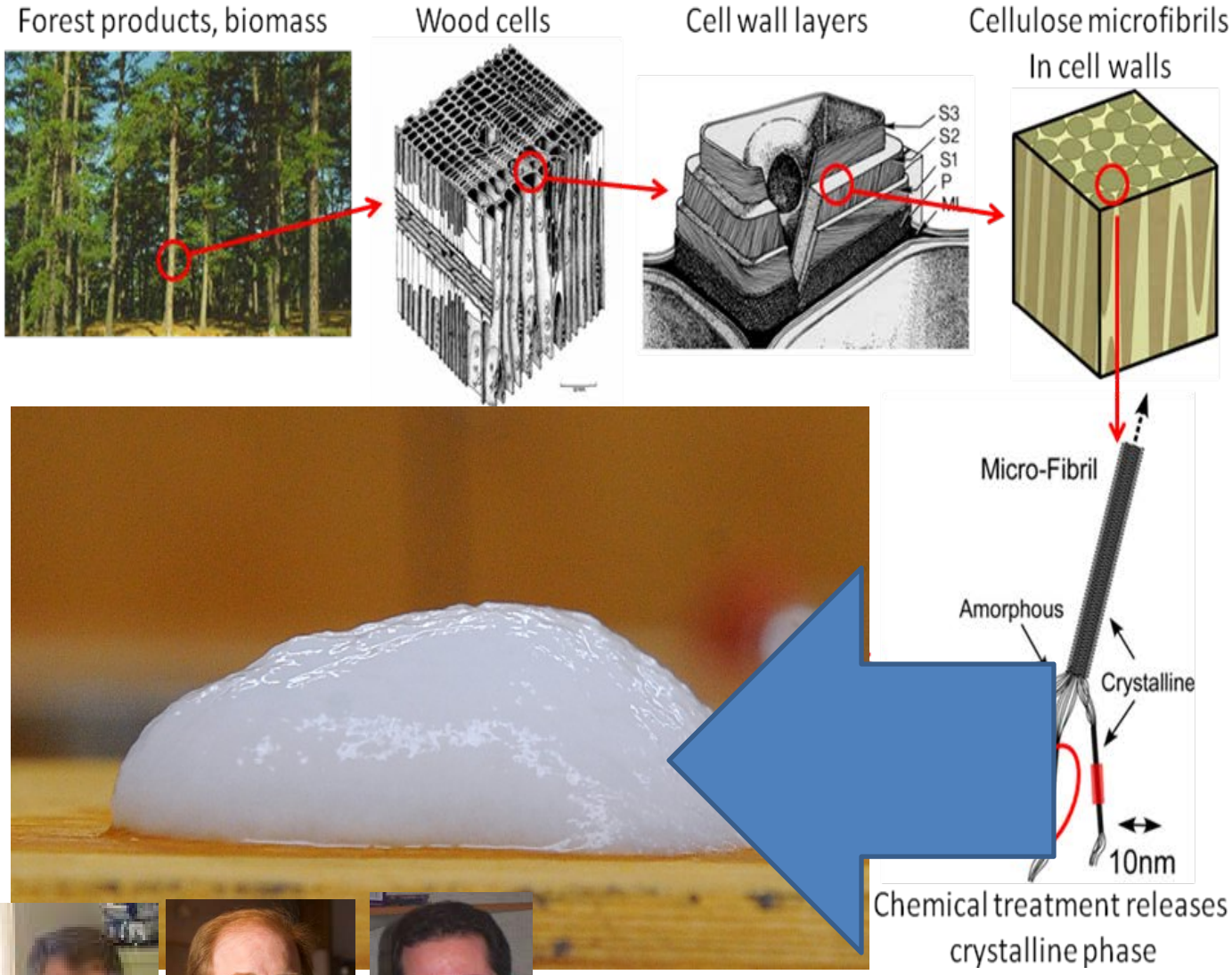
- Biomass drying, size reduction, and screening
- Biomass pretreatment, extraction, cooking
- Fermentation
- Chemical Reactions, both batch and continuous
- Hydrogenation
- Pelletizing
- Liquid-Liquid Extraction
- Distillation
- Micro or ultrafiltration
- Evaporation
- Spray drying of nanocellulose

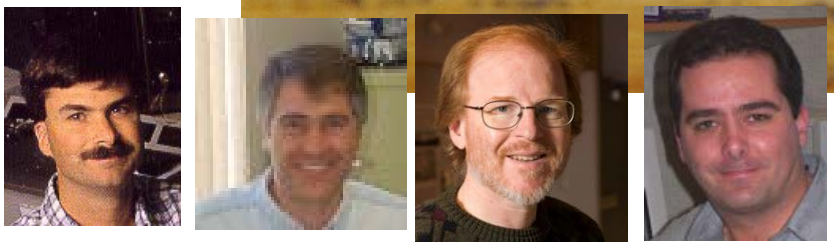
Technology Resource Center (TRC)
Analytical Capability

- Chemical and physical testing for pilot-scale campaigns
- Gas and liquid chromatography
- Atomic and molecular spectroscopy
- Wet chemical characterization
- Analytical method development
- In-process and final product material characterization

http://forestbioproducts.umaine.edu/technology-research-center

Cellulose Nanofibers: New Advanced Material





USDA Forest Products Lab in Madison, WI

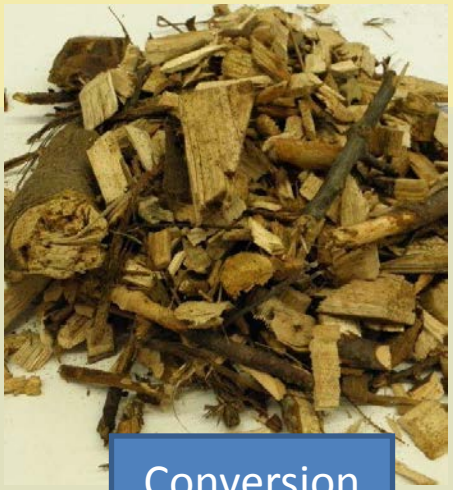
Cellulose Nano Fibrils (CNF)

- First CNF production facility to start up mid-May in Massachusetts
- Southworth Papers, Turners Falls
- CNF based release formed as paper from a water based slurry
- Producing 2 tons/day of release paper

Other CNF Applications

- Extrusions typically add 6-10% wt CNF for strength enhancement
- Poly Lactic polymer plastic bags can be reinforced with CNF particles and reduce plastic sent to waste/landfill/compost
- Automobiles can add CNF to body components to help meet new CAFÉ standards for fuel efficiency

Biomass to Drop-in Fuels



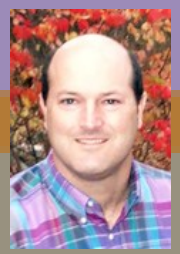
- DOE renewal for a three-year project *
- DLA award for a two-year wood to jet fuel project **

Mild Hydro-treatment

Conversion to Mixed Acids

Neutralization

TDO





THE UNIVERSITY OF MAINE

FOREST BIOPRODUCTS RESEARCH INSTITUTE

2014 Maine Maritime Academy (MMA) cellulose waste to fuel

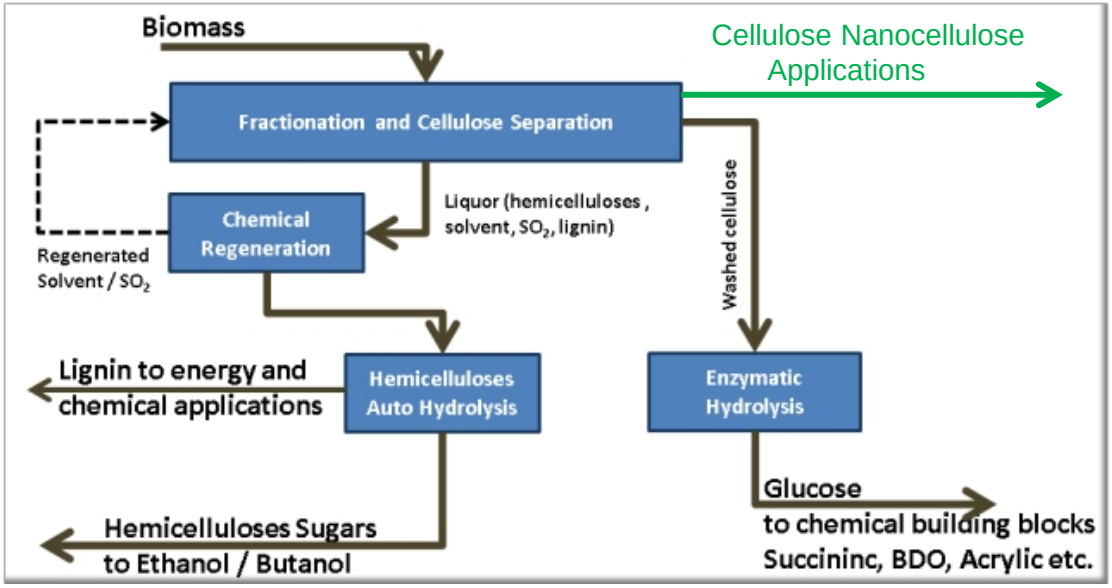
- Hydrocarbon fuel can be created from cardboard, fallen tree limbs, or other cellulose wastes
- Clayton Wheeler, a Umaine Professor of chemical and biological engineering developed the method along with students in his lab [*Phone: 207-581-2280; Email: cwheeler@umche.maine.edu*]
- The process, known as Thermal DeOxygenation (TDO), involves converting cellulose into organic acids, which are combined with calcium hydroxide to form a calcium salt.
- That salt is heated in a reactor, which creates a dark, amber-colored oil (formate assisted pyrolysis process (FasP).
- That oil contains almost none of the oxygen found in the original cellulose, which distinguishes this biofuel from others because less oxygen means less wasted energy in the fuel, according to Wheeler.
- UMaine/FBRI will develop and optimize the TDO and FasP processes to produce liter quantities of marine grade biofuel
- Viable marine biodiesel derivatives will be tested in MMA's Marine Engine Testing and Emissions Laboratory (METEL) diesel engines
- Economics will play a role in adoption since oil price has declined; $100/bbl is approximate breakeven point

Sources:
http://bangordailynews.com/2011/10/27/news/bangor/umaine-researchers-find-new-way-to-draw-fuel-from-trees-trash/
http://mainemaritime.edu/metel/metel/projects/development-of-advanced-biofuels-for-marine-applications/

- American Process Inc., Atlanta, GA has developed a proprietary process AVAP® (American Value Added Pulping) which is a low cost universal sugar platform that can also co-produce cellulose and ethanol.
- Depending on the source, 61-82% of biomass is composed of sugars. These sugars can be converted into hundreds of useful, everyday products currently being produced from crude oil such as transportation fuels, plastics, textiles, and pharmaceuticals.
- While crude oil is a limited, non-renewable resource, biomass is abundant and renewable.

Source: http://www.avapco.com/

- In the first step biomass is fractionated into its three major components: cellulose, hemicelluloses and lignin.
- In a second step, the hemicellulose fraction is auto-hydrolyzed to sugars using residence time and heat.



- **In a parallel second step the cellulose fraction is converted to products.** The cellulose that is generated from **AVAP®** has very low content of lignin and hemicelluloses. It is an ideal feedstock for the production of pure cellulose, nanocellulose or cellulosic glucose.
- The high purity fiber leads to very low cost enzyme dosages to convert the **AVAP®** cellulose to a clean glucose stream in preparation for downstream conversion to chemicals using biological organisms or chemical catalysis.
- Lignin is recovered for use in lignin derived products or becomes boiler fuel to produce the energy to run the process.

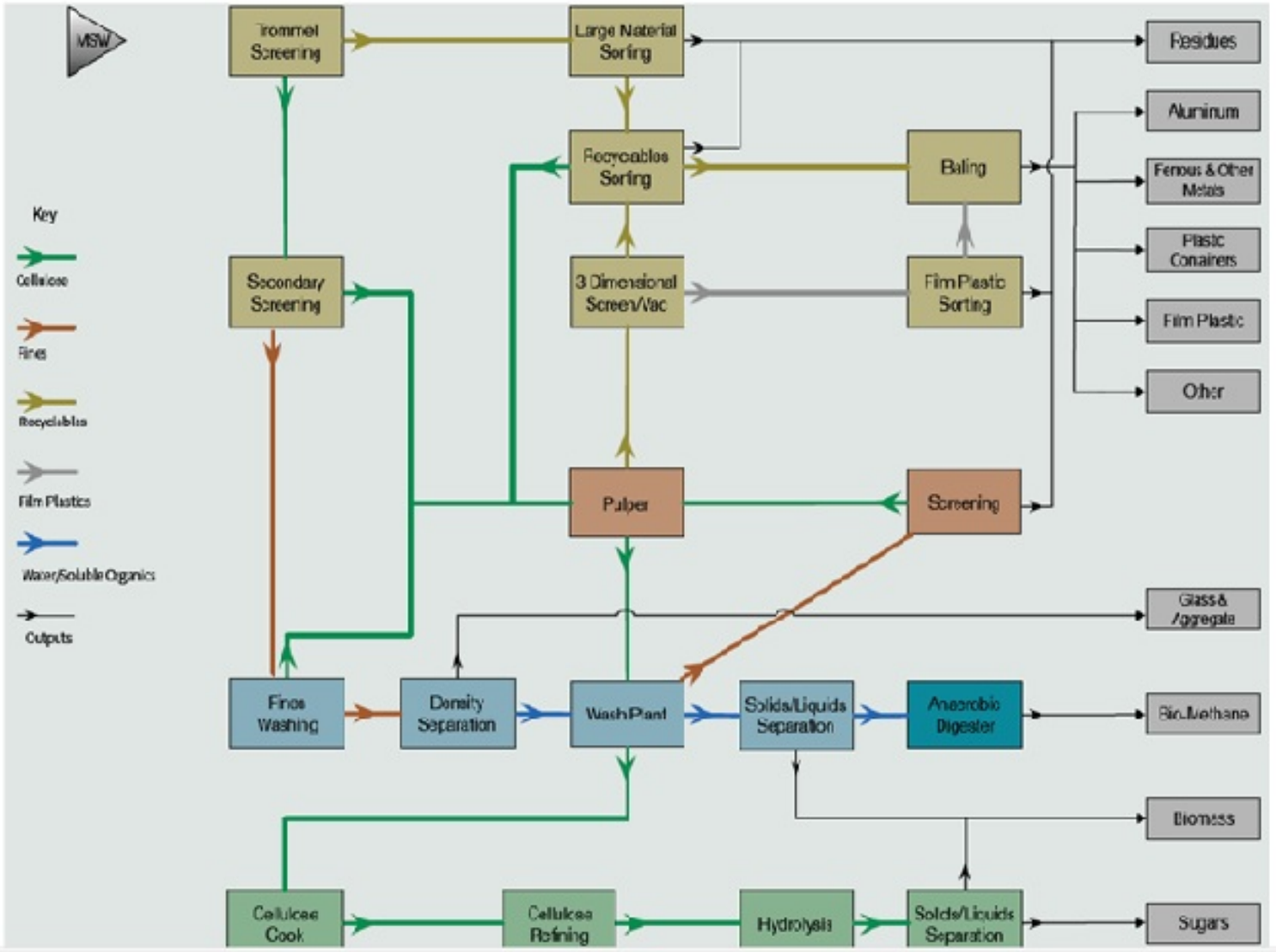
Source: http://www.avapco.com/technology.html

Fiberight LLC MSW to Biogas/Sugars

- Municipal Review Committee (MRC) study
- MRC = non profit representing 187 communities that currently send municipal solid waste (MSW) to PERC trash to energy incinerator in Bangor, Maine
- 2018 is last year of thirty year contract
- Study commissioned to find alternatives to current MSW disposal method
- Fiberight LLC demo plant in VA is using MSW to create C-5 and C-6 sugar solutions
- UMO- FBRI peer reviewed Fiberight's technology and issued Jan-2015 report to MRC
  http://mrcmaine.org/wp-content/uploads/2014/03/UMainePeerReviewReport.pdf
- Findings of review
  - Fiberight's processing technology is sound and capable of converting the insoluble portion of MSW organics to a simple sugar solution.
  - Presently at their pilot plant, Fiberight has successfully used sugar solutions from both the insoluble and soluble portion of MSW to produce biogas through anaerobic digestion (AD)
  - A third party has reported that sugars from the Fiberight process have been used to produce ethanol on a laboratory scale
- Fiberight is retooling a corn to ethanol plant in Iowa, slated for start up late 2015
- Iowa plant will use 650 TPD MSW and supplement that with 350 TPD paper mill WWT sludge
- At $0 tipping fee, break even for one of these processes is ~250 TPD MSW

Sources:
http://mrcmaine.org/about/
http://mrcmaine.org/post-2018/

MSW→Sugar or Biogas



Fiberight MSW → Biofuel

- The Blairstown Iowa ethanol facility was originally designed and built to produce ethanol from corn feedstocks, but was purchased by Fiberight back in 2009 for conversion to process wastes.
- According to Fiberight, it has successfully developed a biomass conversion process that produces commercially viable quantities of renewable biofuel and other valuable biochemicals from municipal solid waste (MSW)
- Its technology efficiently fractionates organic components of MSW such as contaminated paper, food wastes, yard discards and other degradeables for the production of cellulose and hemicellulose into fuel grade ethanol and other sugar platform biochemicals using enzymatic hydrolysis and fermentation
- The process is also said to extract a plastic fraction and methane which can be used to generate enough heat and power to cover the facility's energy requirements
- According to Fiberight, its proprietary extraction, pulping and digestion processes has the potential to unlock over 5 billion gallons (19 billion litres) of renewable biofuel contained in the 175 million tons (159 million tonnes) of non-recyclable Municipal Solid Waste (MSW) generated each year in the U.S.

Source: http://www.waste-management-world.com/articles/2014/07/andritz-technology-for-fiberight-s-municipal-waste-to-biofuel-plant-in-iowa.html

Useful Links

http://forestbioproducts.umaine.edu/research-projects/

http://biomassmagazine.com/articles/11088/fiberight-still-working-at-msw-plant-in-iowa

http://www.waste-management-world.com/articles/2014/07/andritz-technology-for-fiberight-s-municipal-waste-to-biofuel-plant-in-iowa.html

A video looking at Fiberight's planned projects in Iowa can be viewed below.
Iowa City considers joining Fiberight's trashanol venture