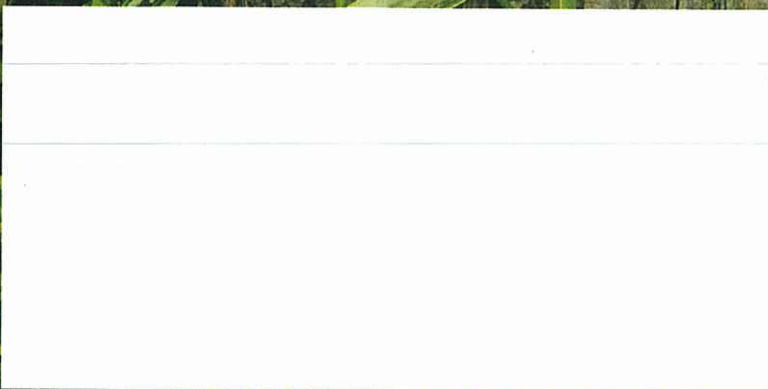


Plugging into the bright future of biofuels



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Substantial investment is occurring in biofuel conversion technologies, but long term partnerships will be critical for success

THE FUTURE IS BRIGHT

The commercial viability of second-generation biofuels grows ever closer as finance pumps into research, and pilot plants for cellulosic ethanol conversion proliferate.

With the goal of producing ethanol-based biofuel for less than US\$1.07/gallon, significant reductions in operating costs are still needed. However pilot and demonstration plants are now operational, and testing a vast range feedstocks, conversion technologies and plant configurations.

Lignocellulosic biomass is an attractive option for future supplies of renewable fuels and progress has been made in the production of ethanol and advanced fuels from the cellulosic biomass.

Research is focused on biochemical and thermochemical conversion technologies for bioethanol and other biofuels. At this stage biochemical initiatives dominate over thermochemical.

UNITED STATES

The US initiatives are generally focused on biofuel production driven by significant government support. The US Department of Energy (DOE) has provided substantial assistance to develop commercial and demonstration facilities. Currently, 11 projects covering biochemical, thermochemical and integrated biorefinery platforms are being supported by DOE grants. The most advanced of the commercial plants are the Range Fuels plant at Soperton, GA, and POET's plant in South Dakota with a commercial facility planned for Emmetsburg, IA.

Table 1 summarizes the progress of US initiatives for the production of 2nd generation biofuels, particularly cellulosic ethanol.

Currently, the US has a goal of making cellulosic ethanol cost competitive by 2012, with a longer term target of 136,260 million litres per year (ML/yr) of renewable fuels production by 2022. This target is only achievable with a majority of this renewable fuel coming from lignocellulosic material, such as corn stover, wood, switch grass, wheat straw and purpose

grown energy crops. To date in the US, there are prospective plants in early stages of development to generate 1,630 ML/yr, or approximately 1% of the target. Globally there is another 1,540 ML/yr capacity being planned.

All demonstration plants, which are sized at 10% of a commercial-scale biorefinery, are expected to be operational by 2012. Commercial-scale plants are in the planning stages.

POET's pilot plant in South Dakota uses a biochemical conversion pathway and has been in operation since early 2009. Corncoobs are used as feedstock and cob collection trials have been run with agricultural equipment suppliers and farmers to find the most efficient and affordable means for harvesting the cobs and husks. POET's commercial cellulosic ethanol plant (Project Liberty) is planned for Emmetsburg in 2011, producing 95 ML of ethanol per annum using similar technology. This project is at Stage 4 (validation) of the DOE process.

Range Fuels is also at Stage 4 in development of its technology for a commercial cellulosic ethanol/methanol plant, in Soperton. The process will use wood residues and a 2-step thermochemical process to produce up to 300 ML/yr of ethanol and methanol. Construction of the first phase of the plant is scheduled for completion by early 2010 with production rate of 38 ML/yr by mid 2010. A US\$80million loan guarantee has been awarded by the US Department of Agriculture for construction of this commercial plant. Range Fuels have operated a fully integrated thermochemical pilot plant at its development centre in Colorado since 2008 converting hardwood and softwood residues into ethanol and methanol.

Verenium's enzymatic hydrolysis demonstration plant at Jennings, LA, is at the optimization stage of development after the completion of startup and commissioning in early 2009. The ethanol being produced is not yet of commercial grade (will require regulatory approval by the EPA from a distilling standpoint)².

Verenium and BP are developing a commercial-scale cellulosic ethanol plant in Highlands, FL, which will begin construction early 2010 and is expected to be producing in 2011. Progress is dependent upon financing. Energy

cane feedstock will be supplied from 20,000 farmable acres adjacent to the site.

Mascoma's demonstration plant in Rome, NY, has a production capacity of 800,000 L/yr of ethanol. Feedstocks include wood chips, grasses, corn stover and sugar cane bagasse which are converted to ethanol using consolidated

bioprocessing (CBP) technology. CBP uses engineered microorganisms that produce cellulases and ethanol at high yield in a single step, which is a major advance in developing a low-cost configuration for cellulose hydrolysis and fermentation. A larger-scale demonstration and commercial plant employing CBP are planned for Kinross, MI.

Table 1 - US CELLULOSIC ETHANOL & BIOFUEL FACILITIES

Project owner	Location	Plant	Planned Output ML/yr	Operating	Status (August 09)	Feedstock	Technology B=biochemical T= thermochemical
Abengoa	Nebraska Kansas	Pilot Comm	0.08 42	2007 2010	operational Stage 3 DOE*	Corn straw, wheat straw, switchgrass	Bio
KL Energy	Wyoming S Dakota	Demo Comm	5.7 19 - 38	2008 2010	operating since 2008	Wood chips (SW) paper waste	Thermo
Range Fuels	Colorado Georgia	Pilot Comm	- 38, 300	2008 2010	in operation USDA loan guarantee	Wood products	Thermo
Verenium	Louisiana Florida	Demo Comm	5.5 136	2008 2011	operational, being optimized construction early 2010	Energy cane, bagasse, wood residues	Bio
BlueFire	California	Demo Comm	15 72	2009 2010	in progress Stage 3 DOE*	Green and wood waste from landfill waste	Bio
Lignol	Colorado	Demo	10.2		cancelled	HW and SW residues	Bio
Coskata	Pennsylvania	Demo Comm	0.16 200-400	2009 2010	in operation Sept 09 planned	Municipal waste, Ag residues, bagasse	Hybrid
Mascoma	New York Michigan	Demo Comm	5 151	2009 2011	operational Stage 3 DOE*	Ag and forest residue	Bio
POET	South Dakota Iowa	Pilot Comm	0.08 95	2009 2011	in operation early 09 Stage 4 DOE*	Corn husks and cobs	Bio
Colusa Biomass	California	Comm	47	2009	commissioning delayed	Rice straw and hulls	Bio
Pacific Ethanol	Oregon	Demo	10.2	2009	Stage 3 DOE*	Ag and forest residue	Bio
Alico	Florida	Comm	52.6	2010	Halted June 08	Wood and muncpal waste, bagasse	Thermo
American Energy Enterprises	Connecticut	Comm	56	2010	applied for DOE grant	Plant biomass & wood waste	Bio
Flambeau River Biofuel	Wisconsin	Demo	60	2010	Stage 3 DOE*	Wood chips (SW) forest residues	Thermo
Fulcrum Bioenergy	Nevada	Comm	40	2010		Municipal solid waste	Thermo
Ecofin	Kentucky	Demo	4	2011		Corn cobs	Bio
ICM	Missouri	Demo	10.2	-	Halted Jan 09	Corn fibre, straw, switchgrass, sorghum	Bio & Th
Iogen	Idaho	Comm	68	-	Halted June 08	Ag residues	Bio
NewPage	Wisconsin	Demo	18	TBA	Stage 3 DOE*	Wood waste	Thermo
Xethanol	Nth Carolina	Comm	19	-	cancelled		
Old town Fuel and Fiber	Maine	Demo	8.4	TBA	Stage 2 DOE*	Woodchips, mixed HW	Bio

* Stages of DOE stage gate process include: Stage 2 = detailed investigation, Stage 3 = development, Stage 4 = validation, Stage 5 = commercial launch

Coskata uses gasification technology (Alter NRG) to convert waste biomass to syngas which is then converted using biofermentation to ethanol. Recent reports indicate that the demonstration facility in Madison, PA, capable of producing 160,000 L/yr has been operational since September 2009¹. Coskata is developing plans for a 200 to 400 ML/yr commercial scale ethanol facility in parallel with the demonstration plant.

GLOBAL

Elsewhere in the world, biochemical technology again dominates, Table 2. In contrast to the US, only four

commercial scale developments have been announced although there are a similar number of demonstration plants. The European initiatives in contrast to the US are being led by chemical companies with greater emphasis on specialty chemicals, not just biofuels.

China Resources Alcohol Corporation (CRAC) is the second largest ethanol producer in China and has been operating a cellulosic ethanol pilot plant in ZhaoDong City since 2006. Corn stover feedstock is processed using modified steam explosion technology followed by enzymatic hydrolysis. CRAC's goal was to install 6 ML/yr of cellulosic ethanol capacity by the end of 2007 and 1,250 ML/yr by 2012, the most ambitious target in the world.

Table 2 - GLOBAL CELLULOSIC ETHANOL & BIOFUEL FACILITIES

Company (global)	Location	Plant	Planned Output Ethanol ML/yr	Operating	Feedstock	Technology B=biochemical T= thermochemical
SEKAB	Ornskoldsvik, Sweden	Pilot Demo Comm	0.14 6 120	2004 2011 2014	Wood waste, Ag waste	Bio
Iogen	Ottawa, Canada Saskatoon, Canada	Demo Comm	2.5 87	2004 2011	Ag residues, HW	Bio
CRAC (China Resources Alcohol Corp)	ZhaoDong City, China	Pilot Demo Comm	6 1250	2006 2008 2012	Wood construction waste	Bio
Dedini	Sao Paulo, Brazil	Demo	1.8	2007	Bagasse	Bio
Abengoa	Salamanca, Spain	Demo	5	2007. Steam explosion added early 2009	Wheat, barley straw	Bio
TMO	Guildford, UK	Pilot Demo		2007 2009	Ag, municipal waste, Wood waste	Bio
Marubeni	Saraburi, Thailand	Demo	3	2008	Bagasse	Bio
Woodland Biofuels	Ontario, Canada	Pilot Demo	0.2 5.6	2008	Wood chips, forest residues	Thermo
Choren	Freiberg, Germany	Demo	16.5 FT liquids	2008	Woodchips, recycled wood, Ag waste	Thermo
Enerkem	Quebec, Canada Edmonton, Canada	Demo Comm	5 36	early 2009 TBA	Treated wood waste	Thermo
BioGasol	Bornholm, Denmark	Demo	5	2009	Ag residues	Bio
Dong Energy	Kalundborg, Denmark	Demo	5.4	2009	Wheat straw	Bio
Ethec	Macleay, Australia	Pilot		2009	Bagasse, wood residues	Bio
Lignol	Vancouver, Canada	Pilot	0.1	2009	HW and SW residues	Bio
Elsam	Denmark	Pilot	~2.3	TBA	Straw	Bio
Bioethanol Japan	Osaka, Japan	Demo	1.4 - 4	TBA	Wood construction waste	Bio
Mission NewEnergy	India	Pilot	0.07	TBA	Ag waste	Bio

Choren is one of the world's leading gasification companies and constructed a biomass-to-liquids (BTL) plant in Freiberg, Germany, in 2008. Shell's Fischer-Tropsch gas-to-liquids technology is used to produce 16.5 ML/yr of F-T liquids from feedstock including wood chips, recycle wood and agricultural wastes. Choren plans to build the world's first full-scale BTL plant in Schwedt, Germany, producing 270 ML/yr of synthetic biofuel³.

Two novel approaches are in India and Australia. Mission NewEnergy operates a pilot plant of 0.07 ML/yr in India. It uses agricultural waste (wheat, rice, corn, barley straw) and a novel hydrolysis process. Lignin is separated from the cellulose and hemicellulose prior to hydrolysis, hydrolysis is conducted without the use of any enzymes, and ethanol yields higher than competing cellulosic ethanol technologies are reported. A commercial-scale plant is planned.

Ethtec is currently constructing a pilot plant located at a sugar mill in New South Wales, Australia. The plant will use hydrolysis and fermentation technology and 'induced phase separation' for ethanol recovery, eliminating the need for conventional distillation and improving the energy balance of the process. The plant will use wood residues and bagasse.

SUMMARY

Substantial investment is occurring in conversion technologies and in determining the most economic, practical and cleanest technology for the production of cellulosic ethanol. Pilot plants are at the cutting edge of developments and have already successfully demonstrated the production of ethanol from feedstocks, such as agricultural waste, but the conversion of wood waste, particularly softwoods, continues to be more challenging.

It is likely there will be no single preferred conversion technologies for the production of cellulosic ethanol, but rather technologies appropriate for specific feedstocks.

Commercial realities are just as critical as technical considerations in the deployment and commercialization of these technologies. Commercial gaps that have been identified² include the procurement of biomass at the quality and price needed, the selling price of the biofuels, difficulty in attracting investors and lenders, costly pilot trials, and compliance with regulations (e.g. National Environmental Policy Act in the US).

Construction of the first large-scale demonstration facilities is well underway. The availability of financing, particularly the willingness of governments to share in the scale-up risks with private industry, will be critical to commercial-scale plants who are forging a new future for biofuels. Co-location and integration with existing infrastructure and facilities, such as pulp and paper mills, power plants and grain-ethanol plants, where various synergies can be achieved has many advantages over stand-alone plants. **PPI**

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REFERENCES

1. <http://www.cleantech.com/news/4995/coskata-leaks-word-demo-plant-and-r>, September 2009
2. TAPPI Bioenergy Technologies Quarterly, Second quarter 2009, p 3.
3. HAYES, D.J. An examination of biorefining processes, catalysts and challenges, *Catalysis Today*, June 2008.



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