PROJECT COMPARISON REVEALS LEADERSHIP GAP

by

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and

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Abstract

Historical Biorefinery commercial experience in North America is reviewed. A comprehensive summary of commercial activities in fuels (liquids and gases), bioenergy production, and the biorefinery are presented. There are substantial, commercial activities in North America but the large pulp and paper companies are not in the forefront of this activity. The only pulp and paper companies with commercial biorefinery activities tend to be the smaller or small independent pulp and paper companies. A comparison of the U.S. Department of Energy (DOE) funded projects with "Section 932" grants is made. They show non-pulp and paper companies have considerable pilot experience and have the willingness to risk millions on scale-up for technologies valued by society (i.e., biomass to energy). This willingness gives the non-pulp and paper companies the opportunity to lead and develop technical and commercial experience at the plant scale. A new model will be needed by the pulp and paper industry if it is to avoid losing its historical place as the unquestioned leader in cellulose and lignin separations, conversion technology, and commercial distribution of forest-service products and materials.

Brief Historical Perspective

The pulp and paper industry has much experience relevant to fuels (liquids and gases) bioenergy production for both the biochemical (sugars liberation followed by fermentation) and thermal conversion platforms. However, this experience is not widely recognized, nor is it in all pulp textbooks. Therefore, not all new technologists are learning what is likely to be important in their future.

The pulp and paper industry has had sugars-based biorefineries[1] on two continents and several countries. The ones in North America were Georgia-Pacific (GP), Bellingham, WA and International Paper (now Tembec), Temiscaming, Quebec, Canada[2]. They were traditional softwood sulfite pulp mills who sold their lignin and fermented the 6 carbon sugars in the residual liquor to ethanol. The 5 carbon sugars went with the effluent. Two mills fermenting hemicellulose to ethanol in Scandinavia are Borregaard in Sarpsborg, Norway and Damsjo in Ornskoldsvik, Sweden. At one time there were at least 20 mills doing this in Europe[3]. Flambeau River Papers, Park Falls, WI has a traditional hardwood sulfite pulp mill. The wood is rich in 5 carbon sugars. Xylose (a 5 carbon sugar) and saleable lignin are extracted from the red liquor off-site. The xylose is then converted to xylitol. Traditional sulfite pulp mills are high cost and are decreasing in number. Because they are regarded as "passé industry", additional research in this area has been "not fundable". Therefore, learning has been minimal. Recent activity suggests that hemicellulose sugars can be more efficiently extracted from both the sulfite and Kraft liquor cycles more efficiently than previously thought.

The commercial thermal conversion experience in pulp and paper is largely in North America. Weyerhaeuser at New Bern, NC has a high temperature, atmospheric pressure Kraft black liquor gasifier running to boost capacity for several years. There were two installations of low temperature gasifiers of identical technology running on carbonate black liquor. The first one to start is now commercially supporting the entire mill at Norampac in Trenton, Ontario, Canada. The second one started at GP in Big Island, VA and was shut down after two years of commissioning experience. While much has been written about these deployments, the reasons that the smaller facility with smaller resources performed better with the same technology have not been fully explained.

There are 3 non-integrated mills in North America that have become fossil fuel free. They are Jackson Paper, Sylva, NC, Gray's Harbor Paper, Hoquiam, WA, and Catalyst Paper, Port Alberni, British Columbia[4]. The technology is biomass acquisition and level use of steam during sudden machine outages. Also note that these are small and mostly independently-owned mills. The technology development and implementation pathway of independent verses large corporations has been markedly different.

While biomass gasification may be relatively new to pulp and paper, it has been used by other industries in North America for 25 years. Table 1 shows there are at least 18 biomass gasifiers in commercial operation in North America in industrial applications[5].

Table 1: Partial List of Commercial Biomass[a] Gasifiers in North America (Plus 4 Interesting European Installations)

Technology Provider	Start Year	No. Units	Amount & Type Biomass	Owner	Location	Use of Syngas
1. TRI	1980's	1	~1 tpd-any	Pilot Line	Baltimore MD	Analysis & trials. 1st unit in CA, 2nd in MD
2. PRM Energy	1982/3	2	125tpd-rice hulls	Pro.Rice Mills	Stuttgart, AR	Exhaust dries rice and steam boils rice
3. EnvirOcycler	1982/3	2	135 tpd wood waste	Norboard	Solway, MN	Heats MEC rotary dryers
4. Homemade[b]	1993	1	900 tpd biomass	GB Packaging	Morrilton, AR	Steam turbine, then 270,000 #/hr to the mill
5. PRM Energy[c]	1995	1	570tpd rice hulls	Pro.Rice Mills	Greenville, MS	7.5 MW power + steam boils rice
6. PRM Energy	1996	1	30 tpd-any	Pilot Line	Tulsa, OK	Analysis & trials-uses PRM technology
7. PRM Energy	1996	3	550 tpd-rice hulls	Riceland	Stuttgart, AR	15 MW steam turbine + 100,000 #/hr steam for the soybean processing plant
8. PRM Energy	1997	1	175 tpd-rice hulls	Riceland	Jonesboro, AR	Exhaust dries rice, steam boils rice
9. Ethopower[d]	1997	1	~20tpd-wd.shavings	Canfor Wood	Smithers, BC	Space heating for remanufacturing plant
10. EPI-modified	1998	2	150 tpd msc biowaste	BFC G&E	Ankeny, IO	Steam used to make salable power
11. Ethopower[d]	2001	1	~15-wd.shavings	Princeton Wd	Princeton, BC	Exhaust from combustor to lumber kiln
12. Nexterra	2004	1	15 tpd-any	Pilot Line	Kamloops, BC	Analysis & trials
13. ChipTec (with modifications)	2004	1	240 tpd 60% wet wood waste & bark	Marion Plywood	Marion, WI	Close-coupled gasifier, the syngas fuels a conventional 900 HP triple pass boiler
14. PRM Energy	2005	1	67 tpd sewage sludge	City	Philadelphia, PA	Dries bio-solids from 90% moisture to 10%
15. PRM Energy	2005	1	66 tpd carpet waste	Shaw Carpet	Dalton, GA	50,000 #/hr steam for manufacturing
16. PRM Energy	2006	1	240 tpd wd waste[e]	Minn. Ethanol	Little Falls, MN	1 MW steam turbine + drying DDG
17. Nexterra	2006	2	40 tpd wd. waste	Tolko Ind.	Kamloops, BC	Exhaust from oxidizer to vainer drying, steam to log conditioning
18. GEM (UK)	2007	1	66 tpd crum rubber	Intrinergy	Coshocton, OH	Syngas to Clow Pipe for gas boilers
19. Nexterra/JCI	2007	3	312 tpd wood waste	U of S.C.	Columbia, SC	Steam for campus heating+1.38 MW to grid
Black Liquor Units						
20. Chemric[f]	1996	1	~300-tpd bl solids	Weyerhaeuser	New Bern, NC	Syngas goes to multi fuel boiler
21. TRI	2003	1	126 tpd bl solids	NorAm Pac	Trenton, ON	Syngas to gas boilers
Notable European Units						
E1. KavernerCFB	1986	1	75 tpd bark	Sodra Cell	Vario, Sweden	Fuel for lime kiln+20% to rotary dryers
E2. PRM Energy	2002	1	144 tpd olive waste	Guascor	Rossano, Italy	Gas engine driven 4 MW turbine[g]
E3. Choren	2007/8	TBD	TBD	TBD	Freiberg, Germany	Worlds first commercial gas to liquid plant on biomass feedstock
E4. PRM Energy	2006	1	30 tpd wood/dist res	Eneria	Moissannes, France	IC Engine 1.0MWe to grid[g]

[a] Any mass that has a biological origin except turkey/chicken parts/waste as most of those were environmentally not energy driven
[b] An old recovery was equipped with a vibrating grate and auger feeders to make a "section 29" gasifier. There could be others.
[c] Some of these units were installed by Prime Energy who used to be a licensee of PRM Energy
[d] This is a predecessor of Nexterra.
[e] The fuel may include corn Stover at a later date. DDG = dry distillers grain (an animal feed)
[f] This is an atmospheric pressure design for capacity gain and is a net consumer of energy
[g] This includes a patented gas cleanup technology

A biomass gasifier is coming on line at the University of South Carolina in Columbia, SC where the thermal output will be used for "district heating". The project developer was Johnson Controls who have to meet the performance criteria.

Finally, there are decades of lignocellulosic pulping research that have been conducted at a number of universities in a number of countries. Clearly, up to the start of this century, the pulp and paper industry has had a dominate lead in the chemistry and physics of lignin separation, cellulose yield and strength optimization, and the use of cellulose in products. The number and quality of textbooks and research articles in these areas that are available from sources such as IPST, FPL, KCL, TAPPI and STFI are outstanding.

One key question is: "Has this research been directed at areas that will be valued by society such as biomass to energy?" Another key question is: "Can and will others now take a technical and commercial lead in areas valued by society?" Finally, we need to ask: "What actions are required for the pulp and paper industry to maintain a leadership role?"

CURRENT PULP AND PAPER BIOREFINERY ACTIVITIES

There is one modern bioenergy[6] project that has been announced in pulp and paper. Intrinergy has announced the installation of a biomass gasifier at Costal Paper in Wiggins, MS. Potlatch Corporation, with financial help from Winrock International, developed a comprehensive Biorefinery Project for their mill in McGhee Arkansas[7]. The biomass feed was to be about 2,000 bone dry (BD) tons per day and the output was about 2,300 barrels per day of renewable refinery feedstock, plus about 150,000 pph steam for the mill and about 14 million BTU/hr tail gas for the lime kiln. Because of integration, thermal efficiency was to be as high as others have achieved with larger gas to liquids processes[8]. Potlatch did not apply for a DOE Section 932 DOE grant, but are continuing to develop the project.

Flambeau River Papers submitted a proposal to the U.S. Department of Energy (DOE) Section 932 grant announcement with significant help from American Process Incorporated, TRI, Cleantech Partners, financial backers and others[9]. The output of the proposed project is 500 tpd AVAP (American Valued Added Pulping™) softwood sulfite pulp, 440 tpd of lignin to supply all the needed energy and 20+ million gallons per year of cellulosic ethanol. This project ranked 9th out of 44 initial submissions. While the project has not received DOE funding, the DOE analysis of strengths and weaknesses[10] used in the Section 932 selection process will be used to strengthen the Flambeau River project and move it forward without the DOE funding.

Comment [MA1]: Do you want to say that eight were invited by the DOE for a face-to-face interviewe and Flambeau missed by only one?

Parsons and Whittemore has constructed a vegetable oil based biodiesel plant co-located with their pulp mill in Claiborne, AL[11]. The synergy is shared utilities and increased thermal efficiency of both facilities.

New York State has given a 10.3 million dollar grant to Catalyst Renewables Corporation to help fund a 130,000 gallon per year cellulosic ethanol plant pilot line in upstate New York. The project is aimed at extracting hemicellulose from woody portions of biomass going to an existing solid fuel boiler that produces power for the electric utility grid and sells by-product steam to a local facility[12].

Weyerhaeuser, Kamploops is in a syngas development program to fuel their Lime Kiln.

Most of these activities are being led by smaller or privately owned companies. There is significant progress. The key question is whether this is sufficient to maintain pulp and paper industry leadership. Many individuals in the U.S. have written articles and documents on the concept of the forest biorefinery and the positive impact that it could have on the pulp and paper industry[13, 14, 15, 16, 17]. The typical response from technical and commercial leaders in LARGE, PUBLIC, U. S. pulp and paper companies has been that there is no proven technology available to justify even a pilot line forest biorefinery.

CURRENT "OTHER" BIOREFINERY ACTIVITIES

Last year the President began to speak about cellulosic ethanol and DOE issued their "Section 932 proposal" to fund up to 40% of a limited number of cellulosic ethanol plants meeting 4 quantifiable criteria. On Wednesday, February 28, DOE announced up to $385 million in matching funds for 6 cellulosic ethanol plants that would have an installed cost exceeding 1.2 billion dollars.[18] Let's look at each in a little more detail.

Company	Abengoa Bioenergy, St Louis, MO
Plant site	Colwitch, Kansas
Project	Ethanol via biochemical routes, syngas for energy via thermochemical conversion routes, with the long term strategy of using the syngas for ethanol and chemicals production.
Technology	Co-processing of agricultural residue at a corn dry grind facility via biochemical and thermochemical conversion routes.
Feedstock	700 tpd corn stover, wheat straw, switchgrass, and other lignocellulosic biomass (400 tpd into ethanol plant, 300 tpd into syngas plant).
Energy products	Initially 15 million gal/yr of fuel ethanol based on 400 tons lignocellulosic biomass feedstock
Yield	79 gallons ethanol per BD ton biomass
Projected investment	Total cost $190 million or greater, DOE match $76 million,
Previous experience	Lignocellulosic biomass: 1.2 tpd pilot facility in York, NE (previous DOE award, 2003,) and 70 tpd integrated process in Spain to startup in 2007. Corn: Portales, NM (1985) - 30 million gallons of fuel ethanol; York, NE (1994) - 50 million gallons of fuel ethanol; Ravenna, NE (2007) - 88 million gallons of fuel ethanol
References	19, 20, 21

Company	Alico, Inc., Labelle, Florida
Plant Site	Labelle, Florida
Project	Ethanol via bioconversion of syngas generated from biomass.
Technology	To produce fuel in the Bioengineering Resources Incorporated process, raw material is first gasified in a two-stage process that reaches temperatures as high as 2350^o F (1290^{o}C), producing a mixture of CO, H_2 CO_2, and water vapor. The hot gases are scrubbed, cooled to 100^{o}F (38^{o}C), passed through activated carbon filtration and fermented in a bioreactor where ethanol is produced.
Feedstock	770 tpd Agricultural residues (citrus peel), wood and later energycane
Energy products	20.9 million gallons ethanol per year, 6,255 KW power, 8.8 tpd hydrogen; also produces 50 tpd ammonia used by ALICO for fertilizer
Yield	75 gallons ethanol per BD ton biomass PLUS energy values of power, hydrogen and ammonia
Participants	Bioengineering Resources, Inc. Fayetteville, AR; Washington Group International Boise, ID; GeoSyntec Consultants, Boca Raton, FL; BG Katz Companies/JAKS,LLC, Parkland, FL; Emmaus Foundation, Inc., AR
Projected investment	Total cost $190 million or greater, DOE match $76 million.
Previous experience	Bioengineering Resources Incorporated has demonstrated process at pilot scale for 6 years
References	19, 20, 22

Company	BlueFire Ethanol Inc., Irvine, CA
Plant Site	Southern California
Project	Ethanol via strong acid hydrolysis of biomass waste and biochemical conversion of the sugars produced.
Technology	Arkenol Process: concentrated acid hydrolysis of sorted green waste and wood waste to liberate sugars that are then converted to ethanol using a fermentation technology developed by NREL to ferment both 5- and 6-carbon sugars.
Feedstock	700 tpd of sorted green waste and wood waste from landfill sites
Energy products	19 million gallons ethanol per year
Yield	68 gallons ethanol per BD ton biomass
Participants	Waste Management, Inc., Houston, TX; JGC Corp., Yokohama, Japan; MECS, Chesterfield, MO; NAES, Issaquah, WA, and Petro-Diamond Inc., Irvine, CA
Projected investment	Total cost $100 million or greater, DOE match $40 million,
Previous experience	Demonstrated in a wood chip-fed pilot plant in Izumi, Japan since 2002, producing 21,500 gal ethanol per year
References	19, 20, 23

Company	Broin Companies (now POET), Sioux Falls, SD
Plant Site	Emmetsburg, IA
Project	Enzymatic hydrolysis biomass waste and biochemical conversion of the sugars produced.
Technology	Advanced corn fractionation and ligniocellulosic conversion technologies that include enzymatic hydrolysis followed by fermentation
Feedstock	842 tpd corn fiber, corn stover, and corn cobs
Energy products	Approximately 30 million gallons ethanol per year from lignocellulosic biomass and (adjacent dry mill plant will make 100 million gpy ethanol)
Yield	83 gallons ethanol per BD ton biomass
Participants	E. I. DuPont, Wilmington, DE; Novozymes, Bagsvaerd, DK; NREL, Golden, CO
Projected investment	Total cost $200 million or greater, DOE match $80 million,
Previous experience	Pilot line being built by POET, a company with considerable experience with corn ethanol. DuPont reported to have a small labratory line
References	19, 20, 24

Company	Iogen, Arlington, VA
Plant Site	Shelley, ID
Project	Ethanol via biochemical conversion of agricultural residues.
Technology	Enzymatic hydrolysis followed by fermentation of the sugars produced.
Feedstock	700 tpd of wheat, barley, and rice straw, switchgrass and corn stover
Energy products	18 million gallons ethanol per year in first plant; 250 million gal/yr in future plants
Yield	71 gallons ethanol per BD ton biomass
Participants	Goldman Sachs, New York, NY; Royal Dutch Shell, The Hague, The Netherlands
Projected investment	Total cost $200 million or greater, DOE match $80 million,
Previous experience	Their technology was demonstrated in a pilot plant near Ottawa, Canada
References	19, 20, 25

Company	Range Fuels, Inc., Broomfield, CO
Plant Site	Soperton, GA
Project	Ethanol and methanol from southern pine
Technology	Thermo-chemical conversion of wood and forest residues to syngas; catalytic conversion of syngas to alcohols.
Feedstock	1200 tpd of unmerchantable pine wood and forest residues
Energy products	10 million gal/yr from first unit; 40 million gallons of ethanol and 9 million gallons of methanol per year from commercial unit
Yield	113 gallons of alcohols per BD ton biomass
Participants	Khosla Ventures, Yeomans Timber, Ga. Forestry Commission, Western Research Institute, Merrick and Company, PRAJ Industries, CH2MHill, and Gillis Ag & Timber
Projected investment	Total cost $225 million or greater, DOE match $76 million,
Previous experience	Their technology was demonstrated in a 5 tpd pilot line in Colorado
References	19, 20, 26

COMPARISON OF PROJECTS

Table 2 shows some critical technical information for: 1) the DOE funded projects, 2) a typical dry mill corn ethanol plant, and 3) the proposed projects at Flambeau River and Potlatch. Other projects can be added as key data becomes known. Critical techno-economic data includes process technology, capital costs, product yields, and capital effectiveness which is capital per gallon per year.

Table 2: Project Comparison

Project	Technology	Capital Cost ($ millions)	Yield (gal/ton)	Capital Effectiveness ($/gal/yr)
Announced Projects				
Abengoa	Gasification & GTL	190 or more	79	more than 16.7
Alico	Gasification & fermentation	83 or more	75+ power, etc.	less than 4.0
BlueFire	Hydrolysis & fermentation	100 or more	68	about 5.3
Broin	Enzyme & fermentation	200 or more	83	cannot break out
Iogen	Enzyme & fermentation	200 or more	~71	about 11.1
Range	Gasification + GTL	~225	113	about 4.6
Corn[27]	50 Million GPY "dry mill"	~ 75	80	new about 1.6
Proposed Projects				
Flambeau	Fermentation of liquor	~40[28]	179[29]	about 2.0
Potlatch	Gasification & GTL	~150	50+steam +gas	less than 4.3

The DOE Section 932 awards went to well funded companies/partners, most of whom had considerable pilot line experience. DOE placed their funding on 3 distinct technical pathways namely: acid hydrolysis, gasification, and enzyme reaction. It appears that DOE has made very good selections. Only one of the projects had a timber company as a key participant and none had a pulp and paper company. The hemicellulose pathway was not funded. However, the capital effectiveness of this pathway warrants further attention.

Comment [MA2]: It may not be a bad idea to state that Venture Capitalists are being involved taking the risk. They would invest in these projects if it doesn't fit into their typical 25-40% return on investment model

The comparison data in Table 2 is from published information and many details are not known. For example reclaimed heat is not known for all projects and must be included in the calculations as it was for Flambeau River. Cost of raw material, operating cost per gallon, and energy ratio information is not yet available and needs to be added for a more complete evaluation. The cost of corn ethanol is estimated at $0.96 per gallon[27]. The same article predicted a cost of $3.35 per gallon for cellulosic ethanol in 2007 dropping to $2.43 per gallon in 2020. It will be interesting to track the performance of the DOE funded projects against this prediction. The 2007 prediction of $3.35 per gallon seems high because the cost estimated for Flambeau River Biorefinery is only about 20% of the prediction -- mainly due to Flambeau River converting all of the tree into high value product streams. Both the Flambeau River project and the Potlatch project compare well from the metrics available. The major difference is that they are not yet funded.

CONCLUSION

Any notion that there are not any technologies worthy of investment has been dispelled by the DOE Section 932 awards. Any notion that companies are unwilling to take large capital risk is also dispelled. Pulp and paper companies were not included in the awards because their research and pilot line experience in biorefineries was not competitive. That speaks volumes to the management allocation of research effort.

There are now non-pulp and paper industry players who have an opportunity to develop both the technology and commercial skill for the forest biorefinery on a plant scale. Clearly, the pulp and paper industry could be in jeopardy of losing its historical leadership role in technology that has been central to its existence in the past and an area that society has deemed important for renewable energy for the future. Whether that will happen or not depends on the response of the pulp and paper industry. The amount of new technical information is doubling every two years; therefore, catch-up can be accelerated.

"Business as usual" within the pulp and paper industry appears to be focused on what some have come to call "the management of decline". Continuation of business as usual, whatever one chooses to call it, will surely mean loss of leadership, faster decline and the closure of many more mills. The full impact will include infrastructure such as forest management, sawmills, building products and suppliers. This can be devastating to employment, rural community health and healthy forests. If you think we are being alarmists please be aware of the recent prediction by one notable columnist: "My forecast for pulp making in Finland, in particular, is that it is doomed"[30]. As you can see, we are dealing with serious consequences.

What seems to be needed is a dedication to capitalizing on new and emerging opportunities and doing it on a competitive basis with others. Capitalizing on biorefinery opportunities may be the only way to avoid massive shutdown and loss of pulp and paper facilities in North America.

We will close by looking at the POTENTIAL impact of one opportunity. The forest products industry harvested 278 million BD tons of wood in 2003[31]. That wood contains roughly 90 million tons of hemicellulose. This pathway looks attractive in an AVAP pulping[32] process which can be adapted to Kraft or more effective alkaline processes can be developed. If the forest products industry can isolate just half or 45 million tons of hemicellulose, it can be fermented to about 20 million tons or 6 BILLION GALLONS of ethanol or 1/7 of the U.S. national 35 billion gallon per year goal. **This does not require harvesting one additional log.**

Just think what the true opportunity could be when our large forest biomass resources and the impacts of tree genetics on forest productivity are considered. It is likely that the pulp and paper industry could produce in excess of 1/3 the national goal.

What has appeared to be missing in the North America pulp and paper industry is the vision and will to boldly seize the opportunity and the fortitude not to accept excuses for poor performance of demonstrations. In today's world, these missing ingredients make the pulp and paper industry "non-competitive".

Fortunately all is not yet lost and we have some recent and excellent examples to use as a reference. Stora Enso and Neste Oil …"see the growing biofuel market as a promising and sustainable business opportunity…". Stora Enso will construct an $18 million dollar demonstration plant integrated into their Varkous mill. "Following the development phase the joint venture will build a full scale commercial production plant at one of Stora Enso's mills."[33] In another development, a group of pulp and paper companies has organized a Value Prior to Pulping consortium to develop the information needed to extract hemicelluloses with the aid of the CleanTech Partners, American Forest and Paper Association's Agenda 2020 Technology Alliance, DOE, and others. However, more and stronger efforts such as these are needed if the pulp and paper industry is to retain its unquestioned and historical leadership and business role in the use of wood.

Comment [MA3]: Do you want to write a short pargraph about BDC as well?

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1 In this article, a BioRefinery is a facility that uses distillation or cracking to export energy.
2 At one time, this mill cooked both softwood and hardwood in campaigns.
3 Private conversation with Vesa Pylkkanen from American Process Inc.
4 Ben Thorp, "Why Not Become Fossil Fuel Free?" *Pulp and Paper*, January 2006-page 56.
5 B. A. Thorp, "Historical and Commercial BioRefinery Overview" presented to the Biorefinery Deployment Collaborative March 2006.
6 In this article, BioEnergy is the production of steam and/or power from biomass. Conventional BioEnergy is typically done with solid fuel boilers. Modern BioEnergy projects use technology like gasification which allows displacement of natural gas. Energy may be consumed onsite or shipped small distances.
7 Tom Belin, "Demonstration of the Forest BioRefinery at the Potlatch, Cypress Bend Mill", 2006 Forum on Energy-May 15-17 2006, Appleton WI.
8 Private communication with TRI.
9 Commercial Demonstration of an Integrated Biorefinery at Flambeau River submitted to DOE Funding Opportunity DE-PS36-06G096016.
10 Private DOE communication to Butch Johnson, Owner FRP.
11 Press Release, Independence Renewable Energy Corporation, September 27, 2006.
12 DOE Press Release, New York Governor Announces 25 Million to Develop Cellulosic Ethanol Facilities, December 20, 2006
13 Ben Thorp and Del Raymond, "Agenda 2020 Reachable Goals Can Double P&P Industry's Cash Flow", *Paper Age*, September 2004, pages 18-20, and October 2004, pages 16-18.
14 Ben Thorp, "Transition of Mills to Biorefinery Model Creates New Profit Streams", *Pulp & Paper*, November 2005, pages 35-39.
15 Steve Kelly, "Forest Biorefineries: Reality Hype or Something in Between", *Paper Age*, March/April 2006.
16 Perry J. Greenbaum, "Biorefining: An Agent of Change", *Paper 360*, December 2006, pages 6-8.
17 AF&PA, Agenda 2020, "Forest Products Industry Technology Roadmap", June 2006.
18 DOE press release February 28, 2007, S. W. McLean.
19 DOE "one pagers" plus material from websites including those listed below.
20 Biomass R&D Initiative Newsletter, March 2007.
21 See www.abengoabioenergy.com
22 See www.alicoinc.com and www.brienergy.com
23 See www.bluefireethanol.com and www. thefraserdomain.typepad.com/energy/2006/07/about_bluefire_.html
24 See www.poetenergy.com
25 See www.iogen.ca
26 See www.rangefuels.com
27 Jerry Taylor and Peter Van Doren, "The Ethanol Boondoggle", The Milken Institute Review-First Quarter 2007. Newer plants have greater energy efficiency.
28 This number includes only the capital for the fermentation plant plus pro rata utilities.
29 This is yield on hemicellulose because cellulose is removed as pulp and lignin provides all the energy. This illustrates the benefit of producing value added co-products.
30 David Price, "Southern [tropical] Pulp", *Paper Age*, March/April 2007, page 23.
31 Eric D Larson et al, "A Cost-Benefit Assessment of Biomass Gasification Power Generation in the Pulp and Paper Industry", Preface, page xiii.
32 Theodora Retsina and Vesa Pylkkanen, "Back to the Biorefinery - A Novel Approach to Boost Mill Profits" *Paper 360*, February 2007.
33 Press release –"Stora Enso and Neste Oil to Join Forces in Biofuel Development", March 16, 2007.

Project Comparison Reveals Leadership Gap

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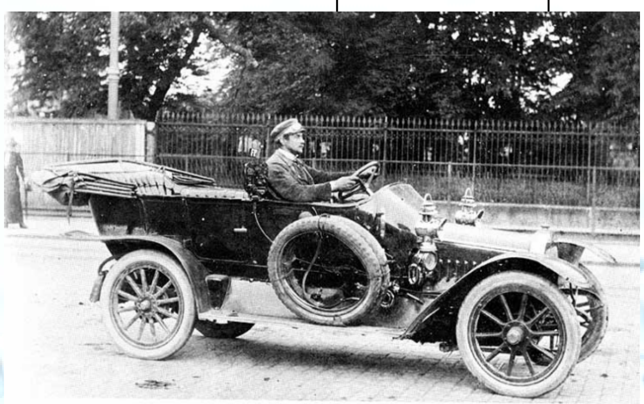
Cellulose Ethanol

1874 Sulphite pulp

1909 The first sulphite ethanol plant

1925 (Lättbentyl, 75% EtOH)



1941 Domsjö, Örnsköldsvik
Organic synthesis, long before the petrochemical industry

1945 34 factories in Sweden produced 80 000 m^3 EtOH

1985 Sekab was formed

2004 Etanolpiloten

1880 1900 1920 1940 1960 1980 2000 2020

Sugar Summary

- GP, Bellingham, WA
- Tembec, Temiscaming, Canada
- Borregard, Norway
- Borregard, South Africa
- Damsjo, Sweden
- Flambeau River Hardwood, WI

Thermo-Chemical Summary

Black Liquor:

- **Weyerhaeuser, New Bern, NC**
- **Norampac, Trenton, Canada**

Biomass for thermal energy:

- **Jackson Paper, Sylva, NC**
- **Grays Harbor, Hoquiam, WA**
- **Catalyst, Port Alberni, Canada**

The technology development and implementation pathway of independent verses large corporations has been markedly different.

Key Questions

A. Has this research been directed at areas that will be valued by society such as biomass to energy?

B. Can and will others now take a technical and commercial lead in areas valued by society?

C. What actions are required for the pulp and paper industry to maintain a leadership role?

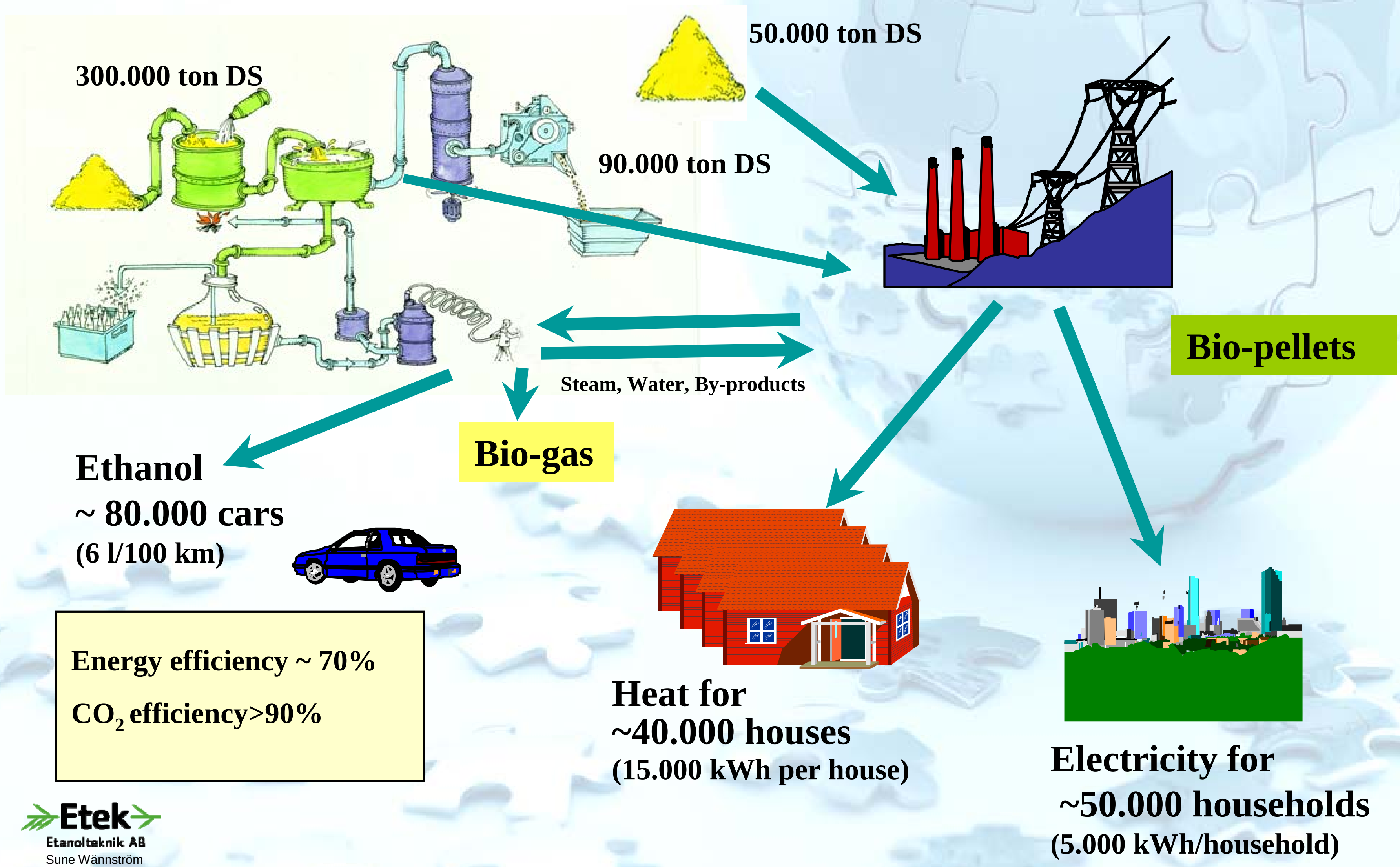
Key Current Activities

- Coastal Paper, Wiggins, MS
- Potlatch, McGhee, AR
- Flambeau River Softwood, WI
- Catalyst Renewables, NY
- P&W, Claiborne, AL
- Weyerhaeuser, Kamloops, Canada

Most of these activities are being led by smaller or privately owned companies.

The typical response is "no proven technology is available to justify even a pilot line forest biorefinery."

Integrated Bioenergy Plant for Ethanol, Electricity and Heat Production



Energy efficiency ~ 70%

CO_2 efficiency>90%

Etek
Etanolteknik AB
Sune Wännström
2007-05-22/10
2003-08-14/LN

Current Biorefinery Activities

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Project	Ethanol via biochemical routes, syngas for energy via thermochemical conversion routes, with the long term strategy of using the syngas for ethanol and chemicals production.
Technology	Co-processing of agricultural residue at a corn dry grind facility via biochemical and thermochemical conversion routes.
Feedstock	700 tpd corn stover, wheat straw, switchgrass, and other lignocellulosic biomass (400 tpd into ethanol plant, 300 tpd into syngas plant).
Energy Products	Initially 15 million gal/yr of fuel ethanol based on 400 tons lignocellulosic biomass feedstock
Yield	79 gallons ethanol per BD ton biomass
Projected Investment	Total cost $190 million or greater, DOE match $76 million,
Previous Experience	Lignocellulosic biomass: 1.2 tpd pilot facility in York, NE (previous DOE award, 2003,) and 70 tpd integrated process in Spain to startup in 2007. Corn: Portales, NM (1985) - 30 million gallons of fuel ethanol; York, NE (1994) – 50 million gallons of fuel ethanol; Ravenna, NE (2007) - 88 million gallons of fuel ethanol
References	19, 20, 21

Current Biorefinery Activities *(continued)*

Company	Alico, Inc., Labelle, Florida
Plant Site	Labelle, Florida
Project	Ethanol via bioconversion of syngas generated from biomass.
Technology	To produce fuel in the Bioengineering Resources Incorporated process, raw material is first gasified in a two-stage process that reaches temperatures as high as 2350° F (1290°C), producing a mixture of CO, H_2 CO_2, and water vapor. The hot gases are scrubbed, cooled to 100°F (38°C), passed through activated carbon filtration and fermented in a bioreactor where ethanol is produced.
Feedstock	770 tpd Agricultural residues (citrus peel), wood and later energycane
Energy Products	20.9 million gallons ethanol per year, 6,255 KW power, 8.8 tpd hydrogen; also produces 50 tpd ammonia used by ALICO for fertilizer
Yield	75 gallons ethanol per BD ton biomass PLUS energy values of power, hydrogen and ammonia
Participants	Bioengineering Resources, Inc. Fayetteville, AR; Washington Group International Boise, ID; GeoSyntec Consultants, Boca Raton, FL; BG Katz Companies/JAKS,LLC, Parkland, FL; Emmaus Foundation, Inc., AR
Projected Investment	Total cost $190 million or greater, DOE match $76 million.
Previous Experience	Bioengineering Resources Incorporated has demonstrated process at pilot scale for 6 years
References	19, 20, 22

Current Biorefinery Activities *(continued)*

Company	BlueFire Ethanol Inc., Irvine, CA
Plant Site	Southern California
Project	Ethanol via strong acid hydrolysis of biomass waste and biochemical conversion of the sugars produced.
Technology	Arkenol Process: concentrated acid hydrolysis of sorted green waste and wood waste to liberate sugars that are then converted to ethanol using a fermentation technology developed by NREL to ferment both 5- and 6-carbon sugars.
Feedstock	700 tpd of sorted green waste and wood waste from landfill sites
Energy Products	19 million gallons ethanol per year
Yield	68 gallons ethanol per BD ton biomass
Participants	Waste Management, Inc., Houston, TX; JGC Corp., Yokohama, Japan; MECS, Chesterfield, MO; NAES, Issaquah, WA, and Petro-Diamond Inc., Irvine, CA
Projected Investment	Total cost $100 million or greater, DOE match $40 million,
Previous Experience	Demonstrated in a wood chip-fed pilot plant in Izumi, Japan since 2002, producing 21,500 gal ethanol per year
References	19, 20, 23

Current Biorefinery Activities *(continued)*

Company	**Broin Companies (now POET), Sioux Falls, SD**
Plant Site	**Emmetsburg, IA**
Project	**Enzymatic hydrolysis biomass waste and biochemical conversion of the sugars produced.**
Technology	**Advanced corn fractionation and ligniocellulosic conversion technologies that include enzymatic hydrolysis followed by fermentation**
Feedstock	**842 tpd corn fiber, corn stover, and corn cobs**
Energy Products	**Approximately 30 million gallons ethanol per year from lignocellulosic biomass and (adjacent dry mill plant will make 100 million gpy ethanol)**
Yield	**83 gallons ethanol per BD ton biomass**
Participants	**E. I. DuPont, Wilmington, DE; Novozymes, Bagsvaerd, DK; NREL, Golden, CO**
Projected Investment	**Total cost $200 million or greater, DOE match $80 million**
Previous Experience	**Pilot line being built by POET, a company with considerable experience with corn ethanol. DuPont reported to have a small labratory line**
References	**19, 20, 24**

Current Biorefinery Activities *(continued)*

Company	**Iogen, Arlington, VA**
Plant Site	**Shelley, ID**
Project	**Ethanol via biochemical conversion of agricultural residues.**
Technology	**Enzymatic hydrolysis followed by fermentation of the sugars produced.**
Feedstock	**700 tpd of wheat, barley, and rice straw, switchgrass and corn stover**
Energy Products	**18 million gallons ethanol per year in first plant; 250 million gal/yr in future plants**
Yield	**71 gallons ethanol per BD ton biomass**
Participants	**Goldman Sachs, New York, NY; Royal Dutch Shell, The Hague, The Netherlands**
Projected Investment	**Total cost $200 million or greater, DOE match $80 million,**
Previous Experience	**Their technology was demonstrated in a pilot plant near Ottawa, Canada**
References	**19, 20, 25**

Current Biorefinery Activities *(continued)*

Company	**Range Fuels, Inc., Broomfield, CO**
Plant Site	**Soperton, GA**
Project	**Ethanol and methanol from southern pine**
Technology	**Thermo-chemical conversion of wood and forest residues to syngas; catalytic conversion of syngas to alcohols.**
Feedstock	**1200 tpd of unmerchantable pine wood and forest residues**
Energy Products	**10 million gal/yr from first unit; 40 million gallons of ethanol and 9 million gallons of methanol per year from commercial unit**
Yield	**113 gallons of alcohols per BD ton biomass**
Participants	**Khosla Ventures, Yeomans Timber, Ga. Forestry Commission, Western Research Institute, Merrick and Company, PRAJ Industries, CH2MHill, and Gillis Ag & Timber**
Projected Investment	**Total cost $225 million or greater, DOE match $76 million,**
Previous Experience	**Their technology was demonstrated in a 5 tpd pilot line in Colorado**
References	**19, 20, 26**

Comparison of Projects

Project	Technology	Capital Cost ($ millions)	Yield (gal/ton)	Capital Effectiveness ($/gal/yr)
Announced Projects				
Abengoa	Gasification & GTL	190 or more	79	more than 16.7
Alico	Gasification & fermentation	83 or more	75+ power, etc.	less than 4.0
BlueFire	Hydrolysis & fermentation	100 or more	68	about 5.3
Broin	Enzyme & fermentation	200 or more	83	cannot break out
Iogen	Enzyme & fermentation	200 or more	~71	about 11.1
Range	Gasification + GTL	~225	113	about 4.6
Corn[27]	50 Million GPY "dry mill"	~ 75	80	new about 1.6
Proposed Projects				
Flambeau	Fermentation of liquor	~40[28]	179[29]	about 2.0
Potlatch	Gasification & GTL	~150	50+steam +gas	less than 4.3

Leadership

- Any notion that there are not any technologies worthy of investment has been dispelled by the DOE Section 932 awards.
- Any notion that companies are unwilling to take large capital risk is also dispelled.

Leadership

- Non-pulp and paper industry players now have an opportunity to develop both the technology and commercial skill for the forest biorefinery on a plant scale.
- The amount of new technical information is doubling every two years; therefore, catch-up can be accelerated.

Serious Consequences

- Continuation of business as usual, will surely mean loss of leadership, faster decline and the closure of many more mills.
- The full impact will include infrastructure such as forest management, sawmills, building products and suppliers.
- This can be devastating to employment, rural community health and healthy forests. A recent prediction by one notable columnist: "My forecast for pulp making in Finland, in particular, is that it is doomed".
- We are dealing with serious consequences.

The Only Known Solution

Capitalizing on biorefinery opportunities may be the only way to avoid massive shutdown and loss of pulp and paper facilities in North America.

What is Missing?

- The vision and will to boldly seize the opportunity, and
- The fortitude not to accept excuses for poor performance of demonstrations.
- In today's world, these missing ingredients make the pulp and paper industry "non-competitive".

POTENTIAL Impact of One Opportunity

- The forest products industry harvested 278 million BD tons of wood in 2003.
- That wood contains roughly 90 million tons of hemicellulose.
- This pathway looks attractive in an AVAP pulping process which can be adapted to Kraft or more effective alkaline processes can be developed.
- If the forest products industry can isolate just half or 45 million tons of hemicellulose, it can be fermented to about 20 million tons or 6 BILLION GALLONS of ethanol or 1/7 of the U.S. national 35 billion gallon per year goal.
- This does not require harvesting one additional log.

All Is Not Yet Lost . . .

- Stora Enso and Neste Oil …" see the growing biofuel market as a promising and sustainable business opportunity…".
- Stora Enso will construct an $18 million dollar demonstration plant integrated into their Varkous mill. "Following the development phase the joint venture will build a full scale commercial production plant at one of Stora Enso's mills."

Conclusion

More and stronger efforts such as these are needed if the pulp and paper industry is to retain its unquestioned and historical leadership and business role in the use of wood.

??Q & A??

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