PERP Program - Biogasoline
New Report Alert
July 2007

Nexant's *ChemSystems* Process Evaluation/Research Planning program has published a new report, ***Biogasoline (05/06S1)***. To view the table of contents or order this report, please click on the link: http://www.chemsystems.com/reports/index.cfm?catID=2

OBJECTIVES OF REPORT

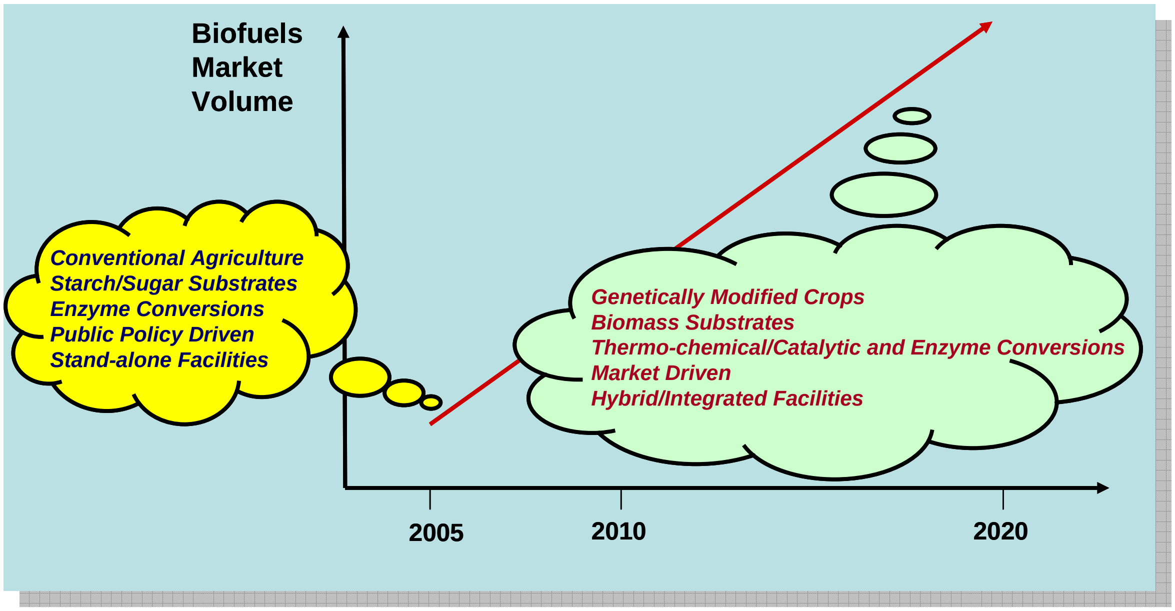
This report focuses on the technical and economic outlook for biologically-based liquid fuels that can substitute for conventional petroleum-derived gasoline (which we call "biogasoline"). Currently, the primary commercial type of biogasoline is bioethanol, but other types are being developed to meet various challenges. We also consider commercial and strategic factors that drive the broad-based global developments in this field. This report is intended to answer the following critical questions regarding biogasoline:

- What is the market outlook over the next 10 years for production and consumption of bioethanol?
- What are the key issues related to availability of starch and sugar substrates (feedstocks) for fermentation bioethanol production?
- What technological developments can be expected in bioethanol production?
- What alternative biogasoline types and associated new technologies can be expected to be developed by 2015?
- How competitive are various options for biogasoline with conventional petroleum gasoline?

Biogasoline Overall Perspective

Overall, the bioethanol industry is evolving, as it must, from a base primarily of fermenting grain (corn, wheat, milo, etc.), sugar (sugarcane and beet), and starch (cassava, potatoes, etc.) to cellulose fermentation and gasification. However, technologies for thermal-chemical conversion of biomass also can serve to make biogasoline, which can have a major impact on overall vehicle fuel supplies in the future. Figure 1 summarizes perceived aspects, in broad terms, of the biogasoline industry's likely evolution from its current state to what it is likely to be in 10-15 years.

Figure 1 Projected Evolution of Biofuels Production



Most Likely Development Pathways

Technology development generally is not a precise process, and can take many routes. The process is not always efficient, and advances reflect a certain element of trial and error as well as luck. Ultimately, however, the history of the process industries indicates that the key drivers that determine "technology evolution" are:

- Investment capital minimization
- Production cost minimization
- Environmental performance
- Energy and carbon efficiency
- Utilization of advantaged feedstocks

Another approach to technology development is to adapt and combine existing technologies, and leverage current experience to achieve a "path of least resistance" configuration, which might be sub-optimum, but which can be commercialized with least risk. The following are several "path of least resistance" configurations that might be used to advance the biofuels industry and come to grips with various basic challenges, which we believe can be most rapidly commercialized with relatively low risk.

Syngas from Coked Biomass to Biogasoline

- "Torrefaction", or coking, of various biomass materials – wood, straw, stover, switchgrass, etc. to produce a low-moisture, increased heating value, storable, granular material resembling coal, followed by,
- Gasification in whatever the leading-edge, most practical oxygen-blown coal gasifier may be adaptable at the time (typical contenders today are Shell, GE (formerly Texaco), GKT, and GTI, and German Choren is developing biomass gasification to make diesel fuel using Fischer-Tropsch catalysis), possibly integrated with power generation, to produce syngas for,
- Catalytic synthesis, including possibly an adapted Fischer-Tropsch catalyst, of biogasoline, separately or co-currently with biodiesel, jet fuel, other hydrocarbon products, and chemical feedstocks

Bioethanol Dehydration to Biogasoline

- Ethanol production from carbohydrates (starch, sugar, or cellulose) by fermentation, or by gasification of cellulose for fermentation of carbon monoxide to ethanol, followed by,
- Dehydration of ethanol to either n-butanol by the Sangi HAP or other similar technology, or to hydrocarbon gasoline by Sangi HAP or by leveraging the well-demonstrated Mobil MTG (methanol-to-gasoline) technology

Liquid Fuels Synthesis via Biomass Anaerobic Digestion Methane

- Methane production from waste biomass by anaerobic digestion (AD), followed by catalytic reforming to syngas by extremely common technology possibly integrated with power generation, followed by,
- Catalytic synthesis, including possibly an adapted Fischer-Tropsch catalyst, of biogasoline, separately or co-currently with biodiesel, jet fuel, other hydrocarbon products, and chemical feedstocks

Another way to organize biofuels technologies is by major routes, or "platforms". The two major platforms vying to make gasoline range motor fuels, fermentation and gasification, have widely different characteristics and involve different developmental issues. Table 1 provides a comparison among these two routes.

Table 1 Comparison of Two Platforms for Biogasoline

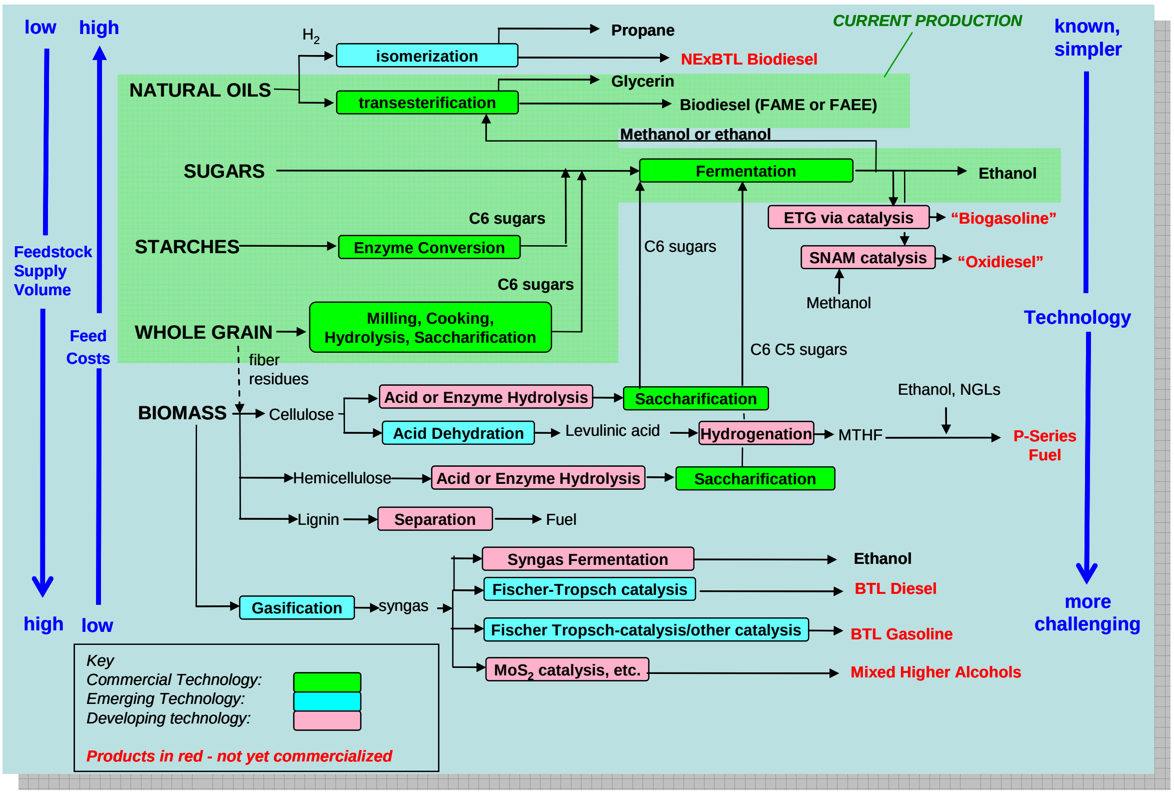
	Fermentation		Gasification
Feasible Substrates	Grain, sugar, biomass, syngas (will require different organisms)		DDGS, biomass, MSW, coal
Six carbon sugars	Yes		Yes
Five Carbon Sugars	Limited		Yes
Lignin	No		Yes
Pretreatment	Both mechanical and chemical		Mechanical
Conversion rate **Rapid< 1 hr., Slow>10 hr.**	Slow		Rapid
Pure product	Yes		No
Temperature/Pressure	Low / low		High / low-high
Cost per gallon **(assuming $30/ton feedstock)**	$1.05 (corn) $0.80 (sugar) $0.61[1] - $1.07 [2]		Current $1.85[3] DOE goal $1.19[3]
Notes	Pretreatment of cellulose has the potentia to result in numerous inhibitors to the ethanologen. Pretreatment conditions must be carefully matched to the ethanologen. Fermentation of mixed biomass is problematical		Thermal conversion at elevated temperature and reducing conditions. Primary categories are partial oxidation and indirect heating. Can handle mixed biomass.

Figure 2 provides a picture of:

- Availability and cost of feedstocks
- Many of the commercial and emerging technology options available or being developed
- The types of fuels that can be made
- Levels of commercialization

We have presented the entire complex of biofuels developments, including biodiesel, to put biogasoline in context with the larger biofuels development effort (with biodiesel elements represented in background tones). Beyond this are related developments in utility generation of electricity through biomass gasification and combustion, anaerobic digestion for substitute natural gas and power production, and chemicals and biobased materials production.

Figure 2 Current and Emerging Liquid Biofuels Technologies



Among potential feedstocks, the hierarchy of supply volumes available is indicated on the left of Figure 2 as increasing from top to bottom, while volumetric costs, inversely, are highest at the top for natural oils and fats and lowest at the bottom for biomass. The technologies, as indicated on the right, are generally arranged from most commercial at the top to less so towards the bottom.

Table 2 profiles the leading biogasoline technologies that Nexant evaluated for analysis in this study.

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Table 2 Status of Selected Emerging Biogasoline Technologies
Mid-2006

Technology	Source/Sponsor	Tech Route	Current Capacity, Status, Prospects
Cellulosic Ethanol	Iogen –	Hydrolysis, saccharification, Fermentation	Experimental plant in Ottawa- 1.0 million gpy reported from wheat straw, oat hulls, etc.; proposed 40,000 gpy plant in Idaho, estimated $300 million capex; supported by Shell and others
	US DOE -	Hydrolysis, saccharification, Fermentation	Extensive sponsorship of bench scale and pilot projects at universities and with enzyme developers
	Dedini –	Solvation, Hydrolysis, saccharification, Fermentation	Claim an ethanol-solvent based process to pretreat bagasse for conversion
	Abengoa -	Hydrolysis, saccharification, Fermentation	Developing a semi-commercial straw-based project in Spain
P-Series Fuel	S. Paul – Trenton Fuel Works, LLC	Acid hydrolysis, hydrogenation	NYSERDA grant to assess and demo hydrogenation of levulinic acid (ex cellulosic wastes) to MTHF co-solvent; levulinic acid pilot plant ran at 140 tpd
Ethanol-to-Gasoline	Sangi (Japan) –	Alcohol dehydration	Very cheap catalyst - 20-l. bench scale demo; product tested with Nippon Oil; $3 million, 3-year development program; international patents
	ExxonMobil / Methanex (New Zealand MTG)	Alcohol dehydration	Commercialized this methanol analog in 1990s based on cheap zeolite catalyst – 14,000 bpd, octane 92-94; shut down in 1997 due to <$30/bbl oil
Higher alcohols	Butanol – DuPont -	Fermentation	Expect to demonstrate 2nd generation by 2007
	Ecalene (mixed)	BIG - catalysis	Seeking partners for front end gasifier

1) Nexant calculation
2) DOE-NREL study on biomass conversion- http://www.eere.energy.gov/biomass/progs/searchdb2.cgi?6483
3) DOE-NREL-Nexant study on mixed alcohols to ethanol- http://www.nrel.gov/docs/fy06osti/39947.pdf

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