

NexantThinking™

Special Reports

**Biobutanol and Downstream Markets:
Will You Be Buying Bio?**

Brochure
April 2014



 **Nexant**

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1.1 OVERVIEW

Biobutanols can be converted into a multitude of specialty chemical and polymer products, as well as supplying the large existing petrochemical butanols markets. Concerns are mounting about the economic costs and environmental sustainability of the world's reliance on non-renewable resources. Consequently, some of the world's biggest players in the energy and petrochemical industries are seeking to develop new feedstocks and products derived from bio-based materials. In fact, two of them have teamed up, namely BP and DuPont, to form Butamax for the production of biobutanol. There are also many smaller start-ups involved in biobutanol development.

Reflecting the paradigm shift towards production of higher value chemicals, fuel markets have been demoted to secondary targets. This is due to the fact that chemical prices are generally at least twice that of fuels and thus will generate higher revenues, with the potential for increased profitability. Nexant's study assesses the technical, commercial, and economic status of producing bio-butanols as well as downstream chemical and fuel derivatives, and answers the questions:

- Will biobutanol be economically competitive?
- What chemical products can be produced from biobutanol?
- What impact, if any, could biobutanol and derivatives have on existing petrochemical-based butanol markets?
- Who are the players and what is their status of development?
- What is the potential threat for existing petrochemical producers?
- What are the potential opportunities for bio-developers?

1.1.1 ABE Biobutanol

The ABE fermentation process was used extensively prior to the introduction of the petrochemical hydroformylation based OXO process, but was generally considered uneconomical afterwards, due to the relatively low productivity, and much lower cost of petrochemical butanol. During the 1950s and 1960s, most ABE fermentations were replaced by petroleum-based chemical plants globally, except in rare cases, such as China and South Africa, though these eventually shut down.

1.1.2 Emerging Next Generation Biobutanol

Unlike historical biobutanol production via ABE fermentation, the vast majority of companies that are currently working to commercialize butanol production are depending on next generation fermentation using engineered organisms. Most are looking to leverage existing bio-based production (e.g., via retrofits of existing ethanol plants). ABE biobutanol only produces one isomer, *n*-butanol. Next generation biobutanol processes are targeting both *n*-butanol and isobutanol.

Numerous companies are developing or have developed new technologies to produce biobutanol, including:

- Butamax (BP/DuPont JV)
- Gevo
- Butalco
- Cobalt Technologies

- Cathay Industrial Biotech
- Tetravita Bioscience
- Green Biologics
- Syntech Biofuel
- Butylfuel LLC
- Bio Architecture Lab (BAL)
- METabolic EXplorer

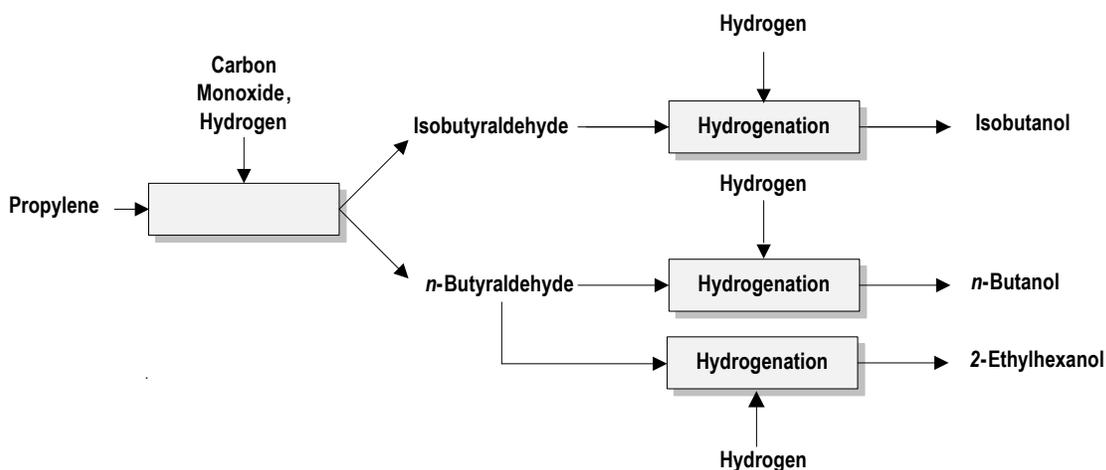
1.2 BACKGROUND TO BUTANOLS

n-Butanol and isobutanol are isomers of butanol that are commercially important alcohols with applications in a variety of specialty chemicals and fuel blending uses. Other notable butanols with some lesser commercial importance, the biological production of which is not being attempted include: *tert*-butanol and *sec*-butanol.

1.2.1 Petrochemical Butanol

The two important butanols that are being targeted for bio-based production, namely isobutanol and *n*-butanol, are conventionally produced using fossil fuel sources, along with other short chain oxo-alcohols by the hydrogenation of the corresponding aldehydes produced by hydroformylation of propylene. Figure 1.1 shows a simplified conventional *n*-butanol and isobutanol upstream value chain.

Figure 1.1 Simplified Conventional *n*-Butanol and Isobutanol Upstream Value Chain



Global *n*-butanol and isobutanol production volumes are approximately 4 million tons and 0.7 million tons respectively.

The traditional value chains for *n*-butanol and isobutanol include a variety of specialty chemical and intermediate uses. Both compounds are esterified to produce butyl acetates, ingredients in artificial flavoring, and are components of commercial plasticizers in various thermoplastic resins. In addition, *n*-butanol is a feedstock for the production of butyl acrylate, a monomer used for the production of acrylate-based resins for water-based paint and acrylate elastomers (acrylic rubber). Another

application for *n*-butanol is for ethylene glycol monobutyl ether, a commercially important solvent. Direct uses of butanols as solvents are also very commercially important, although these uses are declining.

Overall, traditional demand for *n*-butanol is driven by butyl acrylate and butyl acetate, while the far smaller market for isobutanol is driven by use in plasticizers, isobutylamines and as an additive in lube oils.

1.2.1.1 Biobutanol

Virtually all bio-based butanol production has focused on the use of a variety of fermentation platforms with biomass-derived sugars, from first generation agricultural sources or from biomass, as a feedstock.

Biobutanols have attracted considerable interest as a potential fuel additive. Butanol has a number of advantages over other common alcohol blendstocks used for improving octane rating. The net heat of combustion of butanol is 83 percent by volume of that of gasoline compared to 65 and 48 percent for ethanol and methanol, respectively, giving butanol a lower mileage penalty for a given volumetric blend level. In addition, it has better miscibility with gasoline, and less of an affinity for water.

Unlike traditional oxo-alcohol products, bio-based *n*-butanol and isobutanol are also widely regarded as feedstocks for the production of C₄ olefins via established dehydration chemistry, a route generally regarded as unfavorable for traditional petrochemical olefin-derived butanols. The dehydration of *n*-butanol produces butene-1, a commercially important linear alpha-olefin in the production of linear low-density polyethylene (LLDPE), while the dehydration of isobutanol produces isobutylene, a C₄ olefin used in the production of synthetic rubbers, oxygenates, and other applications.

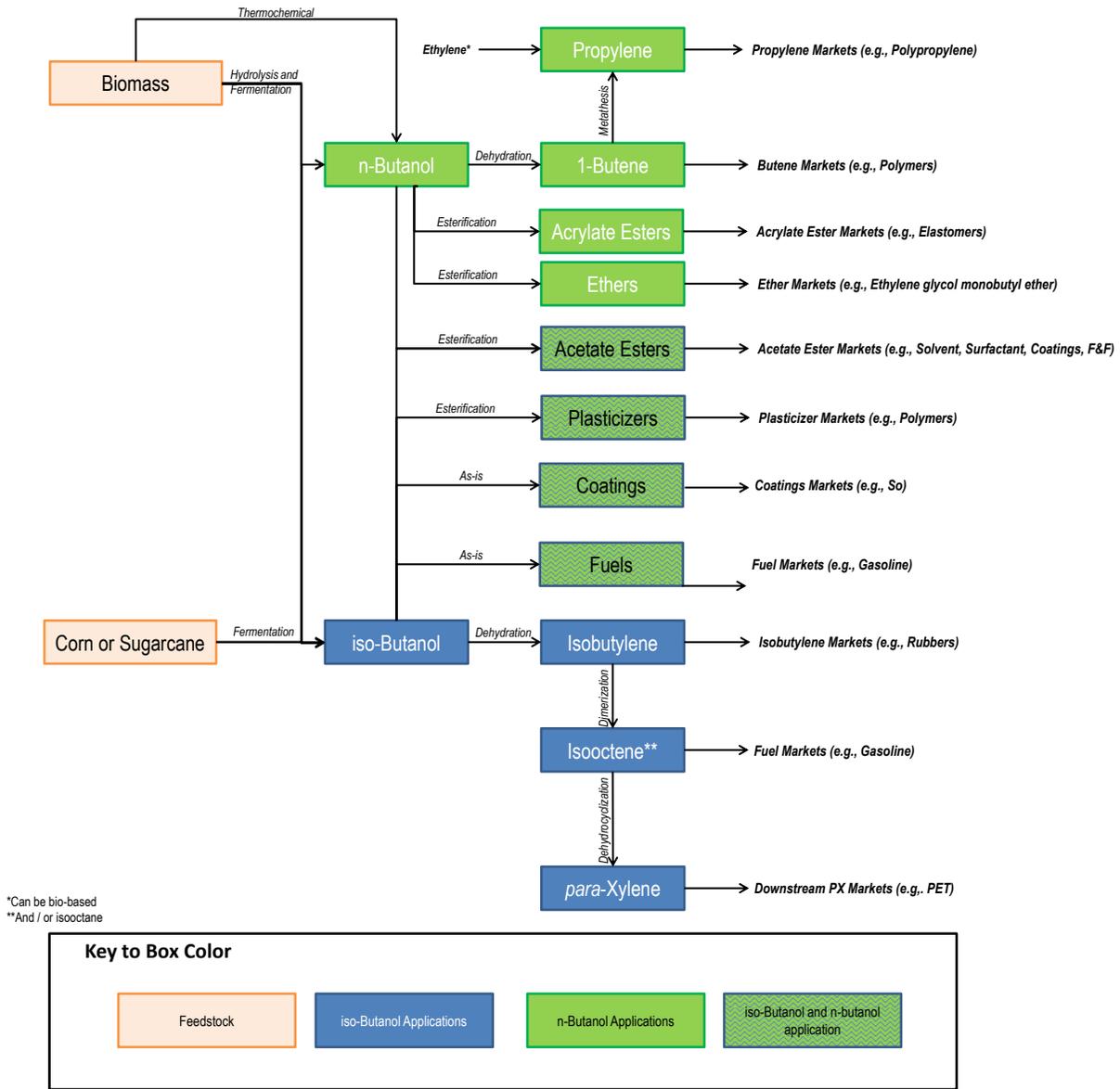
Widespread bio-based butanols production could potentially impact both fuel and chemical markets, preferentially selling to the more profitable but smaller chemical markets. Current specialty chemical *n*-butanol and isobutanol prices would likely bottom out as large amounts of new bio-based supply comes online, with corresponding effects on the pricing of downstream products. However, the proliferation of bio-based butanols would have the greatest impact in the chemical industry on downstream C₄ olefin products, as bio-based products provide an alternative supply chain to mitigate the shortage in C₄ olefins left by the feedstock choices of new ethane and ethane/propane steam crackers. Despite the likelihood of greater penetration within the specialty chemicals markets, the sheer size of the C₄ olefins market ensures that it will remain the largest and most liquid chemical market for bio-based butanol manufacturers to target.

Figure 1.2 shows the biobutanol value chain.

The study gives subscribers a solid grasp of the potential markets for biobutanols, with an emphasis on the economics of their development in industrial applications, including but going beyond the fuel markets. The study also addresses the broader technical and commercial implications such as feedstocks use and siting locations. Nexant evaluates the potential markets for biobutanol technologies, using the OXO process (hydroformylation) as a benchmark conventional technology against the emerging biologically based routes. This prospectus describes Nexant's biobutanol multi-client study, the scope of the proposed report, the methodology to be used, and Nexant's qualifications to perform such a study.

The study was completed in the fourth quarter of 2013.

Figure 1.2 Biobutanol Value Chain



*Can be bio-based
**And / or isooctane

1.3 OBJECTIVE

The study objective assesses the technical, commercial, and economic status of producing biobutanols and associated derivative chemicals, as chemicals typically have values at least twice that of fuels. Chemicals produced from biobutanol have the potential to significantly supplement or even replace petrochemical-based C₄ derivatives going forward. The study also considers critical elements of the bio-feedstocks supply chain as well as the petrochemicals value chain in developing its conclusions.

1.4 SCOPE

The study addresses the competitiveness of biobutanol production routes, as well as select derivative chemicals. Resultant production costs are compared to the economics of conventional routes.

This report assesses:

- Economics and technical feasibility of biobutanol via conventional bio-feedstocks (e.g., corn and/or sugarcane)
- Economics and technical feasibility of biobutanol via biomass-based production
- Economic and technical comparisons to butanols via the OXO route (hydroformylation)
- Commercial status and industry developments
- Evaluation of derivative chemicals opportunities—both existing butanol applications (e.g., plasticizers) and emerging applications (e.g., *para*-xylene)
- A discussion of any other relevant developments (e.g., Global Bioenergies fermentation isobutylene)

1.4.1 Technology Coverage

The report analyzes the following technologies and markets, as relevant:

- Conventional bio-feedstock fermentation to biobutanols
- Biomass hydrolysis and fermentation to biobutanols
- Biomass conversion to biobutanols via thermochemical processes
- Existing downstream applications for biobutanols (e.g., plasticizers)
- Emerging downstream applications for biobutanols (e.g., *para*-xylene)

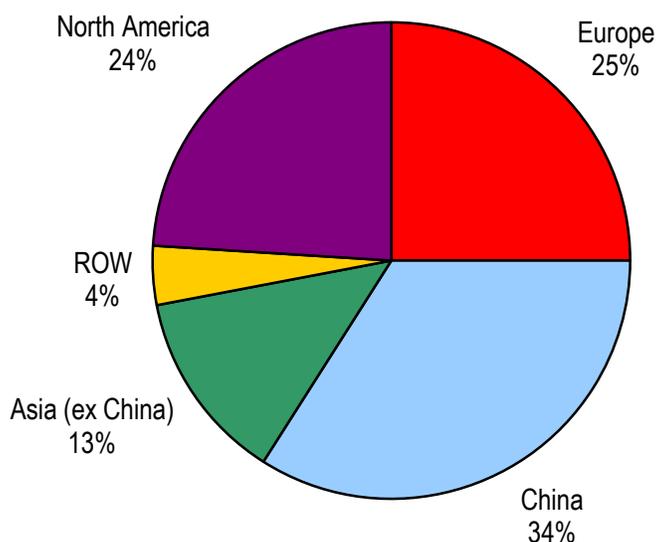
1.4.2 Market Analysis

The study provides a high level global coverage for the purposes of identifying global demand, emerging opportunities, threats, and potential roadblocks to market acceptance of biobutanol and derivatives. Nexant focuses on the following producing regions and markets:

- North America
- Western Europe
- China
- Asia (excl. China)
- Rest of the World

Figure 2.1 presents the regional split of butanol demand.

Figure 2.1 Regional Split of Butanol Demand
(2012)



biobutanol MC charts.xlsx\F2

1.4.3 Economic Analysis

Economics were developed in the fourth quarter of 2012, and are presented using Nexant's proprietary Cost of Production (COP) modeling system. An example COP analysis for butanol via corn dry milling in the United States Midwest is presented in Table 2.1, with all values removed.

Table 2.1 Illustrative Cost of Production

COST OF PRODUCTION ESTIMATE FOR: Biobutanol				PROCESS: Corn Dry Milling			
				CAPITAL COST		MILLION U.S. \$	
Plant Start-up	2012			ISBL		0.0	
Analysis Date	2012			OSBL		0.0	
Location	US Midwest			Total Plant Capital		0.0	
Capacity	0.12 Million Metric Tons/Yr			Other Project Costs		0.0	
	40 Million Gallons/Yr			Total Project Investment		0.0	
Operating Rate	100 Percent			Working Capital		0.0	
Throughput	0.12 Million Metric Tons/Yr			Total Capital Employed		0.0	
PRODUCTION COST SUMMARY				UNITS	PRICE	ANNUAL	
				Per ton	U.S. \$	U.S. \$	U.S. \$
				Product	/Unit	Per ton	Per lb
						U.S. \$	Per gal
RAW MATERIALS	Corn	ton	0.00	0.00	0.0	0.0	0.0
	Sulfuric Acid	lb	0.00	0.00	0.0	0.0	0.0
	Calcium Hydroxide	lb	0.00	0.00	0.0	0.0	0.0
	Sodium Hydroxide	lb	0.00	0.00	0.0	0.0	0.0
	Corn	lb	0.00	0.00	0.0	0.0	0.0
	Ammonium Sulfate	lb	0.00	0.00	0.0	0.0	0.0
	Superphosphate(46)	lb	0.00	0.00	0.0	0.0	0.0
	Calcium Carbonate	lb	0.00	0.00	0.0	0.0	0.0
	Catalyst & Chemicals		0.00	0.00	0.0	0.0	0.0
	TOTAL RAW MATERIALS				0.0	0.0	0.0
BY-PRODUCT CREDITS	Acetone	ton	0.00	0.00	0.0	0.0	0.0
	Ethanol	ton	0.00	0.00	0.0	0.0	0.0
	DDGS	ton	0.00	0.00	0.0	0.0	0.0
	TOTAL BY-PRODUCT CREDITS				0.0	0.0	0.0
	NET RAW MATERIALS				0.0	0.0	0.0
UTILITIES	Power (Purchased)	kWh	0.00	0.00	0.0	0.0	0.0
	Steam (Gas)	ton	0.00	0.00	0.0	0.0	0.0
	TOTAL UTILITIES				0.0	0.0	0.0
	NET RAW MATERIALS & UTILITIES				0.0	0.0	0.0
	VARIABLE COST				0.0	0.0	0.0
DIRECT FIXED COSTS	Labor	0 People	0.00	Thousand U.S. \$	0.0	0.0	0.0
	Foreman	0 People	0.00	Thousand U.S. \$	0.0	0.0	0.0
	Supervisor	0 People	0.00	Thousand U.S. \$	0.0	0.0	0.0
	Maintenance, Material & Labor		0.0	% of ISBL	0.0	0.0	0.0
	Direct Overhead		0.0	% Labor & Supervision	0.0	0.0	0.0
	TOTAL DIRECT FIXED COSTS				0.0	0.0	0.0
ALLOCATED FIXED COSTS	General Plant Overhead		0	% Direct Fixed Costs	0.0	0.0	0.0
	Insurance, Property Tax		0	% Total Plant Capital	0.0	0.0	0.0
	TOTAL ALLOCATED FIXED COSTS				0.0	0.0	0.0
	CASH COST				0.0	0.0	0.0
	Depreciation @	0 % for ISBL & OPC		0 % for OSBL	0.0	0.0	0.0
	COST OF PRODUCTION				0.0	0.0	0.0
	Return on Investment (Incl. WC) @			0 Percent	0.0	0.0	0.0
	COST OF PRODUCTION + ROI				0.0	0.0	0.0

1.4.3.1 Regional Coverage

Economics are presented for the following regions where active development is occurring:

- North America
- South America
- Western Europe
- China

Economics are presented for other regions if developments warrant coverage, at Nexant's discretion.

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The evaluations of conventional technology are based on Nexant's in-house information regarding process technology, augmented by contacts with licensors, engineering contractors, and other experts in the industry. Analyses of emerging technologies are built up from reviews of patents, public domain information, and discussions with the technology development companies and engineering contractors.

Nexant utilizes proprietary and commercial state-of-the-art software tools to develop the technology and economic estimates. These are well established engineering tools in the process chemical industry and are employed by major engineering contractors.

Commercial information and forecasts are developed from Nexant's extensive in-house databases, augmented with selected regional fieldwork. Market projections are developed based on Nexant's in-house modeling systems and experience.

1.5 BACKGROUND

Nexant was established on January 1, 2000 and prior to that date, the staff of Nexant operated as a separate consulting group within a major engineering company. Nexant is now an independent company owned by a number of investors. Nexant acquired ChemSystems, Inc. on September 1, 2001, and the combined entity ("**Nexant**") now has access to even more enriched and extensive experience and resources, offering services that include:

- Master planning/feasibility studies
- Technology evaluation
- Techno-economic and commercial analyses
- Financial evaluation (cashflow modeling, etc.)
- Benchmarking
- Monitoring project implementation

Nexant is very well qualified to undertake the technical, commercial, economic and financial evaluations, from its own offices, without the need to subcontract. Owing to its extensive experience, and known for its "out-of-the-box" thinking, Nexant has received the "Best Large Consultancy" award by the British Consultants and Construction Bureau.

1.6 DESCRIPTION OF SERVICES

Nexant is a specialist, not a generalist company. Our area of expertise is the energy and process industries, including oil refining, natural gas, petrochemicals, polymers, chemicals, pharmaceuticals and fertilizers. Our business has been built upon providing broad management consultancy services to leading companies active in these industries, and also to banks, suppliers, governments, and others interested in these sectors.

Nexant's strengths lie in its combination of techno-economic, commercial, and strategic capabilities. These core competencies are described below:

1.6.1 Technology/Economics

From its foundation in chemical engineering and industrial chemistry, Nexant offers distinctive expertise in process technology and economic analysis. Assignments may be performed on a separate, stand-alone basis or as input to broader consulting engagements.

Services include:

- Economic and financial analyses of projects or businesses
- Valuation of assets or businesses
- Technical audit of existing facilities
- Project feasibility/planning
- Technology innovation and assessment
- Comparative/competitive technology audit and appraisal
- Process design and cost estimation
- Technology availability, screening, licensing arrangements
- Contractor pre-qualification, evaluation and selection
- Project management, including resident advisory services
- Price, margin and profitability forecasting

This discipline is supported by comprehensive economics, cost and price databases.

1.6.2 Commercial

Based upon a technical and commercial understanding of the industries we serve, Nexant supports clients through a variety of market and commercial activities. As with our techno-economic work, these commercial assignments may be performed on a stand-alone basis but are more normally an input to broader consulting engagements.

Services include:

- Feedstock and product market analysis
- Marketing and market research
- Supply/demand analysis and forecasting
- Studies of trends and future markets
- "Benchmarking" of costs and competitiveness
- Medium- and long-range planning

The commercial discipline is supported by databases of global supply, demand and capacity developments in all major petrochemicals.

1.6.2.1 Strategic Planning

Industry specific expertise and an understanding of world market forces distinguish Nexant's work in Strategic Planning. Various innovative tools and methodologies tailored to the energy and process areas are used to challenge conventional thinking. Nexant extends its traditional project team approach to engaging clients directly in the Strategic Planning process. Interactive client consultant relationships promote consensus, a critical factor for successfully developing pragmatic, implementable solutions.

Services include:

- Definition of corporate and business visions
- Portfolio planning
- Entry strategy evaluation
- Diversification, acquisition, divestment studies
- Competitive analysis and business positioning
- Global competitiveness
- Trade flow and impact studies
- Strategic options, selection, and implementation

1.7 ASSIGNMENTS UNDERTAKEN WHICH COVER BIO-FEEDSTOCKS, BIOCHEMICALS, AND/OR BIOFUELS

1.7.1 Multiclient Work

During the past ten years, Nexant has completed a number of major multisubscriber studies. Selected multisubscriber studies which included coverage of biochemicals and biofeedstocks include:

- **PERP Report 09/10S4 Biobased Commodity Feedstocks** – A study of the technology, and economics of producing commodity biofeedstocks
- **PERP Report 06/07S11 “Green” Polyethylene** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering polyethylene, and a comparison to conventional routes
- **PERP Report 07/08S11 “Green” Polypropylene** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering polypropylene, and a comparison to conventional routes
- **PERP Report 06/07S4 Glycerin Conversion to Propylene Glycol** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering propylene glycol from glycerine, and a comparison to conventional routes
- **PERP Report 08/09S11 Plants as Plants (PHAs)** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering polyhydroxyalkanoates(PHAs), as an alternative to conventional polyesters
- **PERP Report 00/01S3 Biotech Route to Lactic Acid/Polylactic Acid** – A study of emerging biotech routes to lactic acid and polylactic acid. Processing technologies, and economics of producing and recovering lactic acid and polylactic acid are investigated
- **PERP Report 08/09S7 “Green” Acetyls** – A study of emerging biotech routes to acetic chemistry. Processing technologies, and economics of producing and recovering acetates are investigated
- **PERP Report 09/10S8 “Green” Glycols and Polyols** – A study of emerging biotech routes to glycols and polyols (e.g., propylene glycol and sorbitol). Processing technologies, and economics of producing and recovering glycols and polyols are investigated
- **Cellulosic Sugars: Unlocking Biomass’ Potential** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering commodity sugars and/or direct products (e.g., ethanol) from cellulosic biomass as well as a comparison to conventional routes
- **Bio-Based Chemicals: Going Commercial** – A survey of the emerging biotechnology, processing technologies, announced project capacities, and a risk adjustment of these announced capacities. This included coverage of commodity monomers and polymers, as well as emerging polymers (e.g., succinic acid and/or 1,4-butanediol for polybutylene succinate)
- **Plants to Plastics** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering commodity polymers such as polyethylene, polypropylene, polyethylene terephthalate, and others as well as a comparison to conventional routes
- **Bio-Acrylic Acid and Derivatives** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering bio-acrylic acid as well as a comparison to conventional routes

- **Biotransformation Routes to Specialty Chemicals** – Includes consideration of conversions of natural oils, fatty acids, fatty acid esters, fatty alcohols and fatty amines, and fermentation technologies and commercial overviews of many bio-based product markets

Nexant has also completed a number of definitive studies on specific regions. These studies have analyzed the business structure and opportunities for many of the chemicals covered in this proposed study within the context of a changing economic environment. In addition to these studies, Nexant maintains a global commercial and technoeconomic database covering the principal petrochemicals, intermediates and polymers.

1.7.2 Single Client Studies

Selected single client studies which included coverage of biochemicals:

- **Multiple Technoeconomic Due Diligences** – In advance of IPOs, Nexant performed comprehensive technoeconomic analysis, including technology and markets. In such capacities, Nexant has investigated and evaluated multiple conversion technologies, including cellulose hydrolysis as well as thermochemical platforms for products from biomass
- **Multiple Technoeconomic Due Diligences** – In advance of IPOs, Nexant performed comprehensive technoeconomic analysis, including technology and markets. In such capacities, Nexant has investigated and evaluated multiple product platforms, including algae based, isoprenoid based product platforms
- **“Forest Refinery” Industry Evaluation** - A U.S. national laboratory retained Nexant to assess the technical and economic feasibility of a forest refinery designed to manufacture chemical products from trees. The analysis screened a variety of biomass conversion technologies and compared the production costs and energy consumption levels of each route to conventional routes. Processes evaluated included fermentation, lignocellulose separation, lignin conversion and gasification
- **Hunest Biorefinery Market Study** - A project to revitalize a former Nitrokemia site in Hungary to convert circa 200,000 tons per year of biomass into biopolymers, green solvents and intermediates. Nexant was engaged to undertake a market study of the commercial opportunities for the project covering mainly pricing and the European market in order to guide the company in developing its marketing strategy for the project
- **Biochemical Opportunities in the United Kingdom** - The National Non Foods Crops Centre (NNFCC) has engaged Nexant to provide a focused analysis of renewable chemical opportunities in the United Kingdom. The project was in part undertaken to gain a better understanding of the opportunities for the United Kingdom to integrate renewable feedstocks into its chemical manufacturing base. Nexant's analysis was used to support the development of research and development programs in both academia and industry organizations
- **Fermentation Routes to Adipic Acid: Petrochemical Competitive Benchmarking** - For a developer of fermentation routes to Adipic Acid (nylon intermediate), this study was to provide analyses of conventional petrochemical routes, issues over nitric oxide emissions, and other critical factors
- **Financial Due Diligence** - Analysis of Myriant Technologies' renewable route to succinic acid and potentially to adipic acid and other valuable green chemical intermediates. Examines technology, intellectual property position, market potential, and competitor positioning
- **Sustainability and Plastics** - Client was interested in understanding how increased awareness of environmental issues and of the related initiatives might impact the polyolefins business in the

future and asked Nexant to provide a high level review of the following conventional polymer displacement threats to conventional polymers: biodegradable polymers, bio-based polymers, and recycling. The main focus was on polypropylene in North America, but wider issues were also considered

- **Fermentation Routes to Bio-Succinic Acid/BDO** – In a series of studies for a number of different stakeholders, Nexant evaluated technologies, markets, and competition for fermentation routes being developed for this potential raw material for polybutylsuccinate, 1,4-butanediol, and other chemicals derivatives, and compared to petrochemical routes
- **PLA** – For this key renewable, biodegradable commodity polymer, polylactic acid, or polylactide (PLA) made from corn or sugar substrates, Nexant evaluated production technologies and markets for a number of different stakeholders
- **Chemicals by Depolymerization of PHAs: Petrochemical Competitive Benchmarking** – For a developer of fermentation and crop-based PHA (polyhydroxyalkanoates) production that exploring the feasibility of depolymerizing these natural polyesters to make commercial chemicals (monomers, intermediates, solvents, etc.) , Nexant provided analysis of the same C₃ and C₄ chemicals production via petrochemical routes, and assisted in developing process and cost models of the speculative depolymerization routes
- **Hydrocarbon Fuels and Chemicals via Sugar Fermentation: Process Development Assistance** – For a biotech developer of sugar fermentation routes to C₅ hydrocarbon-based (isoprene homologues) for vehicle fuels, chemical intermediates and specialty chemicals, this was a series of three projects to provide assistance, including process flowsheet and capex review, troubleshooting, and cost reduction strategies, product recovery studies, and process safety analyses
- **Advanced Biobutanol Process Technology, Economic, and Market Due Diligence** - For a prospective investor in this technology development, Nexant performed a broad-based feasibility study/due diligence with the full cooperation of the developer providing R&D data and existing business models for critique. Butanol was examined for its proposed fuel potential as well as for its large existing market as a solvent and chemical feedstock. The economics of the incumbent petrochemical route was compared
- **Biopolymers for Beverage and Food Packaging** – For a U.S.-based, leading, multinational beverage and food company, Nexant performed a study of the technical and economic feasibility of using, and issues around, selected bio-based polymers for packaging in the future, including PLAs, PHAs, green polyethylene, and others. For this, evaluated and compared three radically different emerging routes to green p-xylene production for feeding production of green PTA to react with green MEG to make 100 percent green PET bottle (and fiber) resin
- **Bio-ethylene for Beverage and Food Packaging** – For another U.S.-based, leading, multinational beverage and food company, Nexant performed a study of the technical and economic feasibility of using, and issues around, green polyethylene. For this, Nexant evaluated and compared green MEG production for PET bottle (and fiber) resin
- **Biopolymer Value Chain** – Investigate renewable feedstocks for biopolymers, biopolymer compounding and polylactide
- **Fermentation Propanol to Green Propylene – Confidential** - This report identifies discusses four routes to producing propylene from renewable feedstock (corn, sugarcane and glycerine). Bio-propylene, bio-based chemicals, biological route, biotechnology, genetically modified organism (GMO), bacteria are included in the study

- **Chemicals from Corn** - This was a broad-based study for the National Corn Growers Association (NCGA), funded by the U.S. DOE, to identify and screen chemicals that could be feasibly produced from corn. The study considered a wide range of potential sugars, and fermentation-derived acids, alcohols, and other building blocks, but emphasized fuel ethanol derivatives, including basic petrochemicals, solvents, intermediates and specialties, and application of the Reactive Distillation technology sponsored by the NCGA. The basic economics of ethanol production and potential improvements, economies of scale, logistics, and other production and value chain issues, are addressed in the study

6.1 CONTACT DETAILS

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