



PROSPECTUS

Is Bio-Butanediol Here to Stay?

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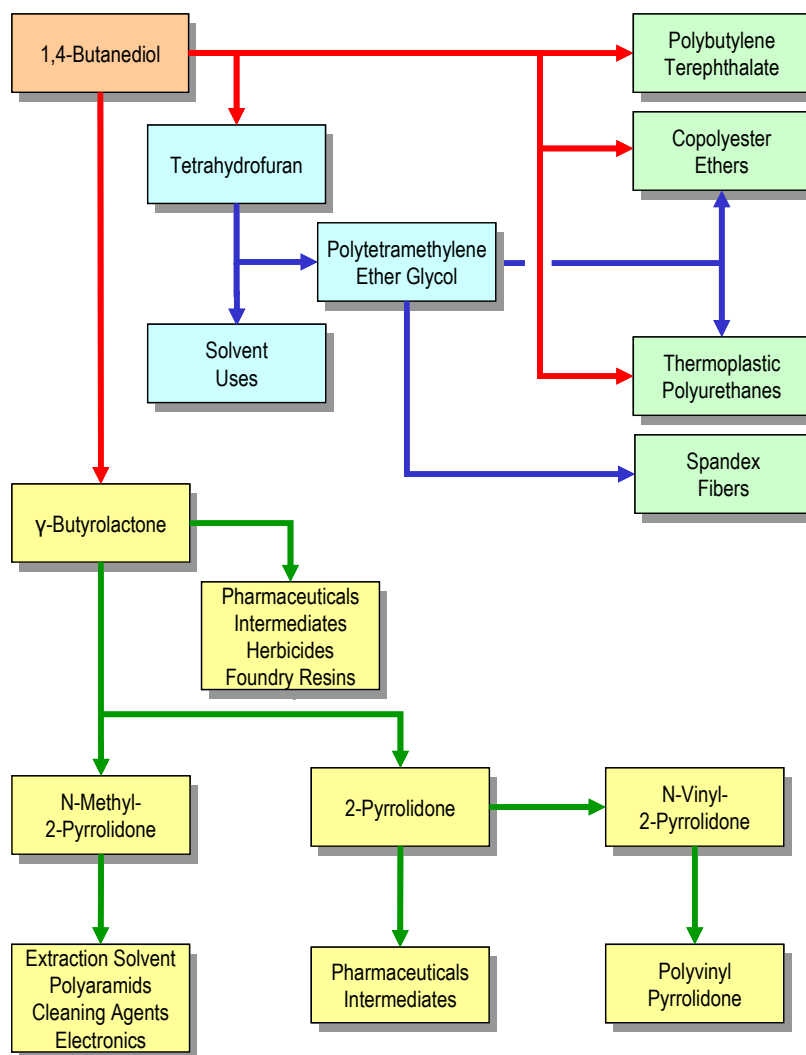


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The global butanediol (BDO) industry appears to be on the cusp of a technological revolution. Biological routes to BDO are being perfected which offer tremendous promise to new participants, but threaten to dramatically alter the business from the perspective of established producers. Indeed, the opportunities are of such great magnitude that even established participants are taking a hard look at bio-based routes. For example, Davy Process Technology is working with Myriant on ways that bio-succinic acid can be employed in Davy's well established process to co-produce BDO/GBL/THF. Further, at least on paper, there may even be an advantage to bio routes in the Davy process as the process can potentially utilize filtered fermentation broth thus avoiding the costs associated with purification and recovery of succinic acid. Another example of an arrangement between bio-firms and established BDO producers is the Memorandum of Understanding between Genomatica and Mitsubishi Chemical to study bio-BDO and derivatives production in Asia.

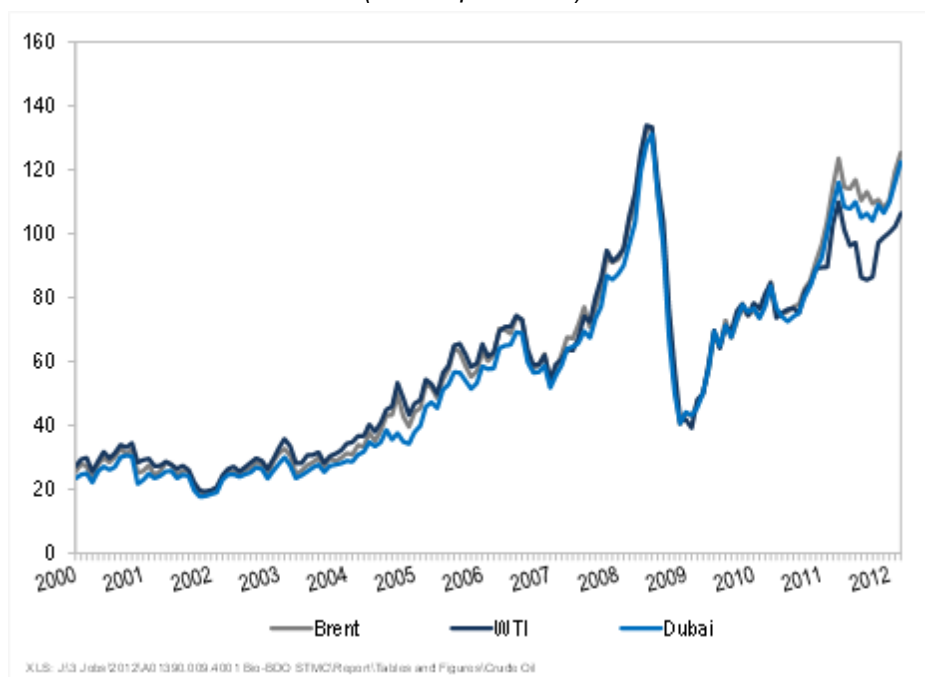
With the global demand for 1,4-butanediol (BDO) estimated at 1.5 million metric tons in 2011, BDO's growth will continue to be derived from its almost exclusive use as an intermediate to synthesize other chemicals and polymers at an annual average rate of almost 4.5 percent until 2016. Figure 1.1 illustrates the value chain downstream of BDO. The principal products are tetrahydrofuran (THF) and γ -butyrolactone (GBL), which in turn both have solvents applications and further high-value derivatives.

Figure 1.1 The BDO/THF/GBL Value Chain

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One of the catalysts to the current interest in Bio-BDO is the desire to reduce the use of petroleum-based feedstocks in light of global oil prices having reached unprecedented levels. After peaking at almost \$140 per barrel in 2008, oil prices fell sharply in the face of the global financial crisis. However, crude oil prices have since rebounded and have settled in the \$80 to \$100 range per barrel, as illustrated in Figure 1.2.

Figure 1.2 Global Crude Oil Prices
(Dollars per Barrel)



Another catalyst is the desire to improve the BDO process' environmental footprint. A broad concern for the natural environment has brought about a new goal for industries, consumers, and governments: to strive toward the reduction of pollutant and greenhouse gas (GHG) emissions. A bio-based BDO process would have a favorable GHG balance when compared to petroleum-based BDO because any carbon sourced from biomass can be directly traced to atmospheric carbon dioxide (CO₂) via photosynthesis.

The BDO industry has already witnessed several technological upheavals in the past. Indeed, there have been three phases in the development of butanediol and derivative technology since the first processes based on acetylene in the 1930s. These phases also characterize the structure of the industry as access to technology in the early years dictated the rate of industry development.

The first phase started with the development of BDO from acetylene by Dr. Reppe of I. G. Farben in the 1930s. During the Second World War, the process was used to provide a feedstock for butadiene, one of the key monomers in the manufacture of "BUNA-S" synthetic styrene-butadiene rubber. The post-war BDO industry continued to be based on acetylene and, using fairly straightforward organic chemistry, tetrahydrofuran (THF - via dehydration), γ -butyrolactone (GBL - via dehydrogenation) and *N*-methyl-2-pyrrolidone (NMP from GBL and methyl amine) became commercial products as well. Up until the late 1970s, BASF, ISP (formerly GAF) and DuPont were the exclusive suppliers of BDO using acetylene based Reppe chemistry, as the ability to safely handle acetylene was a major hurdle to entering the business.

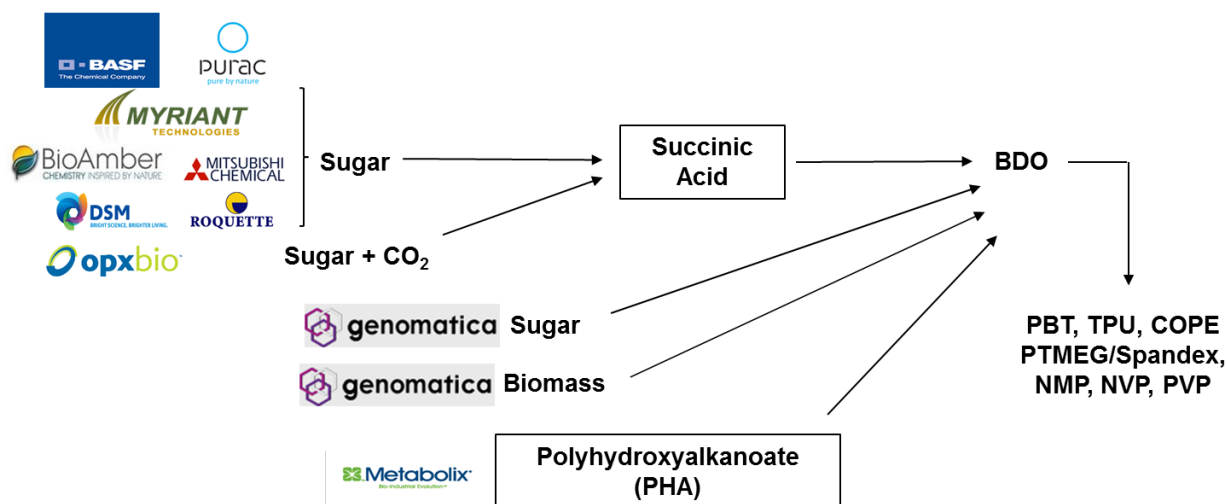
The second phase was characterized by the introduction of new challengers. Mitsubishi Chemical Industries was the first company to break the technology entry barrier into the

butanediol industry through commercialization of its butadiene acetoxylation process in the late 1970s. It was not until the late 1980s and early 1990s that another new technology was commercialized for BDO production, when ARCO exploited its strong presence in the propylene oxide (PO) and derivatives business by developing a BDO process from PO. The early 1990s saw another development, this time by the technology company/engineering contractor Davy (now Davy Process Technology). Davy developed a technology based on the esterification of maleic anhydride (made from either *n*-butane or benzene) with ethanol, followed by hydrogenation of the ethyl ester to diethyl succinate, then GBL, and finally BDO, typically with a THF co-product.

The third phase consisted of commoditization through technology improvements, including a drive to world-scale BDO plants with the introduction (in 1998) of SISAS maleic anhydride-based integrated BDO/THF/GBL technology, producing around 110,000 metric tons per year of BDO equivalents (a combination of BDO, THF, GBL, and NMP expressed as tons of BDO consumed).

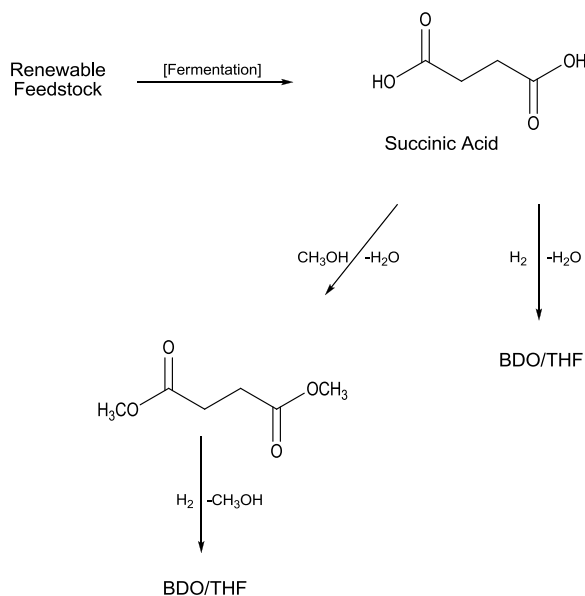
As innovations in BDO/THF technology continue, and improvements in the maleic anhydride-based BDO routes are still being made, new developments emerge for the production of BDO using renewable resources. As before, a whole new set of firms threatens to dramatically alter the BDO landscape through technological advances. Figure 1.3 illustrates the companies currently developing BDO processes using biotransformation technologies. Several of the companies are well-advanced in their construction and/or commercialization plans.

Figure 1.3 Developers of Bio-Based 1,4-Butanediol Routes



Apologies to product/route developers left out – this is only a sample

Many of these developments are centered on the production of succinic acid from biofeedstocks. The premise of this approach is to utilize a renewable sugar substrate (chiefly glucose and other C₆ sugars) with optimized microorganisms that can efficiently convert the glucose to succinic acid via fermentation. Succinic acid can subsequently be converted to BDO/THF using conventional means such as the Davy approach, in which the succinic acid would first be converted to the dimethyl ester and then undergo vapor phase hydrogenolysis to BDO/THF mixtures. This chemistry is shown below.



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In this study, Nexant describes and analyzes technologies that would appear to be competitive or even economically advantaged relative to petrochemical routes. This report provides a comprehensive comparison of the technology, economics, and potential markets for BDO produced via renewable sources versus petrochemical sources, with an emphasis on examples such as the following:

- **Bio-succinic hydrogenolysis to BDO** – companies such as BioAmber, DSM, Purac and Myriant are currently developing technologies that will produce succinic acid from the fermentation of sugar, which can then be used to manufacture BDO.
- **Butanediol from sugar** – BDO can also be produced from the direct fermentation of sugar using *Escherichia coli* (E. coli) bacteria.
- Other developing technologies to BDO include routes from:
 - Biomass
 - Polyhydroxyalkanoate (PHA)

- **BDO manufacturing chemistry is rich, with several routes currently commercially employed, including:**
 - Conversion of maleic anhydride to dimethyl ester, followed by hydrogenation/hydrogenolysis to BDO and THF via GBL.
 - Acetoxylation of butadiene to 1,4-diacetoxy-2-butene, followed by hydrogenation and hydrolysis to BDO.
 - LyondellBasell propylene oxide route.
 - Darien propylene acetoxylation/hydroformylation route.
- **BDO from coal** – BDO can be produced by the reaction of acetylene and formaldehyde, followed by hydrogenation of 1,4-butyne diol (Reppe Concept).

This report also covers the regional and global market outlook for BDO and its main derivatives THF and GBL.

The study was published in July, 2012. The cost of the study is US\$ 20,000 (twenty thousand U.S. dollars).

This study's objective is to assess the technical, commercial, and economic aspects of producing 1,4-butanediol (BDO) from renewable sources such as bio-succinic acid or cellulosic feedstock (i.e., a sugar platform) and provide an economic comparison to conventional routes. The study considers critical elements of the bio-feedstocks supply chain, as well as the technical and economic aspects of BDO manufacture and use in developing its conclusions.

This report covers:

- Bio-based technologies for the production of feedstocks leading to the production of BDO
- New technological developments
- Description of conventional routes to BDO currently in commercial operation
- Economics and cost competitiveness of bio-based routes, compared to conventional routes of BDO
- Market outlook for BDO and its main derivatives THF and GBL

The study addresses the competitiveness of current and emerging BDO production routes, with respect to a wide range of technical and economic assumptions, including: different feedstocks and feedstock prices. Resulting production costs are compared to conventional BDO economics.

2.1 TECHNOLOGY COVERAGE

The types of BDO routes considered in the study include:

- From succinic acid (made from sugar substrates)
- Direct fermentation of sugar substrates
- From polyhydroxyalkanoate (PHA)
- From *n*-butane (via hydrogenation/hydrogenolysis of maleic anhydride)
- From acetylene
- From butadiene
- From propylene oxide
- From allyl alcohol

These process technologies are evaluated from technical, economic, and commercial perspectives. A review and assessment of representative process routes for each major technology is performed. In addition, the stage of process development is characterized.

Cost of production estimates are developed for the above BDO technologies in selected global locations. Sensitivities are performed for feedstock costs.

2.2 FEEDSTOCK COVERAGE

The primary feedstocks covered in the study are:

- Bio-succinic Acid
- Sugar
- Polyhydroxyalkanoate (PHA)
- *n*-Butane (via Maleic Anhydride)
- Acetylene
- Butadiene
- Propylene Oxide
- Allyl Alcohol

2.3 GEOGRAPHICAL COVERAGE

The study provides global coverage, with focus provided for the following markets:

- Global
- North America
- Western Europe
- Asia Pacific (excluding China)
- China
- Rest of World

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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 uses 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 used by major engineering contractors.

Commercial information and forecasts are developed from Nexant's extensive in-house databases, augmented with selected regional fieldwork.

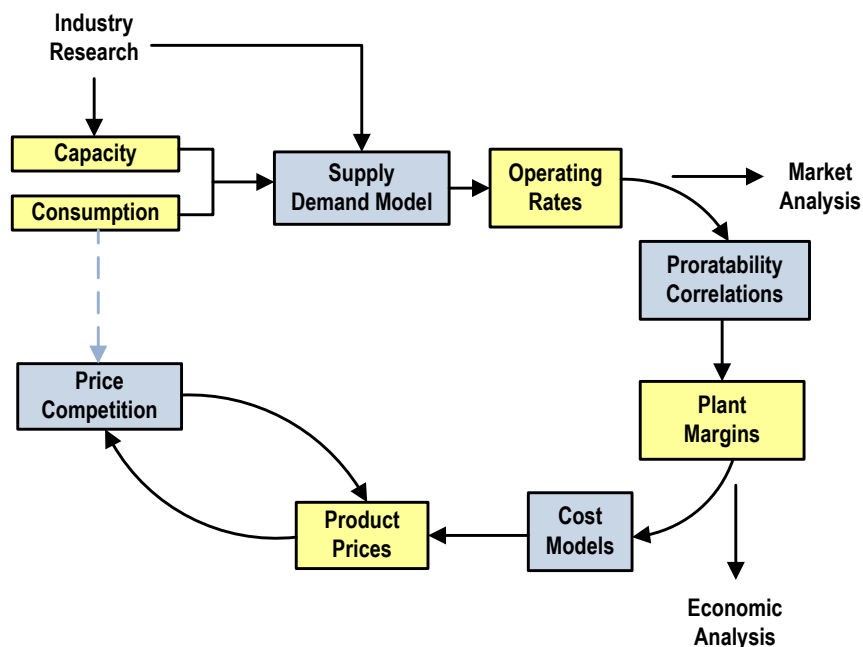
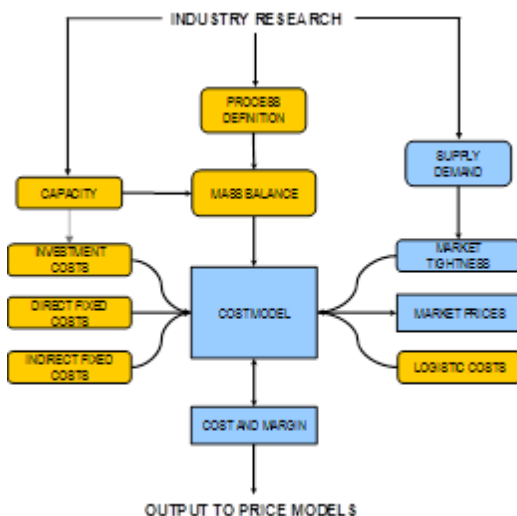
Market projections are developed with the aid of Nexant's supply/demand computer modeling systems, such as Nexant's *ChemSystems* Simulator, which is discussed in more detail below.

Nexant's ChemSystems Simulator

Nexant's *ChemSystems* simulator is the proprietary simulation model developed by Nexant and used to generate all the analysis and forecasts of *ChemSystems* Online® and other offerings including the *ChemSystems* Petroleum and Petrochemical Economics (PPE) Program. The simulation model is an experience-based database running commodity petrochemical business logic algorithms to produce multi-scenario simulations of the global industry.

The integrated *ChemSystems* Online® Simulator simultaneously develops, as illustrated in Figure 4.1, forecasts of regional consumption, production, imports, exports and inventory changes for all commodity petrochemicals in all countries/regions.

The simulator is integrated from end-use markets back to petrochemical feedstocks. It considers inter-material competition, inter-regional price relationships, chain margins, product substitution, logistical costs and trade drivers. Costs and prices are integrated from crude oil, natural gas and petrochemical feedstocks to downstream products. One of the functional blocks, depicted in Figure 4.1, has been expanded on the next page (Figure 4.2) to illustrate the interconnectivity of these drivers and the complex relationships that are built into Simulator algorithms.

Figure 4.1 *ChemSystems Simulator Simplified Logic Diagram*Figure 4.2 *ChemSystems Simulator Functional Blocks*
(Simplified cost model logic diagram)

Nexant's *ChemSystems* simulator delivers step change improvements in market forecasting and business/corporate planning, while reducing the resources and time required to evaluate multiple hypotheses and scenarios.

5.1 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 Chem Systems, 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 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's ChemSystems Group has also received the honorable award of "**Best Large Consultancy**" by the British Consultants and Construction Bureau. This award was contended by a number of companies. However, Nexant was judged the winner for its outstanding contribution in developing a real-time, on-line chemical industry simulator. Nexant's ChemSystems Group is now part of Nexant's Energy & Chemical Consulting (E&CC) division.

5.2 DESCRIPTION OF SERVICES

Nexant is a specialist, not a generalist company. Areas of expertise for the E&CC Division (of which the ChemSystems Group is a part) are 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, as well as to banks, suppliers, governments and others interested in these sectors.

Nexant's strengths lie in its combination of technoeconomic, commercial and strategic capabilities. These "competencies" are described below, followed by an outline of the practice areas into which the E&CC Division is organized.

5.2.1 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.

5.2.2 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 technoeconomic 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.

5.2.2.1 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

5.3 ASSIGNMENTS UNDERTAKEN WHICH COVER BUTANEDIOL AND BIO-CHEMICALS

The E&CC division has also completed a number of definitive studies covering 1,4-butanediol, including both petrochemical and bio routes. These studies have analyzed the business structure and opportunities for BDO within the context of a changing economic environment. In addition to studies specifically covering BDO, Nexant has also been extremely active in engagements covering bio processes and routes in general. A sampling of our qualifications as related to BDO and bio processes are as follows:

- **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
- **BDO and Derivatives Technical Due Diligence. Confidential** - Nexant conducted a technical due diligence for the client's butanediol and derivatives business. The business consists of an existing plant and a planned new plant. The due diligence has consisted of a visit to the company and a tour of the existing plant, discussions with process technology engineers, and an independent analysis of company data and supporting documentation

- **1,4-Butanediol (BDO) Project – Saudi Arabia** - Nexant was retained as technical (and market) advisor to the project on behalf of ABN Amro/Saudi Hollandi Bank. The project, sponsored by GACIC, a wholly owned subsidiary of Sipchem, is the first BDO Project in the Middle East. The process involves novel butane isomerization technology, and co-produces tetrahydrofuran for export
- **1,4-Butanediol and Derivatives** – A chemical producer in Eastern Europe retained Nexant to determine market opportunity for 1,4-butanediol, tetrahydrofuran, gamma butyrolactone and *n*-methyl pyrrolidone. Nexant developed a price forecast, evaluated technologies and technoeconomic analysis to assess market opportunity from potential competitors and to provide the client with a marketing strategy
- **1,4-Butanediol, *n*-Butanol and Acetic Acid** - Commercial and technical analysis of 1,4-butanediol, *n*-Butanol and Acetic Acid. 1,4-butanediol U.S. producer economics were provided
- **1,4-Butanediol via Hydroformylation of Allyl Alcohol** – This study provided a comparison of 1,4-butanediol routes. New processes to produce 1,4-butanediol via gas-phase hydroformylation of allyl alcohol to produce 4-hydroxybutyraldehyde were discussed. Conventional routes analyzed are acetylene and butadiene based routes
- **Butanediol via Carbonylation of Allyl Acetate** - Compared economics of conventional acetylene/formaldehyde butanediol production with new GE process that uses a cobalt catalyst in the hydroformylation of allyl alcohol
- **Butanediol, Tetrahydrofuran, and Gamma-Butyrolactone** – This study provide an in-depth industry analysis that evaluated and summarized new and improved process technology, economics, and market information for butanediol and tetrahydrofuran
- **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
- **Bio-succinic Acid Benchmarking** – For a leading Japanese biopolymers developer; a detailed, sites-specific cost benchmarking of the Succinium (DSM-Roquette) succinic acid facility to be built at Lestrem, France and the Bio-Amber succinic acid facility at Bazancourt, France, covering process design, micro-organism selection, mass balance, energy balance, fermentation protocols, plant plot plan, site-specific technoeconomics
- **Ethanol** – Analysis of fuel ethanol production by dry corn milling fermentation
- **Global Maleic Anhydride Business** – This multi-client study covers the technologies, markets, economics and issues for the following applications: unsaturated PET resin, 1,4-butanediol, tetrahydrofuran, butyrolactone, fumaric acid (food), malic acid (food), succinic acid (food), artificial sweetener (aspartic acid), lube oil additive, and agricultural chemicals (fungicide/pesticide)

- **Glycerine** – Comparison of the natural oil and synthetic-based production routes considering production technologies, economics, feedstocks, and global markets
- **Maleic Anhydride** – This report is part of Nexant's Process Evaluation/Research Planning (PERP) Program and discusses recent market, economic, environmental and technology issues for maleic anhydride. The report covers the following applications: agricultural chemicals, unsaturated polyester resins, fumaric acid, malic acid, succinic acid, lubrication oil additives, styrene copolymers, polymers, 1,4-butanediol/THF, detergents and aspartic acid
- **Plants as Plants** – A study of the emerging biotechnology, processing technologies and economics of producing and recovering polyhydroxyalkanoates (PHAs) - natural polyesters – by alternative routes of fermentation and in crops, including analyses of agricultural production economics, PHA extraction costs, byproduct biomass fuel utilization, and potential PHA markets
- **Biodiesel Glycerine Byproduct - Market Dynamics** – For a major U.S.-based multinational agricultural and food company with a growing stake in biofuels, Nexant analyzed the market demand/price elasticity (with a growing glut of biodiesel glycerine byproduct), existing uses of glycerine, potential substitutions for others polyols such as propylene glycol and sorbitol, and potential future applications, including reaction derivatives of glycerine in various applications and fuel uses. Nexant considered the near term and emerging and long-term market outlets for USP and other refined grades of glycerine, as well as for crude biodiesel glycerine byproduct, which is of a more problematic quality than soap and oleochemical byproduct. The study required developing views of biodiesel growth, and pricing scenarios under various assumptions
- **Biodigestion of Food Wastes** – Nexant performed technology audits and market studies for MOM-ECAP, and another, Kuwait-based developer of projects in New York City, New Jersey and Kuwait to ferment food wastes to produce liquid and solid fertilizer/fungal disease suppressant products by the (aerobic) EATAD process of IBRC of Vancouver, BC. This also included analyses of competitive anaerobic based biodigestion technologies
- **Biomass Ethanol Process Evaluation** - Nexant performed a detailed technical and economic analysis of a commercial scale plant for the production of fuel grade ethanol from wood biomass via fermentation, a process developed by a national energy laboratory. Among the goals of the program was the incorporation of the latest R&D developments into the design. The results from this study were compared against earlier designs
- **Biomass Ethanol Development Technical Support** - Under a multiyear program, Nexant provided technical support for the SERI program to develop viable alcohol fuels production technology based on cellulosic feedstocks. Activities included: investigation of prototype cellulose to ethanol via hydrolysis plant designs for capacities of 50 MM to 250 MM gallons per year; detailed design and capital cost estimate for an anhydrous ethanol plant based on enzymatic hydrolysis of hardwood chips; techno-economic evaluation of proposed processes

including biomethanation of biomass pyrolysis gases and liquid fuels from cellulosic biomass

- **Business Analysis** - Nexant analyzed the profitability and cash margins for olefins, provided supply/demand for 1,4-butanediol and its derivatives and applications, and provided supply/demand for polypropylene globally
- **Cellulosic Ethanol Feasibility Analysis** - A synfuels company retained Nexant to determine the technical and economic feasibility of using cellulosic feedstocks to produce commercial quantities of fuel grade ethanol. Alternative feedstocks (corn and other grains) and by-products were included in the evaluation
- **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
- **Economic Evaluation** - Nexant provided a detailed economic evaluation of a patented process for the production of tetrahydrofuran (THF) from butanes based on information available in the literature including any patents applied for and/or granted. Because feedstock pricing is expected to play a central role in this tetrahydrofuran process, the production of maleic anhydride (MAN) was of importance in evaluating the economics and, thus is an integral part of the study
- **Enzyme Process Assessment** - Nexant assessed the impact on process economics and energy consumption resulting from substituting immobilized cells of *Zymomonas Mobilis* for conventional yeast in a commercial corn-based ethanol facility
- **Ethanol Market and Cost Competitiveness Evaluation** - Nexant was retained by an ethanol producer and its financial advisor to provide an independent market study and evaluation of project cost competitiveness to help raise funds to convert an existing sugar- and corn-based ethanol plant in Louisiana to process organic waste (biomass) as a feedstock
- **Ethanol versus MTBE – Litigation Support** – Nexant advised the U.S. Department of State in an action defending California against methanol interests for claims of losses in the phase-out of MTBE and use of ethanol as a substitute gasoline oxygenate. This work included a detailed analysis of the ethanol production and distribution infrastructure in the United States and addressing practical, environmental, safety, and issues of using ethanol in gasoline
- **Ethanol Project Management** - A Midwestern U.S. ethanol producer of corn-based gasohol retained Nexant to assist in the implementation of its 40 million gallon per year project. This included a review of the process technology and hardware provided by technology licensors

and vendors. Nexant's study assisted the client to obtain Federal loans and secure bank financing

- **European Ethanol Markets Analysis** - A study for a Japanese client reviewed the West European ethanol business including synthetic and fermentation sources. Demand, pricing, grades, end-uses, ethanol production by location and production economics were provided. In another study for this client, Nexant compared the economics of the four plants producing synthetic ethanol with the most efficient (molasses) fermentation ethanol producer
- **Fatty Alcohols from Coconut Oil Project – (Cebu, The Philippines)** – This was an extensive technical and market due diligence for a bank on the client's proposed new fatty acids/fatty alcohols plant, which involved visiting the client on Cebu, and a number of experts and oleochemicals sites in the Philippines, meetings with the process technology vendor, Lurgi AG, in Cebu and in Frankfurt, Germany to review technology, flowsheets, and project budget, and performing a competitive market study (Asia and global supply/demand, prices, competition, etc.). The study included consideration of byproduct glycerine purification and disposition
- **Financial Due Diligence** – For a Middle East client, Nexant provided an analysis of its renewable route to succinic acid and potentially to adipic acid and other valuable green chemical intermediates. The study examines technology, intellectual property position, market potential, and competitor positioning
- **“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
- **Fuel Ethanol Opportunity Analysis** - A major oil/chemical company interested in developing fuel grade ethanol facilities in the Midwest retained Nexant to assess the competitive aspects of ethanol/gasohol. Factors evaluated included state incentive programs and change prospects, freight costs to prospective markets and the current level of penetration of unleaded gas by ethanol
- **Global Biofuels Strategy** - For a leading U.S.-based multinational firm grounded in the agricultural sectors, Nexant performed a comprehensive analysis comparing technological, supply chain, and geographic options for involvement in the biofuels sector
- **Market Assessment** - Analyzed the feasibility of using maleic anhydride as a 1,4-butanediol feedstock and explored market opportunities for butanediol derivatives due to expected insufficient supply of acetylene feedstock
- **Market Assessment** - Analysis of the market for 1,4-butanediol in Far East and the opportunities in applications and for new producers

- **Market Overview** – Nexant provided a market overview, price forecasts and a summary of environmental, health, safety, handling and transportation issues for selected chemical products derived from the C₃ and C₄ streams, including 1,4-butanediol, potentially available from PDVSA's refinery
- **M2M Feasibility for Developing Economies** – For USAID, Nexant studied the feasibility of capturing various streams of fugitive methane and bringing them to market (“methane-to-market”, or M2M), including anaerobic biodigestion of agricultural waste biomass
- **Oleochemicals Feasibility Study** - For London-Sumatra’s proposed new production in Indonesia, Nexant surveyed the global oleochemicals industry and markets, focusing on palm and palm kernel oils, glycerine, fatty acids, and fatty esters compared to other natural oil-based products and competition with food markets
- **Opportunities Analysis** - For a planned joint venture that was to result in a major surplus above the foreseen needs of the present business, the company preferred to add value to production rather than offer it for sale on the merchant market and wanted to identify and examine potential opportunity. Nexant provided potential application in agrochemicals, food acids, lube oil additives, detergent and other polymers, and butanediol/tetrahydrofuran production
- **Price Forecasts** – For a state-owned chemical company in China, Nexant provided historic prices and price forecasts for selected raw materials and products, including 1,4-butanediol
- **Production Economics** - Provided economics and cash cost of production of 1,4-butanediol on a site-specific basis for the two existing producers: GAF Huels at Marl and BASF at Ludwigshafen
- **Production Economics** - Assessed technoeconomics of the process for producing 1,4-butanediol from propylene oxide and allyl alcohol, a new proprietary process, and compared it to the conventional Reppe process
- **Producer Evaluation** - In this study of 1,4-butanediol producer economics (Reppe route) in West European and potential competitor economics (maleic anhydride route), Nexant examined the economics of butanediol production by analysis of the major producers and considered opportunity for a third producer
- **Product Screening** - The objective of this study was to identify and screen potentially attractive business investment opportunities for the Paraguana region. The selected products included 1,4-butanediol
- **Regional Price Forecasts** – Nexant was retained by Sipchem to provide certain market forecasts for the products from its methanol and butanediol projects at Jubail
- **Renewable Succinic Acid Opportunity Analysis. Confidential** – Nexant was retained to support the client’s evaluation of potential investment opportunities in bio-succinic acid. The primary tasks were to: assess the strengths and weaknesses of potential renewable succinic acid competitors and estimate their manufacturing cost of production and to conduct

interviews with potential succinic acid customers with respect to substitution dynamics including acceptance, demand drivers and pricing

- **Succinic Acid Derivatives** - This study was prepared to validate succinic acid as one of the most interesting targets for bio-based processing. The study discusses markets, operating and capital costs, technology, production economics and price forecasts for maleic anhydride, BDO, THF, and GBL
- **Supply/Demand Forecast** – Nexant prepared supply/demand profiles for 1,4-butanediol in North America, Europe and Asia
- **Surveys of Global Oleochemicals Markets and Technologies** – Nexant addressed natural and synthetic-based oleochemicals markets for a major chemical company
- **Synthesis Gas (Future Sources)** - This report reviewed the technology for production of synthesis gas (H₂, CO mixtures) from a number of sources. Most emphasis was devoted to coal and biomass (municipal solid waste and wood) gasification and new gasification technology. The report discussed downstream processing requirements and examined coal and biomass properties and their impact upon gasifier design. The economics of producing industrial fuel gas (gasifier effluent after acid gas removal) via different routes were compared to the direct use of natural gas and low sulfur fuel oil
- **Technology Assessment** - Evaluation of new process for producing butanediol via Davy McKee's diethyl maleate process
- **Technology, Company, Finance, and Project Due Diligence in Biofuels** – Nexant has performed a number of recent due diligence assignments for financial institutions assessing the feasibility and value of technologies, companies, businesses, or proposed projects focused on bioethanol or biodiesel

Section 6

Contact Details and Subscription Information

6.1 CONTACT DETAILS

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6.2 AUTHORIZATION FORM, TERMS AND CONDITIONS

Subscription Terms and Conditions

1. The undersigned (hereafter "Client") hereby subscribes to purchase from Nexant, Inc. ("Nexant"), Nexant's study, "*Is Bio-Butanediol Here to Stay?*" (The "Subscribed Report"), in accordance with the following terms and conditions.

Nexant will provide to Client the following information and services:

- (a) Access to electronic downloads of the report via a password-protected area from the web site, www.chemsystems.com. Nexant will provide users of the service with a user name and password. Subscriber will inform Nexant if any of its employees who are registered users leave Subscriber's employment.
2. While the Subscribed Report will represent an original effort by Nexant based on its own research, it is understood that portions of the Subscribed Report will involve the collection of information from third parties, both published and unpublished. Nexant does not believe that the Subscribed Report will contain any confidential technical information of third parties. Nexant does not warrant the accuracy or completeness of information.
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 8. Nexant does not accept responsibility for the accuracy of the information in the Subscribed Report. Client is responsible for use of the information contained in the Subscribed Report and Nexant will not be responsible for any reliance Client places on the contents thereof.
 9. A person who is not a party to this Agreement shall have no right to enforce any of its terms.
 10. By signing the Authorization, Nexant and Client agree that the Proposed Table of Contents, Authorization and Terms and Conditions represent the complete agreement between them regarding the Subscribed Report. No change, modification, extension, termination or waiver of this Agreement, or any of the provision herein, shall be valid unless made in writing and signed by duly authorized representatives of the parties.
 11. This Agreement and the relationship between the parties shall be governed by and interpreted in accordance with the laws of the state of New York, United States of America.
 12. Upon authorization, Client will be billed by and shall pay to Nexant a total of US\$20,000.00 (twenty thousand U.S. dollars). Client shall be invoiced the full Subscription Fee upon signature of this Agreement. Amounts are due upon receipt of invoice and payable within thirty (30) days. If payment is not made within 30 days from the date of invoice, Client will be subject to late payment charges. Such charges will be calculated at a monthly rate of 1.5 percent of the invoice amount, compounded for each period or part period of 30 days that the invoice remains unpaid. Fees quoted do not include any applicable sales tax, or use or value added tax, all of which are for the account of Client.

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Is Bio-Butanediol Here to Stay?

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