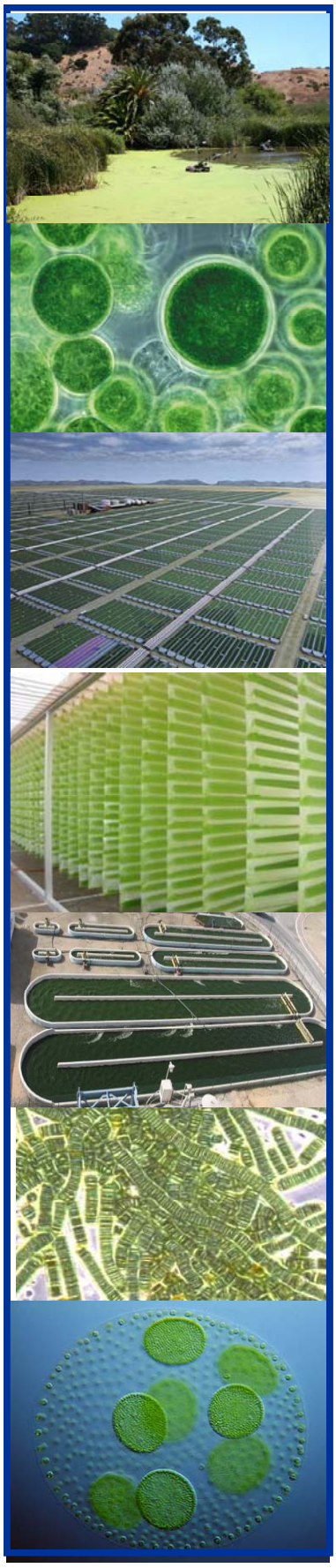

Prospectus

Algae: Emerging Options for Sustainable Biofuels

Nexant

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Algae: Emerging Options for Sustainable Biofuels

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Contents

The science is sound for using selected microalgae to convert CO_2 to natural oils and other biomass. Commercialization to produce specialty chemical products is well advanced. However, commercialization to produce high volume biofuels faces extensive challenges with regard to biological, engineering, and economic factors. For biofuels via microalgae to succeed, Nexant expects that significant genetic breakthroughs will be needed, and high volume fuel production will need to be supported by other income streams such as from co-production of higher value specialty products, and/or wastewater treatment charges.

The Challenges Driving Interest in Algae

The world is faced with multiple challenges that impact the use of fuels. The most important are:

- Climate change and the imperative to take action to mitigate global warming
- Waning petroleum resources combined with political conflicts that threaten supplies
- Growing economies competing with developed nations for fuels, food, and other commodities
- Pressure on water resources

In 2006, Nexant described and analyzed these problems, and considered biofuels as potential solutions in a landmark and widely subscribed report, ***"Liquid Biofuels: Substituting for Petroleum".*** A subsequent report, published in 2008, ***"Liquid Biofuels: The Next Generation"*** updates the information and analyses of the earlier report and extends coverage to new developments, including a sub-section on algae. These two reports examined mainly ethanol and other alcohols and fatty acid methyl esters biodiesel (FAME) derived from crops or other large plants, and converted to fuels either directly or by combinations of fermentation, transesterification, or thermochemical routes. This new study, ***Algae: Emerging Options for Sustainable Biofuels,*** builds on the extensive knowledge gained during the course of these and other studies that Nexant has performed over the last few years.

Society has set its sights on developing sustainable energy and chemicals from alternative sources. Many believe that liquid biofuels represent a good first step and short-term solution, but many also have come to believe that the biofuels being produced today (ethanol and biodiesel), are in a critical competition with food production. In the longer term, the hope is that wastes and purposely-grown cellulosic biomass will be the main source of feeds for biofuels production, with a phaseout of food commodities such as corn, soybeans, other oilseeds, and rendered fats. However, cellulosic biomass is comprised primarily of a mixture of polymeric sugars, or carbohydrates, which contain much oxygen, in contrast to the more energy-dense hydrocarbons of conventional petroleum vehicle fuels and natural gas. Natural oils (lipids, and esters made from them) contain much less oxygen, and are closer to hydrocarbons in energy content and density. A number of stakeholders are now looking at growing lipid-producing algae as a

superior, sustainable, and potentially very large volume option for producing high-quality biofuels. The residual algal biomass could also be used as a fermentation feedstock. These developments initially are focused on producing mainly diesel and jet fuels, but possibly could also produce high quality gasoline.

What is Algae?

The term "algae" encompasses many different groups of living organisms. Algae have been commonly regarded as simple plants. Others, such as cyanobacteria, are more closely related to higher plants or animals in character. Algae have been part of the pattern of life on earth since primeval periods and range from small, single-celled organisms to much larger, multi-cellular organisms that are related to plants, but without a vascular system, roots, steams, leaves, or embryos (fruits and seeds). They are mainly aquatic and are the primary producers in the aquatic food chains. Some are fairly complex with differentiated forms, such as giant kelp, which are algal species that grow in underwater "forests" to be nearly 200 feet long. This report is concerned only with microalgae, which are microscopic, though they can be single-celled, colonial, or multi-cellular. In bench and larger scale demonstrations, some microalgae have been shown to be orders of magnitude more productive of oils per unit of land area than the best oilseed crops, such as palm oil and jatropha.

Algae Need Carbon Dioxide for Commercial Production

Carbon capture for displacement of fossil fuels is another likely role for growing oil-producing algae. Many industry participants are seeking to develop what appear to be very expensive and elaborate chemical/mechanical technologies and systems to capture, concentrate, and sequester in the earth or the oceans the carbon dioxide (CO_2) generated in fossil fuel burning for power and heat generation by industry. Algae need a high volume and concentrated source of CO_2 to thrive. Algae can perform an equivalent capture function and utilize the captured and concentrated CO_2 (or even just the CO_2 in stack gas) to "recycle" the CO_2 photosynthetically using sunlight as the source of energy. While this carbon will be immediately re-released upon burning the algal biofuels, the entire process has the net result of capturing stack carbon to make the fuel and leaving an energy equivalent amount of fossil carbon in the earth. The algae route is thus sustainable and at least as carbon neutral as other biofuels feeds, but additionally could offer a fossil fuel burner a directly verifiable sink for carbon disposal. How this could be monetized and at what price is not yet clear.

Some developers are also integrating algae production with wastewater treatment as a source of nutrients and a value-added service. Others also have broached the problem of lipid harvesting by growing aquatic animals (e.g., tilapia, brine shrimp) on the algae and extracting fats from these for biodiesel production, while byproducing protein meals for animal feed.

The algae route to commercial biofuels production is still developing, and many approaches are being considered. Thus, growing algae is proposed for open pond systems on dry land or ocean impoundments, or alternatively in closed systems contained in rigid or flexible plastic tubes,

bags, or other transparent media, called photobioreactors (PBRs). Such systems for fuel production contained in glass tubes were proposed in the early 20th Century.

Microalgae production systems are well commercialized in a number of countries for production of nutritional supplements, primarily *Arthrospira platensis* (Spirulina). These are mostly operated in shallow, high rate ponds with open raceways wherein the continuous flow of algal suspensions is driven and mixed by paddle wheels. However, the food microalgae market is relatively low-volume, with high values of $5-$5,000 per kg. The pond systems are similar to designs used for wastewater treatment and lead to the concept of integrating ponds for the two purposes. Some analyses show that photobioreactors (PBRs) have capital and operating costs that are too high for fuels production as contrasted with these raceway high rate ponds.

One of the greatest practical challenges of microalgae technology is harvesting the algae and dewatering the biomass for extraction of oil. The solution may be in bio-flocculation of the microalgae cells. Other areas of biotechnology research are focused on improving oil productivity and properties, disease resistance, and other qualities of algae strains. Work is also ongoing to develop strains capable of producing hydrocarbons instead of lipids, and getting the algae to release the oils or other fuel products (e.g., ethanol) to the outside of their cells.

Some of the challenges and risks associated with systems for growing commercial algae for photosynthetic oil production are:

- Dependence on large streams of continuously-fed concentrated CO_2, which need to be relatively uncontaminated
- Moisture control can be a problem in open systems
- Only a very thin layer of suspended algae, a few centimeters deep, is actually active in photosynthesis
- Byproduct hydrogen can be a safety risk in closed systems
- Open systems are subject to infiltration of alien microbes (such as rotifers, which feed on algae) or the proliferation of genetically modified algal strains to the ecosystem; with closed systems, the same risk is expected to exist in the long run
- Algal suspensions are extremely dilute and difficult to concentrate to levels where oils can be economically recovered

Some developers are looking to use microalgae cell biomass residual after oil separation as feed to alcohols fermentation or anaerobic fermentation to produce biogas (methane + CO_2) for fuel, or for use as animal feed or even human food.

In summary, algae strains could be a more sustainable option because of the “green multitasking” they can potentially perform, including:

- More efficiently using non-agricultural land or existing water bodies (fresh or salt) for biofuels production
- Recycling point-source CO_2 to produce a biofuel in a distributed or centralized manner

- Remediating municipal sewage or other wastewater streams
- Co-producing animal feeds, foods (proteins), and other fuels or chemicals (e.g., as oils, other biological co-products, or via biogas, fermentation ethanol, or other alcohols)

Alternatively, other types of microalgae can potentially yield hydrocarbons by fermenting sugar s without performing photosynthesis with CO_2.

Governments have had and will continue to play a role in algae development. This can be done by supporting research and analysis, providing biofuels incentives, regulating biofuels, purchasing products, and providing guidelines and incentives for carbon capture monetization. Nonetheless, Nexant believes that private investments by large energy and biotech companies, as well as venture capitalists, will be the most effective route for developing algal biofuels in the near future.

While to date the United States is the major country driving microalgal fuels development, initiatives in other countries in the Americas, Asia, Europe, and elsewhere are also underway.

This study provides subscribers with a thorough evaluation of the fundamentals of algae oil for biofuels production, covering the current status, key new developments, competitive economics and Nexant's view on opportunities as well as potential challenges of participating in this emerging new alternative fuel.

The cost of the study is US$14,000 (fourteen thousand U.S. dollars).

The objective of this study is to assess the technical status and economic viability of biofuels production via microalgae.

The following types of algal systems and issues are discussed and assessed:

- **Biotechnology developments** for microalgae, including bio-prospecting for native strains, trans-genomic research, and lipid or hydrocarbon accumulation in cells
- **Algae growing systems**, including **open ponds** and closed systems (photobioreactors, or **PBRs**, and sugar-fed types of algae, grown in **non-photosynthetic** systems)
- **Integration with CO_2** sources (e.g., power plants, fermentations, chemicals manufacturing, cement plants, and other such large industrial sources)
- **Harvesting oils** by such means as using oil-release algae, dewatering algae/extracting oils, integration with aquaculture (e.g., fish or shrimp eat algae, harvested for fat extraction, with protein meal co-product)
- **Uses for residuals** – feedstock to ethanol production, other fermentations, food/feed or methane production from residues
- **Specialty chemicals** co-production
- **Fuel product quality**

Technology Evaluation – A review and status assessment of the various algae technologies and issues is presented for what Nexant deems to be the salient cases representative of different types of algal technology. The status of process commercial development is characterized, with a listing of existing and announced projects. Players and their unique approaches are analyzed.

Cost of production estimates were developed for conceptual facilities representative of the technologies. Sensitivities to key cost factors were performed, typically for byproduct values (including CO_2 capture monetization) and capital and operating cost. Technical issues are identified as appropriate, and estimates are made of the costs and impacts of potential improvements.

Economic Evaluation – The study assesses the competitiveness of the several potential fuel products (FAME and others) and processes with respect to different fuel and co-product prices, scale factors, policy incentives (tax and other), other key technical economic and market assumptions, and different crude oil price levels.

Commercial Evaluation – Nexant performed an analysis of how algal could be commercialized under various assumptions, such as the actual potential of combining algae production with carbon sources and wastewater treatment. Other aspects include a review of feasibility of monetizing in carbon emissions utilized for algae growing. Nexant also explores the issue of non-applicability of ASTM D6866 carbon dating for validation of "renewables" content of products when utilizing fossil carbon from process stacks. The study evaluates the competitive position of algal biofuels relative to conventional petroleum products. The technologies

evaluated represent the key global offerings, including from the United States, and elsewhere. In addition, the report examines the experience with the few existing specialties products manufacturers utilizing algal routes.

Sustainability - Nexant examines the pros and cons of algae fuel production systems, and qualitatively addresses salient Life Cycle issues. This includes species diversity and risks of genetically-modified algae species release to land or water bodies, land use, carbon trading, and other relevant issues that have appeared recently.

The evaluations of conventional technologies are based on Nexant's in-house information regarding algal biological and process technology, augmented by contacts with algae biofuel government and academic researchers, process developers, licensors, engineering contractors, government agencies, and other experts in the industry. Analyses of these technologies are "built up" from such internal and field-derived information, reviews of patents, other public domain information, and discussions with the technology developing entities.

Much information is leveraged upon the data and analyses in two previous major multiclient studies by Nexant – "*Liquid Biofuels: Substituting for Petroleum*" and "*Biobutanol: The Next Big Biofuel*" – as well as upon the non-proprietary aspects of numerous relevant single-client assignments that Nexant has performed for a wide range of clients in or relevant to the algae fuels space.

Nexant uses proprietary and commercial state-of-the-art software tools to develop its estimates of technology and economic performance. These are well-established engineering tools in the process chemical industry. 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.

Please visit www.chemsystems.com to authorize engagement of the study or return the following authorization form to one of the Nexant offices listed below.

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1. The undersigned (hereafter "Client") hereby subscribes to purchase from Nexant, Inc. ("Nexant"), Nexant's study, ***Algae: Emerging Options for Sustainable Biofuels.*** Nexant will provide to Client access to electronic downloads of the report via a password-protected area from www.chemsystems.com

2. While the information supplied by Nexant to Client will represent an original effort by Nexant, based on its own research, it is understood that portions of the report will involve the collection of information available from third parties, both published and unpublished. Nexant does not believe that such information will contain any confidential technical information of third parties but cannot provide any assurance that any third party may, from time to time, claim a confidential obligation to such information.

3. The information disclosed in this report will be retained by Client for the sole and confidential use of Client and its 51 percent or greater owned affiliates in their own research and commercial activities, including loaning the reports on a confidential basis to third parties for temporary and specific use for the sole benefit of Client.

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7. The report will be provided in electronic format (Adobe Acrobat pdf file) to all subscribers, and this version of the report will be the deliverable for the subscription. Printed copies of the report are available at US$500 each. The complete report will also be available electronically on CD-ROM at a cost of US$200.

8. The obligations of paragraphs 3 and 4 shall terminate five (5) years from receipt of reports.

9. Unless specified otherwise, there are no warranties of any kind for reports and consulting services provided under this Agreement. Nexant's total liability under this Agreement is limited to the total amount paid to Nexant for the reports.

10. This Agreement will be governed by the laws of the State of New York.

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7.1 GENERAL

Nexant uses multidisciplinary project teams drawn from the ranks of our international staff of engineers, chemists, economists and financial professionals, and from other Nexant groups to respond to the requirements of each assignment. Most of the staff of consultants possess credentials in both scientific and commercial disciplines plus substantial industrial experience. The collective talents of our staff are strategically located and closely linked throughout the world, result in valuable insights gained through a variety of perspectives.

ChemSystems is an international consultancy that is now part of Nexant, Inc., and is dedicated to assisting businesses within the global energy, chemical, plastics and process industries by providing incisive, objective, results-oriented management consulting. Over four decades of significant activity translate into an effective base of knowledge and resources for addressing the complex dynamics of specialized marketplaces. By assisting companies in developing and reviewing their business strategies, in planning and implementing new projects and products, diversification and divestiture endeavors and other management initiatives, Nexant helps clients increase the value of their businesses. Additionally, we advise financial firms, vendors, utilities, government agencies and others interested in issues and trends affecting industry segments and individual companies. Whether identifying opportunities, managing change or confronting competitive challenges, we adhere to the highest ethical and professional standards.

ChemSystems, founded in 1965, was originally an independent, management-owned consultancy. IBM acquired it in 1998, and from early 1998 until August, 2001 *ChemSystems* was a part of IBM Global Services and IBM's Chemical and Petroleum group. Effective September 1, 2001, the *ChemSystems* unit of IBM was acquired by Nexant, Inc. Nexant, Inc. is an independent industry-expert consulting firm, that was spun off from Bechtel over eight years ago, that provides technology solutions and experienced-based technical and management consulting services to electric utilities, energy producers, chemical companies, oil and gas companies, governments, and energy end-users worldwide. All of the staff and intellectual capital of *ChemSystems* was acquired by Nexant, Inc. The acquisition of *ChemSystems* by Nexant, Inc., has enhanced *ChemSystems'* ability to successfully serve its clients. This merger's success arises from complementary methodologies and technologies, which are used to provide services to clients and allow us to provide more complete and effective consulting. Thus, Nexant, Inc., with *ChemSystems* as part of its Energy and Chemical Consulting Division, continues to maintain fully integrated operations in White Plains, New York; London, England; San Francisco, California; Bangkok, Thailand; and Washington, D.C. Other business unit offices are located in Boulder, CO and Phoenix, AZ, and satellite business or project offices are located in Tokyo, Beijing, Shanghai, Seoul, and Houston. We also work with representatives throughout the world.

From major multinationals to locally based firms and governmental entities, our clients look to us for expert judgment in solving compelling business and technical problems and in making critical decisions.

Nexant's clients include most of the world's leading oil and chemical companies, financial institutions, and many national and regional governments. Nexant, Inc. is active in most of the industrialized countries of the world, as well as in most of the developing areas including the Middle East, Africa, and East and Southeast Asia.

Major annual programs are:

- Process Evaluation/Research Planning® (PERP)
- *ChemSystems* Online®/Petroleum and Petrochemical Economics (CSOL/PPE) – United States, Western Europe, and Asia

The PERP service covers technology, commercial trends, and economics applicable to the chemical industry. The program has more than 50 subscribers, including most of the major international chemical companies. Many of the processes to be analyzed in this multiclient have been assessed in the PERP program.

CSOL/PPE covers the market and manufacturing economics for major petrochemicals.

Over the past six years, the program has been completely overhauled and upgraded. The models and databases that run the analysis have been replaced with a start-of-the-art industry simulation program that has taken the 30 years of industry knowledge and experience of our consultants and enhanced it to a proven new level of forecasting expertise.

The new simulation model is used to generate the PPE reports and also an internet serviced brand *ChemSystems* Online® that provides global data, analysis, and forecasts of:

- Plant capacity
- Production
- Consumption
- Supply/demand and trade
- Profitability analysis
- Forecast
- Price forecast
- Techno-economic analysis

A subscription to *ChemSystems* Online® includes both written reports (the PPE program) on the petroleum and petrochemical industry and internet access to all data analysis and forecasts. Your subscription may be tailored to meet your specific company requirements and the fees reflect the value brought to your business. Insightful analysis and a reliable forecasting methodology provide the means to significantly improve your business performance though better investment decisions and improved competitive position.

7.2 SPECIFIC SINGLE-CLIENT EXPERIENCE RELEVANT TO BIOFUELS PRODUCTION AND USE

Nexant is exceptionally qualified to perform this comprehensive analysis based on our multidisciplinary business approach and has been carrying out studies of this type throughout our more than 40-year history.

RELEVANT NEXANT PERP PROGRAM MULTICLIENT SUBSCRIPTION REPORTS

Relevant recent reports from this program include:

"Green" Polyethylene – Analysis of the technology and economics of converting ethanol to ethylene by catalytic chemical dehydration and next to polyethylene by conventional polymerization technology, including comparisons with the incumbent routes from hydrocarbon feeds.

Biomass Gasification – A review of developments in gasification of biomass, and technology, economics, and commercialization initiatives, including of making liquid biofuels by catalytic processes.

Biogasoline – Techno-economic and market analyses of various types of bio-based alcohols and hydrocarbons that can blend with or substitute for petroleum gasoline

Ethanol – Analysis of fuel ethanol production by dry corn milling fermentation

Biodiesel (including a 2008 update – Developments in Biodiesel Production Technologies) – A review and analysis of production technologies (commercial and developmental) and economics, feedstock issues, regulatory and market drivers, supply and demand, and byproduct glycerine disposition

Glycerine – Comparison of the natural oil and synthetic-based production routes – considering production technologies, economics, feedstocks, and global markets

Glycerine Conversion to Propylene Glycol – Review of routes to the important industrial chemical, propylene glycol, from the glycerine that has become more abundantly available as a byproduct of FAME biodiesel production, with comparisons to the conventional petrochemical routes.

Methanol – Nexant has done a number of PERP as well as other Multiclient and single client reports on methanol and its derivatives.

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.

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.

Refinery of the Future as Shaped by Environmental Regulations – Reviews issues of supply and quality of crude oil feeds to refineries, trends in quality and volume requirements for refined products, and environmental drivers for both refinery operations as well as fuel specifications.

Biodesulfurization of Petroleum Fractions – Compares various versions of conventional refinery hydrodesulfurization with developments in fermentation-based biodesulfurization.

RELEVANT SINGLE TOPIC MULTICLIENT STUDIES

Liquid Biofuels: The Next Generation – This report updates the earlier study, **Liquid Biofuels: Substituting for Petroleum,** but is organized somewhat differently, with a broader viewpoint on biogasoline and biodiesel beyond ethanol and FAME. It also has a more extensive analysis of policy and sustainability issues, and the status of development of second and third-generation feedstocks, biofuels, and process technologies.

Biobutanol: The Next Big Biofuel - Analysis of the historical, currently emerging, and potential future technologies to produce biobutanol, as well as a profile of and comparison to the current petrochemical route considering key elements of the value chain, including feedstocks, logistics, vehicle use and processing, comparisons with ethanol, and with techno-economic modeling of competing routes. Also includes a consideration of the current large chemical/solvent market for butanol and likely development trajectories for biobutanol.

Liquid Biofuels: Substituting for Petroleum – Milestone analysis of current, emerging, and potential future technologies to produce biogasoline (ethanol and others) and biodiesel, considering key elements of the value chain, including agricultural, logistics, and processing, and emphasizing techno-economic modeling of ethanol and biodiesel alternative processes. Widely subscribed among clients from a range sectors including energy (domestic, multinational, and national companies), agricultural, biotechnology, and governments.

Brazil's Biofuels Industry: Outlook for a Global Leader - Assesses the technical, commercial and policy status of existing and anticipated biofuel and biofuels-related activities in Brazil. The study draws conclusions on opportunities and challenges in the industry. It forecasts changes to come, considering critical elements of the Brazilian biofuels supply chain. It examines related markets, such as flexible-fuel and dedicated ethanol vehicles. It also profiles Brazil from a global perspective, highlighting local opportunities as well as key issues for companies considering investment options worldwide.

Carbon Management: CO_2 Capture, Transport and Sequestration - This is a milestone multiclient study, which considers a wide range of chemical and physical solvent carbon capture systems, policy drivers and ramifications, and discusses a number of leading applications.

INDIVIDUAL CLIENT STUDIES

A partial list of relevant projects includes:

Due Diligence on Biobutanol Technology Development and Business Plan – For an investor, Nexant performed a full-scope technical, economic, and commercial assessment of the developments and business plan of a startup company seeking to commercialize a leading fermentation-based biobutanol technology.

Jatropha Biodiesel Feedstock Feasibility Assessment – Nexant reviewed the status of agricultural and industrial development of this emerging sub-tropical plant-based non-food oil seed option for biodiesel feed, with special attention to the question of cost of producing the oil, and the feasibility of achieving a mechanical harvesting model despite the property of co-current flowering and seed maturation. This study also includes a preliminary review of prospects for algae oil production.

Sourcing Low-Cost Fats, Oils, and Greases for a Biodiesel Business – For an emerging biodiesel producer Nexant developed volumetric U.S.-wide source models based on geography, population, demographic, and industrial/commercial parameters, and special sources of waste oils, fats, and greases to feed their technology which is capable of handling low-grade, high FFA waste lipids. This was the second project with this subject for Nexant, following a technology and finance due diligence on a similar project/business rollout for another client.

Bio-Ethanol and Bio-Methanol Market Feasibility - For a venture seeking to commercialize alcohols production from syngas via gasification of the paper fraction of municipal garbage streams, Nexant analyzed markets and logistics (storage and shipment) for sale of chemical and fuel alcohol streams in selected proposed project locations around the United States.

Chemicals from Corn – This is 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 considers a wide range of potential sugars, and fermentation-derived acids, alcohols, and other building blocks, but emphasizes 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.

Biodiesel Glycerine Byproduct - Market Dynamics – For a major U.S.-based multi-national 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. This subject was also addressed in two recent papers presented at international conferences.

Switchgrass Energy Utilization – For a major multinational energy company examining a technology that would express natural polyesters and extract them form switchgrass, Nexant performed an evaluation of options for energy utilization of the ground and solvent-extracted of the switchgrass residue at world-scale. The study included integrated fermentation and gasification, and freestanding gasification processes, as well as the option of co-firing in a specific group of coal-fired power plants in Iowa.

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 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.

Biobased Fuel Cells – At the BIO World Congress on Industrial Biotechnology and BioProcessing, Orlando, FL, April 20-22, 2005, Nexant presented a paper on biofuels use in fuel cells based on a study of Stationary Fuel Cells for Nexant's PERP program, and also chaired a panel on Bio-based Fuel Cells, which included discussions of enzyme-based fuel cell membrane and electrode technologies to utilize hydrogen or biofuels.

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 multi year 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 50-250 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.

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.

"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.

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. Alternatives feedstocks (corn and other grains) and by-products were included in the evaluation.

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.

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.

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.

Ethanol Drying - For a Japanese client, Nexant reviewed the methods used in Western Europe to dry ethanol (including fermentation sources), discussed the merits of newer technologies, and investigated international legislative actions to restrict the use of benzene or cyclohexane in azeotropic distillation.

Ultra Clean Fuels Study – For Conoco, under U.S. DOE sponsorship, Nexant performed a comprehensive review of the future for ultra low sulfur diesel (ULSD) and other petroleum distillates in transportation: considered regulatory and market drivers, production technology and economics, petroleum refining impacts, environmental/resource depletion impacts, vehicle engine and performance, consumer acceptance, distribution and refueling logistics, diesel and gasoline ICE operational issues, stationary combustors, fuel cells: the objective was to determine the feasibility of using GTL fuels – Fischer-Tropsch distillate and naphtha and methanol (comparisons to hydrogen, ethanol and biodiesel included). At issue was the use of biodiesel as a lubricity additive to counter the reduced lubricity with loss of sulfur in ULSD and GTL.

Synthesis Gas (Future Sources) - This report reviewed the technology for production of synthesis gas (H_2, 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.

LNG Competition with Clean Diesel – For a multinational industrial gas company with a stake in technology for LNG as an alternative vehicle fuel/CNG refueling strategy, Nexant studied the current status of "clean diesel" (e.g., engine modifications along with ultra low sulfur diesel fuel enabling use of particulate traps and catalytic tailpipe controls to reduce soot and NOx emissions), and assessed the competitiveness of biodiesel in this context.

Global Finished Automotive Lubricants Market Drivers – For a leading U.S.-based multinational lubricants additives maker, Nexant studied the current and projected global market dynamics for finished automotive lubricants for the next two decades. Market segments/products included passenger car and diesel/heavy-duty crankcase, gear oil, automatic transmission, tractor, off-road and small engine lubricants. Fleet growth in various regions, ultra low sulfur diesel, and trends to "dieselization" of fleets in various regions were relevant issues examined. In this and other related work, Nexant has opined that a key vector for use of biodiesel, aside from as a fuel, will be as a lubricity additive to ultra low sulfur diesel. In addition, key will be demand for biodegradable, non-toxic biodiesel fuel in small boats in place of other marine fuels.

Synthetic-Based Drilling Fluids (SBFs) – For a multinational specialty chemicals company with a stake in oleochemicals and GTL, Nexant studied market issues and projected markets for SBFs in deepwater drilling, as driven by recent U.S. EPA regulations or these oil-based systems with respect to disposal of drilling spoils (especially in the Gulf of Mexico, but in other seas as well). The only systems allowed, by consensus in a stakeholders-involved regulatory development process, are those based on Internal Olefins (IOs) and vegetable esters (essentially, "biodiesel"). These alternatives strike a balance in meeting both toxicity and biodegradability limits.

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.

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.

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 Frankfort, 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.

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

Surveys of Global Oleochemicals Markets and Technologies – Nexant addressed natural and synthetic-based oleochemicals markets for Dow Chemical.

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