Prospectus

Liquid Biofuels: Substituting for Petroleum
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Abstract</td>
<td>1</td>
</tr>
<tr>
<td>2 Scope</td>
<td>10</td>
</tr>
<tr>
<td>3 Approach</td>
<td>12</td>
</tr>
<tr>
<td>4 Contact Information</td>
<td>13</td>
</tr>
<tr>
<td>5 Authorization Form</td>
<td>14</td>
</tr>
<tr>
<td>6 Qualifications</td>
<td>16</td>
</tr>
<tr>
<td>6.1 GENERAL</td>
<td>16</td>
</tr>
<tr>
<td>6.2 SPECIFIC SINGLE-CLIENT EXPERIENCE RELEVANT TO BIOFUELS PRODUCTION AND USE</td>
<td>18</td>
</tr>
</tbody>
</table>

Cover photos - Courtesy of NREL
Nexant, Inc. (“Nexant”) has recently performed a number of analyses of technology and market prospects for biofuels, including studies on biodiesel, biodiesel byproduct glycerine, fuel ethanol from dry corn milling, and fuel ethanol from wood. A key driver for these developments is the uncertainty in petroleum fuel supplies, which are currently undergoing change and stress, and are likely to continue to be problematic in the long term. This new study, *Liquid Biofuels: Substituting for Petroleum*, provides a timely assessment of the technologies available to achieve a multi-faceted, sustainable liquid biofuels production scenario, and an analysis of the economics of producing and using these biofuels compared to petroleum-derived motor fuels that they could supplement or replace.

This study should be of interest to companies considering market entry or expansion, acquisitions, partnering, or offering goods or services to the emerging biofuels sector. It will also help understand the potential impact of biofuels on the petroleum motor fuels value chain, the energy sector, and the world economy as a whole.

Sheik Yamani, the former Saudi Oil Minister, long ago commented that, “The Stone Age didn’t end for lack of stone, and the oil age will end long before the world runs out of oil”. The United States consumes one quarter of the world’s oil production, mostly to fuel its vehicles. The “End of Oil” – defined as the higher rate of growth of petroleum demand and resource depletion than of new supplies - is an apparent and widely discussed concept today. Major oil companies, including Shell, BP, and Chevron, have announced programs to come to grips with these concerns, at least with a view towards the end of “easy oil”. Figure 1.1 illustrates a range of likely scenarios of petroleum reserves significantly declining by 2020 due to increasing production (essentially equivalent to demand) and resource depletion not being matched by new discoveries. Further, market perception of reduced reserves and greater difficulties in discovering and developing resources will tend to drive petroleum prices higher.
Climate change and pollution problems are other issues related to fossil fuel use that also cause concern across society. Biofuels are seen as neutral with respect to net carbon dioxide emissions, as contrasted with fossil carbon in petroleum, since the carbon that is absorbed from the atmosphere to grow a plant is simply released again upon combustion of the plant’s derivatives.

Many policy makers, industry planners and aware citizens are interested in the potential for substituting biologically-derived fuels for those based on petroleum or natural gas, especially gasoline and diesel motor fuels. The apparent multiple motivations for this interest include:

- Long term fuel supply security and reducing geopolitical pressures of obtaining imported petroleum and natural gas supplies
- National balance of payments
- Reducing carbon dioxide “greenhouse gas” emissions related to climate change
- Reducing other pollutant emissions associated with supply, processing, and use of liquid fuels
- Rural development, enhancement of the agricultural sector
- Sustainable economic development

There is a wide diversity of sources for electricity generation, from coal and natural gas combustion and nuclear fission to photovoltaic and solar thermal energy. Natural gas, gas condensates, fuel oil, petroleum residuals, and waste materials serve most of the total of space heating and industrial fuel needs, and for the latter, there is a high degree of switching capability in place. In contrast, motor fuels have a very specific range of properties required to serve the existing vehicle fleet and to be handled in the existing distribution and refueling infrastructure. The existing investment in motor fuels refining and a vast distribution infrastructure is in the trillions of dollars in the United States and globally. The vehicle fleet would take decades to be substantially turned over if we were to use alternative fuels with very different properties and characteristics, such as CNG, electricity, or hydrogen. It is therefore desirable to produce biofuels that blend well with conventional liquid fuels or are “drop-in” substitutes for them.

Among the key properties required for gasoline are high octane number and low volatility. For diesel-type fuels, high cetane number and sufficient lubricity are required. Additionally required or desirable for both types of fuel are very low sulfur content, low toxicity (generally related to
low contents of aromatics, olefins, heavy metals and nitrogen compounds), heating density, and certain levels of oxygenates. These, in general, are naturally provided by biofuels, while refiners have had to struggle for decades to meet these requirements using increasingly poorer quality crude oil supplies. In fact, at the outset of the automobile industry, ethanol was a common fuel for spark-ignited engines, and Rudolf Diesel started his development of compression-ignited engines with vegetable oil fuels. These were superseded quickly by cheaper, more abundant, but generally poorer quality petroleum-derived fuels,

Unlike other fuels proposed and being developed as alternatives to petroleum fuels, such as CNG, LPG, Fischer-Tropsch liquids (GTL), DME, methanol, and hydrogen, which are either fossil fuels themselves, or would be derived from fossil fuels in the short term and midterm (i.e., within the next 25 years), biofuels can potentially be de-coupled from fossil fuels in the near term. Even for fuel cells, biofuels such as ethanol and glycerine are demonstrated to be usable directly with proton exchange membranes (PEMs), and more advantageously than methanol. They can also be reformed to hydrogen for use in any type of fuel cell by a number of conventional and emerging technologies. GTL, methanol and hydrogen are currently derived from natural gas, but in the long term will need to switch to renewable sources, such as biomass, in order to be ultimately sustainable. Essentially then, the biofuels we are considering are both attractive near-term “drop-in” technical solutions, as well as longer-term sustainable solutions to a range of society’s concerns.

There is a public debate underway in the technical literature and even in the popular media as to how much net energy is needed to produce crops and process biofuels. Though the overwhelming majority of experts disagree, a few analysts conclude that it takes more energy than is produced, or nearly as much, to make grain ethanol and biodiesel fuels. In examining their arguments, we find that these few analysts are using old data, false premises, and faulty models, and that today, even biofuels made from valuable carbohydrate substrates or natural oils are strongly positive in net energy production. If in the future biofuels are made from biomass wastes or low-input crops such as grasses, shrubs and trees, the net energy picture can only be more positive.

Biomass resources are potentially the world's largest and most sustainable energy source (i.e., requiring low net inputs of fertilizers, crop protection chemicals, irrigation, or valuable farmland). Biomass supplies are estimated to total about 220 billion dry tons (about 730 billion barrels of crude oil equivalent, and compares favorably to about 29 billion barrels of global demand for crude oil in 2004) per year of primary production. This estimate includes only agricultural and wood and forestry residues and herbaceous crops grown specifically for energy,
and excludes municipal garbage, industrial wastes, and forest plantations grown specifically for
energy. Only about 6 percent of this (about 43 billion barrels per year, or 120 million barrels per
day) could be considered available on a sustainable basis and at competitive prices (considering
logistics). Dedicated energy plantations, such as exist today in Brazil, Scandinavia, the United
States and elsewhere, could total 50 million acres or more, globally, by 2020, and add enormous
dimensions to the current supply. The problem is not availability of biofuel energy but its
sustainable management and delivery.

Renewable energy, including hydropower, provides only about 5 percent of U.S. energy needs
today, and only about 6 percent of the total renewable energy use is for transportation, primarily
as ethanol. This use has more than doubled since the year 2000, but it is still less than 1 percent
of the energy supplied by petroleum.

The leading approaches to utilizing biological materials for motor fuels are:

- The widely applied fermentation of sugar substrates (directly available or made from
  starches) to ethanol to blend with gasoline
- Emerging catalytic technology to convert ethanol to mixed hydrocarbon streams that are
  attractive as gasoline blendstocks
- Hydrolysis of cellulose and hemicellulose in biomass using mineral acids or enzymes,
  followed by fermentation of C₅/C₆ sugars to ethanol, technology that is just now
  commercially emerging, and whose development is being pursued by many private and
  public organizations
- Trans-esterification of natural oils to biodiesel, including ethyl (FAEE) and methyl (FAME)
  esters, by conventional and new technologies, for diesel blendstock or substitute, lubricants,
  and lubricity additive for ultra low sulfur diesel
- Fuel use of byproduct glycerine from trans-esterification directly in or reformed to
  hydrogen for fuel cells, or in gas turbines, boilers, etc. - being examined by a number of
  private and public organizations
- Pyrolysis or thermal-depolymerization of various biological materials (composed of
  cellulose, hemicellulose, lignins, proteins and/or oils) to make a “bio-oil” as a diesel
  blendstock or substitute (tax incentives equivalent to biodiesel are offered in the Energy Bill
  of 2005) – emerging commercial
- Gasification of various biological materials to make syngas produced by various catalytic
  processes:
  - Fischer-Tropsch liquids (GTL) as a diesel blendstock or substitute,
  - Hydrogen for petroleum upgrading in refineries
  - Mixed alcohols (e.g., “Ecalene™”), as gasoline blendstock or substitute

These technologies are at various stages of development and commercialization, but
large-scale biomass gasification is not currently commercially offered
Widely practiced **anaerobic digestion of cellulose and hemicellulose** (agricultural waste, energy crops, MSW, etc.) to make methane, which can be gasified, with the syngas produced converted to GTL, hydrogen, or mixed alcohols.

The production and use of fuel ethanol, biodiesel, bio-oil from pyrolysis or thermal depolymerization, and other biofuels are strongly supported by the new Energy Bill of 2005, and by initiatives mounted by various U.S. states and governments around the world, in the form of purchasing goals and requirements, fuel standards, tax incentives, subsidies, loans, R&D funding, and many other types of assistance. The growth rates of ethanol production in the United States and of biodiesel in Europe, especially in France and Germany, have been phenomenal, partly due to such government interventions, but also due to customer interest in biofuels. Figure 1.2 summarizes the scope of biomaterials feeds, process routes and biofuel products to be considered in the study, and relationships among them. The feeds listed to the left are in descending order of value ("protein & fat" are processing wastes, not foods).

This graphic implies the exciting possibility of producing E85 (85 percent ethanol, 15 percent gasoline - wherein the gasoline is required for proper engine functioning), from 100 percent renewable sources, independent of petroleum, by blending ethanol with either mixed higher alcohols, Sangi “Biogasoline”, or a combination.
For each of these alternative fuel sources, the study will provide a review of production technologies and product quality characteristics, and a cost of production model analysis that will also compare the costs of each alternative fuel with the current prices of the petroleum derived fuels and materials to which they are most relevant. Thus, the following comparisons will be made:

- Ethanol from sugar, starch, and cellulose/hemicellulose fermentation to gasoline
- Synthetic gasoline from ethanol to conventional gasoline
- Biodiesel (FAME and FAEE) to conventional diesel fuel, lubricants and lubricity additives
- Byproduct glycerine to methanol for direct fuel cells, and to distillate fuels for gas turbines and boilers
- Pyrolysis and thermal depolymerization “bio-oils” to distillate fuels for vehicle engine and stationary uses
- Syngas costs from biomass to syngas from natural gas
- Mixed alcohols ex syngas to gasoline

Fuel ethanol capacity in the United States is being rapidly developed in response to market and policy drivers. Figure 1.3 shows the locations of current plants and those under construction. Other plants are also being planned closer to major urban markets, such as two new fuel ethanol plant projects in New York State.
There are several drivers for fuel ethanol use in the United States:

- Oxygenate for RFG - generally added at 10 percent by volume - to provide the oxygenate content required by U.S. EPA rules for Reformulated Gasoline (RFG), seasonally, in certain smog-prone urban markets under the Clean Air Act, substituting for MTBE in the many states that have banned it

- Mandates by some states or other jurisdictions for its use in blends for general distribution and/or in government fleets, and/or to satisfy renewable fuels guidelines

- Selection by gasoline blenders as an economically and technically attractive high octane blendstock

Any automobile is technically capable of using E10 (10 percent ethanol gasoline), but because of certain materials issues, higher blends can be problematic. However, it is little publicized that many U.S. automobile models – made by Ford, GM, and Daimler-Chrysler - are designed as “bi-fuel” vehicles; that is, capable of using E85 (85/15 ethanol/gasoline blends).

Biodiesel capacity in the United States is also being rapidly developed in response to market and policy drivers. Among the most important of these, respectively, are the usefulness of biodiesel as a lubricity additive in the ultra-low sulfur diesel that is mandated to be essentially all of the diesel fuel supply in the United States by the end of 2006 (and which has very poor natural lubricity), and tax incentives in the recently enacted Energy Bill of 2005. In fact, demand for use as a lubricity additive could easily overwhelm any other current demand driver. Figure 1.4 shows the locations of current plants and those under construction. Additional biodiesel plants are also under earlier stages of consideration.

Figure 1.4
Current and Proposed Biodiesel Production Plants – April 2005

Source: National Biodiesel Board
Similar to ethanol, as a fuel, biodiesel is usually blended 20/80 by volume with conventional diesel (called B20), but as a lubricity additive may be used at levels of 1-2 vol percent. There are many issues surrounding biodiesel production that are addressed at various, appropriate levels of detail in the study, including:

- Markets for byproduct glycerine – Biodiesel economics are sensitive to byproduct glycerine values, and prices of glycerine have dropped dramatically in Europe, which has expanded rapidly to a relatively high level of biodiesel production, overwhelming the market there and also affecting world prices. Markets considered include current ones in competition with propylene glycol and sorbitol, and newer, potentially larger ones, such as for cattle feed, freeze protection, fuels and chemical feedstock (some of which could use crude versus USP or industrial grades, a distinct advantage)
- Natural oil supply and the quality of biodiesel from various types of oil
- Transesterification by conventional routes, versus the feasibility of newer routes
- Producing “completely renewable” ethyl esters using bio-ethanol, versus “partially renewable” methyl esters using natural gas-based methanol, versus using methanol from biomass pyrolysis

It can be seen from the figures above that ethanol plants are less widely distributed throughout the United States and more concentrated in intensely agricultural regions than are biodiesel plants, many of which are closer to population centers. This contrast is due to the logistics limits in transporting grain containing much unconvertible material and requiring an animal feed market for the byproduct “distillers dry grains” (DDGs) to support ethanol production, as contrasted with natural oil obtained from either oilseed processing or food service/food processing wastes for biodiesel. Logistics considerations are thus very important in the biofuels sector, and even more so for biomass-based routes than for oil, starch or sugar-based ones. The study addresses these as well as other significant value chain issues affecting the viability of biofuels to supplement or replace petroleum liquid motor fuels.

Each of the biofuel value chains considered in the study has many additional ramifications that are selectively treated to varying degrees of detail in the study. For example, agricultural field and/or processing byproducts that can affect the design and/or economics of biofuels production facilities include:

- Corn stover (residues of cobs, stalks and leaves), which is generally either left in the field as a soil amendment or “green manure”, or is collected, chopped, and stored as silage (with fermentation, used for cattle fodder), but can also be the cellulose/hemicellulose biomass for feeding to hydrolysis to make C5/C6 sugars for fermentation to ethanol. Soybean and other green biomass can be treated similarly.
- Wheat, rice and other grain straws, which are generally not used as silage, being either left on the field or sometimes burned, but may also be hydrolyzed, as is being done commercially with wheat straw by Iogen of Ontario, Canada to produce fuel ethanol.
- Distillers Dry Grains (DDGs), soybean meal (from oil extraction), and other oilseed meals from “expelling” or oil extraction are valuable animal feeds, and compete in this market with
each other, as well as with whole grains, silage, hay, and other byproducts such as whey and molasses.

Any of these byproduct materials, as well as byproduct lignins, manure, and other biomass from the relevant agricultural or forestry value chains may be gasified or pyrolyzed to produce liquid fuels, possibly anaerobically digested to make methane, or directly combusted to provide energy for liquid biofuels processing.

The study has a target completion date of end Q2 2006. The cost of the study is US$15,000 (fifteen thousand U.S. dollars).
The objective of this study is to assess the technical status and economic competitiveness of various types of liquid biofuels that could supplement or replace petroleum motor fuels.

The following types of liquid biofuels and routes are considered in the study:

- **Fermentation of sugar** substrates (directly available or made from starches) to ethanol to blend with gasoline (E10 and E85)
- Emerging catalytic technology to convert **ethanol to mixed hydrocarbon** streams as gasoline blendstocks
- **Emerging technology for hydrolysis of cellulose** using mineral acids or enzymes, followed by fermentation of C5/C6 sugars to ethanol,
- Conventional and newer technologies for trans-esterification of **natural oils to biodiesel**, including ethyl (FAEE) and methyl (FAME) esters, for diesel blendstock or as a diesel substitute, lubricants, and lubricity additive for ultra low sulfur diesel
- **Fuel use of byproduct glycerine** from trans-esterification directly in or reformed to hydrogen for fuel cells, or in gas turbines, boilers, etc.
- **Pyrolysis or thermal-depolymerization** of various biological materials (composed of cellulose, proteins and/or oils) to make a “bio-oil” as a diesel blendstock or substitute
- **Gasification** of various biological materials to make syngas produced by various catalytic processes at various stages of development and commercialization, including:
  - **Fischer-Tropsch liquids** (GTL) as a diesel blendstock or substitute,
  - **Hydrogen** for petroleum upgrading in refineries
  - **Mixed alcohols** (e.g., “Ecalene™”), as gasoline blendstock or substitute
- **Anaerobic digestion of cellulose** (agricultural waste, energy crops, MSW, etc.) to make methane, which can be gasified

Each of these fuels and process technologies are evaluated from technical, economic and commercial perspectives, as follows:

**Technology Evaluation** – A review and status assessment of the various process routes will be performed for what would be considered representative of the technology, and the stage of process commercial development is characterized, with a listing of actual and announced projects.

Cost of production estimates will be developed for conceptual plants representative of each of the technologies. Sensitivities are performed for feedstock costs and capital costs, technical issues are identified as appropriate, and estimates are made of the costs and impacts of potential improvements.
**Economic Evaluation** – The study will assess the competitiveness of these products and processes with respect to different feedstock costs, scale factors, policy incentives (tax and other), other key technical economic and market assumptions, and different crude oil price levels.

**Commercial Evaluation** – Nexant will perform an analysis of the major biofuel products considered in the technical and economic evaluation, including addressing issues of commercial viability such as technical compatibility with gasoline and diesel motor fuels in the distribution and refueling infrastructure, and onboard vehicles.

The study will evaluate the competitive position of these biofuels relative to conventional petroleum products. The technologies evaluated are globally sourced, with key offerings from the United States, Europe, Japan and Latin America. Also, the report will refer to experience with biofuels manufacturing, market development and trade throughout the world, making it relevant to subscribers with multinational concerns.
Section 3  

Approach

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 developing 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.
Section 4  Contact Information

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

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e-mail: phunt@nexant.com
1. The undersigned (hereafter "Client") hereby subscribes to purchase from Nexant, Inc. ("Nexant"), Nexant’s study, Liquid Biofuels: Substituting for Petroleum, in accordance with the following terms and conditions.

Nexant will provide to Client the following information and services:

(a) Three (3) bound copies of the report
(b) Access to electronic downloads of the report via a password-protected area from www.nexant.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.

4. Client further agrees that it will use reasonable efforts to keep the information in the reports for its sole use, however, this restriction shall not apply to information which is or becomes generally available to the public in a printed publication, which is already in the possession of Client, or which is received by Client in good faith from a third party without an obligation of confidentiality.

5. Client shall not republish any of the report except within its own organization or that of its 51 percent or greater owned affiliates. Client further agrees to refrain from any general publication of the reports, either directly or through its affiliates, so as to constitute passage of title into the public domain or otherwise jeopardize common law or statutory copyright in said report.

6. Upon authorization, Client will be billed by and shall pay to Nexant a total of US$15,000.00 (fifteen thousand U.S. dollars). Client shall have the option of being invoiced the total amount upon authorization or in two equal installments, one upon authorization and the second six months later. Amounts are due upon receipt of invoice and payable within thirty (30) days. Late payments shall accrue interest at the rate of 1.5 percent per month. Fees quoted do not include any applicable sales tax, or use or value added tax, all of which are for the account of Client.

7. Additional 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$1,000.

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.
AUTHORIZATION FORM

AGREED TO AND ACCEPTED BY:  AGREED TO AND ACCEPTED BY:

CLIENT: ___________________________  NEXANT, INC.

Name: ___________________________  Name: ___________________________

Signature: ________________________  Signature: ________________________

Title: ___________________________  Title: ___________________________

Date: ___________________________  Date: ___________________________

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Section 6  Qualifications

6.1  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, 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 three 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 four 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 Chemicals and Petroleum 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, 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®* (CSOL)/Petroleum and Petrochemical Economics (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 four 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.
6.2 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:

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

**Biodiesel** – Including production technologies (commercial and developmental) and economics, feedstock issues, regulatory and market drivers, supply and demand

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

**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.

INDIVIDUAL CLIENT STUDIES

A partial list of relevant projects includes:

**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.

**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.

**Ethanol vs. 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.

**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 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.
**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 Western 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 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 (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.

**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 per se, will be as a lubricity additive to ultra low sulfur diesel. Also 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