BIO-BUTANOL: THE GAME CHANGER
An Emerging Biofuel and Biochemical

A Multi-Client Study

In Partnership with
Chemical Strategies Group

May 2013

The Opportunity
The biofuels and renewable chemicals markets are at a crossroads, and bio-butanol can play a critical role in both.

Biofuels
In the biofuels market, bio-butanol solves two critical problems:

- **Punching through the 10% ethanol (E10) “blend wall,”** since bio-butanol can be blended at 16% by volume and each gallon of bio-butanol generates 1.3 renewable identification numbers (RINs); and
- **Eliminating the need for refiners to purchase RINs from independent blenders – at prices that have recently been many times higher than in past years –** since bio-butanol can be blended at refineries and transported in existing pipelines (unlike ethanol, which is usually blended downstream at terminals).

In 2013, for the first time, the effective allocations to corn-based ethanol and undifferentiated advanced biofuels (mainly Brazilian sugarcane-based ethanol) under the Renewable Fuel Standard (RFS2) will involve volumes significantly exceeding the E10 blend wall. Given hurdles to adoption of E15 and limited use of ethanol as flex-fuel (E85), it will be challenging to blend mandated quantities of ethanol. This problem will become more urgent in 2014, when obligated parties deplete their RIN inventories.

Bio-butanol – butanol from renewable feedstocks – not only can solve the current blend wall problem but also has a number of favorable characteristics as a fuel, as described in the following box.
Bio-butanol: The Game Changer

Moreover, bio-butanol can qualify as an advanced biofuel if it meets a 50% greenhouse gas reduction threshold. Importantly, existing ethanol plants can be retrofitted to produce bio-butanol, allowing production of ethanol, bio-butanol or both biofuels – and thereby creating market flexibility. Under present market conditions, butanol provides significant financial advantages to petroleum refiners and to facilities currently producing ethanol.

Bio-butanol’s Advantages as a Fuel

- High energy content, near gasoline
- Blends of 16% by volume are allowed
- Not hydroscopic (i.e., attracting moisture) or corrosive
- Compatible with existing engines and storage infrastructure
- Low vapor pressure, so the blended fuel can meet government restrictions on vapor pressure without the need for specialized blendstock (RBOB)
- Can be blended at refineries
- Transportable in existing petroleum pipelines
- Useable as feedstock to bio-gasoline, diesel and jet fuel

The market for renewable chemicals has emerged and is expected to grow rapidly. Butanol is a versatile four-carbon alcohol that is currently produced by the petrochemical industry. It has an established history as a chemical and solvent, particularly for use in paints, coatings, printing inks, adhesives, sealants, textiles and plastics. The annual global market for butanol currently exceeds 1.2 billion gallons and is valued at over $6 billion. Relative to conventional butanol, bio-butanol can be produced sustainably, in large quantities and at a cost that is expected to be competitive. The initial market for bio-butanol is for high-value chemicals. As lower production costs are realized, the market will expand to a myriad of chemical derivatives.

About the Study

This multiclient study will provide a unique interdisciplinary assessment of the potential for bio-butanol to be a game changer in biofuels and a gateway to renewable chemicals. By bringing together consulting firms that have technical and economic expertise and extensive experience spanning the renewable fuel, chemical and agricultural markets, we offer unparalleled
analysis and understanding of the feedstocks, processing and markets for bio-butanol – and the associated economics.

**Background on Bio-butanol**

There are four isomers of butanol, with n-butanol and isobutanol accounting for the largest volume in commercial chemical usage. Both renewable forms will be marketed as “bio-butanol.” Over a dozen companies around the world have focused on the development and commercialization of low-cost bio-butanol production technology.

Bio-butanol can be produced at retrofitted corn and sugarcane ethanol facilities, providing a huge existing base of capacity for adoption. With the waning of government financial incentives for ethanol, biofuel producers are looking for higher-margin products. Refiners are looking for practical ways to comply with RFS2 and gain control of the process of obtaining RINs. Moreover, cellulosic sugars from wood and pulp and paper mills – and potentially other cellulosic feedstocks – will be another avenue to bio-butanol production, allowing bio-butanol to qualify as a cellulosic biofuel under RFS2.

**The Study**

**Objective:** The objective of this study is to analyze the future growth potential and related economics of bio-butanol, specifically n-butanol and isobutanol.

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**Key Questions to be Answered**

- What is the informed outlook for bio-butanol, and what are the best opportunities?
- Does bio-based n-butanol or isobutanol have a more favorable outlook?
- What is the outlook for bio-butanol as a fuel? Timing?
- To which chemicals will bio-butanol be a viable gateway?
- Which technologies, approaches and companies are most promising?

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**Preliminary Study Outline**

I. Executive Summary
II. Introduction
III. Technology and Production Economics
   A. Commercial Production Processes
   B. Emerging Production Processes, Including Retrofitting of Corn-Based Ethanol Facilities
   C. Bio-butanol as a Platform Molecule to Chemicals and Fuels
IV. Market Fundamentals and Associated Economics
   A. Established Applications
      1. n-Butanol
      2. Isobutanol
   B. Emerging Applications for Bio-butanol
1. Biofuels
2. Renewable Chemicals

V. Feedstocks
   A. Existing Use of Propylene
   B. Corn
   C. Sugarcane
   D. Cellulosic Sugars from Biomass

VI. Profiles of Selected Emerging Bio-butanol Players

VII. Conclusions and Implications to Stakeholders

Study Details

The study will have two major components:

- **Techno-economic assessment**: An assessment of the technology and economics of bio-butanol production; and
- **Commercial analysis**: An analysis of bio-butanol markets and the associated economics.

Details about the work to be conducted within each of these two major components are provided below, by section of the preliminary study outline.

I. Executive Summary

II. Introduction

III. Technology and Production Economics
   A. Commercial Production Processes

   The study will begin with a **techno-economic assessment** of butanol production. Today, most of the world’s supply of n- and iso-butanol is produced from propylene using the oxo process. The commercially practiced routes, oxo using propylene and acetone-butanol-ethanol (ABE) from sugars, will be shown.

   B. Emerging Production Processes

   For the most promising emerging routes, indicative hypothetical plant configurations, capital costs and production economics will be developed utilizing patents, among other resources. These emerging technologies will be compared to each other and to current processes. A sensitivity analysis of production costs will then be developed. One focus of this assessment will be the retrofitting of existing corn-based ethanol facilities. Additionally, technologies that are further from commercialization will be discussed.

   C. Bio-butanol as a Platform Molecule to Chemicals and Fuels

   While the main focus of the study will be on the production and markets for bio-butanol itself, bio-butanol's potential as a gateway molecule to a range of chemical derivatives and drop-in fuels also will be reviewed, and potential production routes will be discussed.
IV. Market Fundamentals and Associated Economics

A. Established Applications
   1. n-Butanol
   2. Isobutanol

The commercial analysis will begin with a detailed breakdown of the existing markets for n- and iso-butanol as chemicals and solvents, focusing on the U.S. but also addressing the global market. The applications will be discussed and quantified, by use and by country or region. Historical demand will be estimated, and future levels of consumption will be forecast. The supply analysis will include current producer capacity, production and trade. With butanol prices for industrial uses ranging from $5 to $10 per gallon in recent years, these markets are attractive initial targets for bio-butanol.

B. Emerging Applications for Bio-butanol
   1. Biofuel
      a. Policy Framework and Outlook

The Renewable Fuel Standard (RFS2) has been the primary federal policy driving biofuel usage in recent years. However, due to the confluence of the 2012 drought and the increase in the effective RFS2 allocation to ethanol to levels above the E10 blend wall, the RFS2 is under attack like never before – from a coalition of petroleum, livestock and food manufacturing interests. Bills have already been introduced into Congress that would severely reform or even eliminate RFS2. Such changes would have significant implications for the fuel use of bio-butanol but would not necessarily preclude its development, given its advantages as a fuel. Accordingly, the first step in evaluating the prospects for bio-butanol within the renewable fuels market will be to review the policy framework for biofuels and specifically the structure and future outlook for RFS2.

There are other federal and state policies and initiatives that also merit review due to their potential to encourage the use of bio-butanol. Butanol’s low vapor pressure provides financial advantages for refiners needing to meet EPA air quality regulations, particularly in non-attainment zones. The Department of Defense (DOD) has begun to undertake a biofuels initiative focusing on drop-in fuels, particularly for jet and marine applications. Importantly, the State of California has implemented a Low Carbon Fuel Standard (LCFS), and if bio-butanol can be produced economically in a low-carbon-intensity manner, this could be a large-volume market in the coming years.

b. Market Assessment

The market assessment for bio-butanol as a renewable fuel will focus on gasoline blends, as this holds the potential to be the single largest market for bio-butanol. The ability to meet specific RFS2 category requirements will be assessed, with particular attention to the blend wall and issues related to the future adoption of
E15 and flex-fuel ethanol (E85). As part of the analysis of the blend wall, the future trajectory of gasoline consumption in the U.S. will be forecast.

The benefits and economics of bio-butanol/gasoline blends and bio-butanol/ethanol/gasoline blends will be reviewed. As part of the economic analysis, gasoline prices will be forecast, and the relative pricing of bio-butanol will be assessed considering other biofuel options. The timeframe for the commercialization of bio-butanol as a fuel also will be evaluated.

While the main focus will be on the usage of bio-butanol in gasoline, other potential fuel applications also will be addressed, including:

- **Diesel blends**: Bio-butanol has a much lower vapor pressure than ethanol, potentially allowing blending with diesel. In this case biobased n-butanol, which has a higher cetane rating than iso-butanol, is preferable.
- **Aviation fuels**: Airlines are eager to fly on fuel that can reduce their carbon emissions while diversifying the supply of one of their largest expense categories. They have signed nonbinding agreements with providers to purchase more than one billion gallons of biofuel in the future. The European Union has mandated reductions in airline carbon emissions, which will drive demand for biobased options. As mentioned above, the DOD has undertaken a biofuel initiative, and the U.S. Navy in particular has been evaluating technology to convert butanol into jet fuel and diesel, and it is actively working with several bio-butanol companies.

As a final component of the market assessment, a case study will be conducted regarding the potential role of bio-butanol as a renewable fuel in California, given the LCFS and the state’s status as a boutique fuel market.

2. **Renewable Chemicals**

Competitively priced bio-butanol is an attractive gateway to a number of chemical derivatives, including propylene. The applications of the major derivatives will be characterized, and the markets for these derivatives will be evaluated.

V. **Feedstocks**

A. **Existing Use of Propylene**

The feedstocks used in butanol's production will be analyzed. Propylene, a basic petrochemical, is presently the major butanol feedstock, and its use and competitiveness will be reviewed. (In the techno-economic section, the potential for making propylene from bio-butanol also will be addressed.)
Bio-butanol: The Game Changer

B. Corn
   1. Baseline Supply/Demand Balance and Price Outlook
   2. Outlook Based on Expanded Production of Bio-butanol

If bio-butanol can be produced at a cost that is competitive in the biofuel and chemical markets, corn will be the primary feedstock for the foreseeable future, with production occurring in retrofitted ethanol plants. Accordingly, a baseline forecast of the supply/demand and price of corn in the U.S. will be provided (reflecting only limited production of bio-butanol), and then the impact on corn supply/demand and price from larger-scale production of bio-butanol as a biofuel and chemical will be analyzed. The potential substitution of bio-butanol for a segment of the current fuel ethanol market also will be considered.

C. Sugarcane

While the focus of this study will be on the production of bio-butanol in the U.S., as with ethanol there is potential competition in bio-butanol production from sugarcane mills in Brazil. An overview of the outlooks for the Brazilian sugar and ethanol markets will be provided, and a review and general assessment of the potential for substantial quantities of sugarcane to be used as a feedstock for bio-butanol production in Brazil will be conducted.

D. Cellulosic Sugars from Biomass

As a final component of this section, a review and general assessment of the role of cellulosic sugars from biomass as a feedstock for bio-butanol production in the U.S. will be conducted. Biomass feedstocks will be compared, and the commercialization status and potential future trajectory of the supply of cellulosic sugars will be addressed.

VI. Profiles of Selected Emerging Bio-butanol Players

Another useful feature of this study will be profiles of the emerging bio-butanol players. Profiles will be developed for key companies in the industry. The profiling process will begin with an extensive search of the public literature, including company filings and patents. From this information, a preliminary profile will be developed that will be refined with field contacts. All of the major bio-butanol developers/producers will be approached to conduct interviews, in order to round out the information obtained during the desk research.

VII. Conclusions and Implications to Stakeholders

The information developed in the techno-economic and commercial analyses will be combined and further analyzed to develop conclusions regarding the future role of bio-butanol and in the fuel and chemical markets and implications for key industries/sectors. The industries/sectors addressed will include, at a minimum:
• Refiners and the petroleum sector;
• Renewable fuel producers;
• The chemical industry;
• The transportation sector; and
• Corn producers and the agriculture sector overall.

Study Deliverables
The project will involve several specific deliverables for participating clients, including:

• **Comprehensive Study Report and Presentation Materials.** Subscribers will receive an electronic copy of the study report containing the full text along with supporting tables and figures. Subscribers also will receive an electronic copy of the PowerPoint materials used in presenting the study results.

• **Post-Study Presentation.** A Web-based presentation of the study findings and their implications will be conducted following delivery of the report.

• **Optional Report Presentation at Clients' Offices.** Following the group presentation, representatives of the study team will be available to travel to client offices for individualized presentations of the study findings, as requested, at additional cost. These seminars will be tailored to each client’s individual needs and interests.

Study Schedule
• **May-June 2013:** Study kick-off;
• **September 2013:** Study completed and final report sent to clients; and
• **October 2013:** Web-based presentation of study findings, and optional individual presentations at client offices.

Study Fees
The fees for participating in the study are $14,500 for existing clients of the firms conducting the study and $16,500 for non-clients. **A one-time early subscriber price of $10,500 is provided to organizations that subscribe by May 31, 2013.** The fees include the full study report and the Web-based presentation of the findings to the subscriber group. The study team will be available to present the findings and answer questions at the clients’ offices at an additional discounted fee, plus travel expenses. (Please inquire if you are interested in this option.)
ENROLLMENT FORM

☐ Yes, I want to participate in the multiclient study, “Bio-butanol: The Game Changer.” The cost of the study is $14,500 for current clients and $16,500 for non-clients. A special one-time early subscriber price of $10,500 is provided to organizations that subscribe by May 31, 2013. One-half of the study fees will be billed upon initiation of the study, and the remaining half will be billed upon delivery of the final report.

☐ Please have someone contact me to provide further information.

Name: ________________________ Signature: ________________________

Title: ________________________

Company: ________________________

Street Address: ________________________

City, State, ZIP: ________________________

Telephone: ________________________ Fax: ________________________

E-mail Address: ________________________

Please Return This Form Via Email or Fax to:

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Chemical Strategies
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Sleepy Hollow, NY 10591
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Facsimile: (510) 443-6467
E-mail: Jevangelow@aol.com

It is understood that the information contained in the study is for the sole and confidential use of the subscriber. The purchaser agrees to use reasonable efforts to protect the confidential nature of the information contained in the study for a period of three (3) years from the issue date.
APPENDIX:
QUALIFICATIONS OF STUDY PARTNERS

Chemical Strategies
The developer and co-author of the bestselling "Bio-butanol: The Next Big Biofuel" (2008)

JVP International

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INFORMA ECONOMICS, INC.

Informa Economics, Inc., is the world leader in agribusiness/food, energy and transportation consulting and related commodity market analysis. Founded in 1977, the company now serves hundreds of firms and institutions worldwide. In December 2003, the company was acquired by Informa plc, a global business information group. The Informa Economics Group now encompasses Agra CEAS Consulting, Informa Economics FNP Brazil and Washington Policy & Analysis, creating an international network of services and clients with offices in the U.S., Canada, the United Kingdom, Belgium and Brazil, and employing roughly 225 people.

Informa offers several broad categories of services:

- Management consulting for agribusinesses, renewable fuels companies, conventional energy companies, transportation service providers/users, related trade associations and government agencies;
- Agricultural and energy commodity market analysis;
- Risk management strategies; and
- Education and training.

Washington Policy & Analysis, which is part of the Informa Economics Group, is an international consulting firm specializing in energy, environment, trade, transportation, technology, and maritime security and intelligence issues.

Our mission is, "To be a vital force in the success of agriculture, food, energy and transportation interests around the world."

Commodity Market Analysis

Informa offers a comprehensive package of well-respected, timely and highly detailed commodity market information. Informa constructs estimates and forecasts of U.S. and world crop and livestock/meat supply and demand fundamentals and prices. Additionally, Informa analyzes energy markets, transportation, government policies and long-term sector trends. The scope of this work covers the following areas:

- All major grains, oilseeds and products, cotton and fibers;
- Livestock, meat, poultry and dairy;
- Soft commodities, including sugar;
- Specialty vegetable oils;
- Energy;
- Transportation services; and
- Weather services.

Additionally, Informa has developed a global framework for conducting long-term forecasts of supply/demand balances of crops (primarily grains and oilseeds) and livestock, meat and poultry for major countries and world regions. In addition to forecasting global supply/demand balances, prices are forecast for major commodities traded in North America.
Consulting Services

Informa’s Consulting Group provides management and economic consulting services to organizations in the agriculture, food, renewable fuels, conventional energy and transportation sectors. Clients include corporations, cooperatives, trade associations and government agencies in the U.S. and globally. Informa advises clients on a broad range of economic, market, risk management, financial, strategic and regulatory issues.

In order to meet client objectives, Informa utilizes a variety of methods, including:

- Economic impact analysis;
- Econometric analysis;
- Market analysis and forecasting;
- Strategic planning;
- Business plan development;
- Financial projections and feasibility determination;
- Site selection studies; and
- Risk management strategies.

In addition to business- and market-related services, Informa’s Consulting Group conducts analyses of government policies and regulations. Informa Economics consults with government agencies, non-governmental organizations, agribusinesses and trade associations regarding the impacts of policies and regulations on the agricultural and energy markets and industries. Informa consultants also have participated in a variety of international economic development projects.

Informa has conducted dozens of consulting projects on renewable fuels over more than 20 years. Informa has also conducted multi-client studies on renewable fuels (including several specifically on ethanol), conventional energy, vegetable oils and “feedstocks of the future” (i.e., cellulosic biomass and unconventional sources of vegetable oils). For a full set of renewable fuels projects Informa has conducted, please contact the Informa representative listed on the enrollment form.
JAMES EVANGELOW  
President & Principal, CHEMICAL STRATEGIES

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Mobile: (914) 843-6973  
Email: jevangelow@aol.com

QUALIFICATIONS IN BRIEF:

Chemist and Chemical Process Engineer with broad background in commercial development, strategic and business planning and market evaluation in the chemical, energy and allied industries.

Over thirty years of consulting experience in the chemical and biofuels industries. Particular emphasis on commodity and specialty chemicals such as: renewable fuels and chemicals, polymers, solvents, lubricants, coatings, inks and adhesives; among others. Globally recognized ethanol and butanol consultant.

EMPLOYMENT HISTORY:

Chemical Strategies  
President & Principal  
1989-Present

Chem Systems  
Senior Consultant  
1978-1988

Kline & Company  
Staff Consultant  
1976-1977

Witco Chemical Corp.  
Chemical Sales  
1976

Chemical Construction Corp.  
Chemical Process Engineer  
1974-1975

ACADEMIC BACKGROUND:

M.S.  Industrial Management  
Polytechnic Institute of New York  
1974

B.S.  Chemistry  
Polytechnic Institute of New York  
1974

PROFESSIONAL AFFILIATIONS:

American Chemical Society  
1978-Present

Commercial Development & Marketing Association  
1978-2005
RELEVANT EXPERIENCE:

- Developed a successful, and well received, major multiclient study, “Bio-butanol: The Next Big Biofuel” (2008), which was jointly undertaken and coauthored with Nexant Chem Systems.

- Headed a consulting team that provided global commercial and technology assistance to a company with innovative biobutanol technology.

- Retained for a year by a startup bio-butanol producer as their interim business development person, until the full-time position could be filled. Developed several promising leads, potential opportunities and made industry introductions.

- Authored “The World Ethanol Business” and "The Outlook for Ethanol in the U.S., Europe, Brazil and Japan", two major multiclient studies.

- Worked on the feasibility studies of many of the modern US fuel ethanol plants built during the birth of this industry in the late 1970's and early 1980's.

- Lead ethanol consultant to Morgan Stanley in their successful acquisition of Williams Bio-Energy from the Williams Companies. The company has since been renamed Aventine Renewable Energy and went public.

- Lead ethanol consultant to Detroit Edision (DTE) in their attempt to acquire GreenField Ethanol, Canada’s largest ethanol producer.

- Consultant to Sergenti Investment Partners on their successful acquisition of SODES, France’s sole synthetic ethanol producer.

- Planning consultant to SADAF, the joint venture of Shell Oil and Saudi Basic Industries (SABIC), on their ethanol facility in Jubail, Saudi Arabia.

- Consultant to Japan’s ethanol industry for over 25 years, providing commercial information that has guided market development inside the country and lead to the deregulation of the government run monopoly.

- Assisted fuel ethanol producers in developing strategies to diversify both their product and market position.

- Presently working with several startup companies focusing on the production of chemicals and biofuels from biomass.
QUALIFICATIONS IN BRIEF

Chemical engineer and executive manager with broad background in catalyst and process development, catalyst production, sales and licensing, plant operations and general management, in the chemical and allied industries. Forty years of industrial experience in the chemical industry, from engineering and process development, to general management of a catalyst business, and executive management of a catalyst and process technology company, concentrating in the global petrochemical industry. Over ten years of experience consulting with organizations to evaluate proposed new catalyst and/or process technology R&D and commercialization. Consulting areas include petrochemicals, inorganic chemicals, pulp & paper, energy generation, hydrogen, bioprocessing, innovative reaction and separations technologies.

EMPLOYMENT HISTORY

JVP International, Inc., President and Principal  Jan. 2001 to present

SCIENTIFIC DESIGN COMPANY, INC., President and CEO  1988-2000

CHEM SYSTEMS, INC., Director, Process Evaluation/Research Planning 1987-88

HALCON SD GROUP, INC., Montvale, NJ, and New York City
  President  1985-1987
  Vice President, Technology  1980-1985
  Vice President, Development  1977-1980
  Vice President & General Manager, Catalyst Development Corp.  1975-1977
  Director of Development  1970-1975
  Technical Director, Ethylene Oxide R & D  1964-1970
  Development Engineer, Engineering Development  1960-1964

ACADEMIC BACKGROUND

Columbia University School of Business (Executive Program)  1975-1977
  M.S. in Business Policy

Columbia University School of Engineering  1954-1960
  D. Eng. Sci. in Chemical Engineering  1963
  M.S. in Chemical Engineering (Monsanto Fellow)  1958
  B.S. in Chemical Engineering  1956
Columbia College (Columbia University) 1951-1954
A.B. in Pre-Engineering, (Ford Foundation Scholar) 1955

PROFESSIONAL AFFILIATIONS

American Institute of Chemical Engineers 1960 to present
Board of Directors 1998-2000
Fellow and Past Chair, Management Division 2005
Management Division Award 2005
AIChe Management Conferences
Co-chair of 2007 Conference Advisory Committee 2007
Chair of 2005 Conference Advisory Committee 2005

Société de Chimie Industrielle 2001 to present
Vice President of Finance 2004 to 2008
Vice President of Membership 2011 to present

Assoc. of Consulting Chemists & Chemical Engineers, Inc. 2001 to present
Past President

Member of American Chemical Society, Chemical Consultants Network.

RELEVANT EXPERIENCE

- Evaluation of proposed R&D projects and auditing of their progress and readiness for commercialization, for the U.S. Department of Energy, petrochemical and catalyst companies and occasionally as a sub-contractor to consulting companies.
- Merit Reviewer for industry areas within the U.S. DOE’s ITP Program, including the Chemicals, Forest Products, Fuels and Materials for Separations sectors. Chaired peer reviews for the Forest Products and the Chemicals sectors.
- Led two major multi-year projects for the ITP Program. CPAT: development of a computer model for estimating the economic viability and energy savings for new process developments. Bandwidth: analysis of the energy efficiencies of production technologies used to produce 50 major chemical products.
- R&D and process design audit for a new petrochemical process technology
- Evaluation of a process technology package donated to an academic institution
- Market study and economic evaluation of a novel preparation method for catalysts
- Market studies, technical reports and economic models for a developer of biomass-based production processes for major chemicals (e.g., butanol and ethanolamines)
- Advising both major and emerging companies on preparing new process technologies for the market place.
- Led the development of two technology alliances that strengthened the competitive position of the company in its most important product lines.
- P&L responsibility and technical oversight of a 50+ subscriber multiclient service.
SAM NEJAME
President, PROMOTUM

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QUALIFICATIONS IN BRIEF:

For more than 25 years Sam Nejame has provided management consulting and engineering services to Fortune 500 Companies, Start-ups, universities, investment banks and investors. His practice focuses on issues of sustainability and technology commercialization in the fields of energy, efficiency, water, transportation and critical materials. He has consulted extensively with the renewable chemicals and fuels industries.

RELEVANT EXPERIENCE:

• Provided strategy management consulting services to Abengoa BioEnergy, an international biofuels producer, evaluating butanol opportunities in global markets.

• Directed market analysis & technology due diligence for Koch Industries' purchase of Invista (DuPont Textiles & Interiors) for $4.2B. Successful acquisition of world's largest integrated fiber enterprise (polyester, nylon and spandex).

• Led technology, market and equities analysis of biofuel/renewable chemical companies for investment banks, a multi-billion dollar private equity firm and a large family wealth fund.

• Conducted market and economic analysis of various renewable fuel and chemical opportunities. Presented at national/international conferences on the advantages and coming opportunities for biobased chemicals including: EIA, BBI, Platts, Infocast, AIChE, the US National Renewable Energy Lab and others.

• Served on the board of directors of a bio-butanol company. Helped develop the company’s business plan and made industry introductions.

• Conducted strategic and competitive analysis for International Paper; preceding N. American expenditure >$100MM.

• Founded company w/ angel money from CFO of Intel.