T2+2™ Market Overview

Catalysts Used in Converting Biomass to Fuel

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This report focuses on the market for catalysts used in the production of biofuel technology, encompassing both the bioethanol and biodiesel industries. Biofuels can be produced from a number of advanced catalytic processes including fermentation, distillation, hydrolysis, gasification and catalytic conversion to liquid fuels (biomass to liquid, or BTL).[1]

While market sizes are hard to estimate, the following describes how we arrived at a figure for the total addressable market for catalysts used in the production of biofuel. We estimate the market size to be approximately:

Market Niche Size			
Market Size in Dollars	***Growth Rate***	***Base Year***	***Detailed Basis for Estimate***
$38.4 million	n/a	2009	We estimate the average weight of biofuel to be approximately 0.8 kg/liter.[2] Where 1 tonne=1,000kg, the ratio of liters to tonnes for biofuel equals 1,250 l/tonne. When this is applied to a 2009 Frost & Sullivan report that estimates that total biofuel production in 2009 will be approximately 173,530 tonnes, a total of 217 million liters is derived. Using the average estimated cost to produce both biodiesel and bioethanol (approximately $.77 cents/liter),[3] we are able to calculate a total production cost of $167 million. It is then estimated that approximately 77% of production costs stems from the price of feed stocks and capital costs[4] leaving a remaining 23% for catalyst costs which equals a $38.4 million market for catalysts used in biofuel production.

A dramatic increase of crude oil prices, environmental concerns and the desire to be less dependent on imports have greatly elevated the interest in alternative energy sources over the past few years.[5] This demand has given rise to increased investment in fuel derived from biomass. Volatile "oil prices are increasing the search intensity for bio based fuels, biopolymers, and others, so that the dependence on petroleum-based feed stocks can be reduced. This gives an impetus to research in catalysis for bio based products."[6] Biomass fuels are important, as they can be used in a variety of industries and can be converted from various feed stocks. Biological wastes such as cellulosic wood waste, grass, and

[1] "Biofuel Production." IEA Energy Technology Essentials, January 2007. http://www.iea.org/Textbase/techno/essentials2.pdf (accessed May 1, 2009).
[2] "Specific Gravity of Liquids." SI Metric web site. http://www.simetric.co.uk/si_liquids.htm (accessed May 1, 2009).
[3] "Biofuel Production." IEA Energy Technology Essentials, January 2007. http://www.iea.org/Textbase/techno/essentials2.pdf (accessed May 1, 2009).
[4] Kumar, Naveen. "Biodiesel Production Technology and Feedstocks for India." University of Minnesota, October 2006. http://www.hhh.umn.edu/img/assets/24452/Naveen%20Kumar%20-%20October%2024%202006.ppt#298,1,Slide 1 (accessed May 1, 2009).
[5] LePree, Joy. "Cleaning Up With Catalysts: as Worldwide Regulations Grow More Stringent, Catalyst Development Focuses on Providing Cleaner Energy Sources and Cleaning up Air Pollution.(Newsfront)." Chemical Engineering. 2008. HighBeam Research web site (subscription required). http://www.highbeam.com (accessed May 1, 2009).
[6] "North American Refinery and Polymerization Catalysts Markets." August 2007. Frost & Sullivan web site (subscription required). http://www.frost.com/ (accessed May 1, 2009).

algae can be converted to a synthesis gas (syngas) consisting of carbon monoxide and hydrogen, which in turn will be converted into liquid hydro-carbons of various forms, including synthetic diesel and jet fuels.[7] Current BTL technologies involve the production of syngas as the first step, which is where catalyst development plays an increasingly important role.[8]

The market size and growth rate is a function of the number of people in the market and the anticipated rate of buying. As markets transition between emerging, growth, shakeout, mature, and declining, the basis for competition and the number of competitors usually changes, along with the factors influencing adoption of innovation. The number of and growth rate for customers suggests how many units might be sold.[9]

Our Current View on the Phase of the Market	
Today	***Trend***
Emerging	Emerging/Growth

The market for catalysts appears to be in an emergent stage as end user industries are already commercial in some countries yet production is still limited and subject to further improvement and optimization.[10] In many areas, research and development in biomass utilization are still in their infancy;[11] this is especially true for BTL and the Fischer-Tropsch (FT) conversion processes, as they have not been fully commercialized and are still only in use in the laboratory.[12] This is expected to change, however, as growth of "biomass-to-liquids facilities will help drive strong synthesis gas catalyst demand, particularly over the longer term."[13] In the longer term, the trend is likely to be in a growth phase as Biomass-to-Liquid (BTL) fuels could achieve a market share of 10% in

[7] "Syntec Acquires Access to Catalyst Technologies for Converting Biomass Waste to Diesel and Jet Fuel." Gulf Oil & Gas, July 2008. http://www.gulfoilandgas.com/webpro1/MAIN/Mainnews.asp?id=5709 (accessed May 1, 2009).

[8] LePree, Joy. "Cleaning Up With Catalysts: as Worldwide Regulations Grow More Stringent, Catalyst Development Focuses on Providing Cleaner Energy Sources and Cleaning up Air Pollution.(Newsfront)." Chemical Engineering. 2008. HighBeam Research web site (subscription required). http://www.highbeam.com (accessed May 1, 2009).

[9] For a detailed discussion of the "innovativeness dimension," see Everett M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995). For further readings related to market phases and innovation, see also James Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1996) and Vijay K. Jolly, *Commercializing New Technologies: Getting from Mind to Market* (Boston: Harvard Business School Press, 1997).

[10] "Strategic Analysis of Second Generation Bio-feedstock." April 2009. Frost & Sullivan web site (subscription required). http://www.frost.com/ (accessed May 1, 2009).

[11] Rinaldi, Roberto. Schüth, Ferdi. "Design of Solid Catalysts for the Conversion of Biomass." Energy and Environmental Science, April, 2009. http://www.rsc.org/delivery/_ArticleLinking/DisplayHTMLArticleforfree.cfm?JournalCode=EE&Year=2009&ManuscriptID=b902668a&Iss=Advance_Article (accessed May 1, 2009).

[12] "Syntec Acquires Access to Catalyst Technologies for Converting Biomass Waste to Diesel and Jet Fuel." Gulf Oil & Gas, July 2008. http://www.gulfoilandgas.com/webpro1/MAIN/Mainnews.asp?id=5709 (accessed May 1, 2009).

[13] "Global Chemical Catalyst Market Value Demand to Rise 6.3% Annually through 2012." January 2009. Market Research Bulletin. http://www.marketresearchbulletin.com/?p=100 (accessed May 1, 2009).

Europe by 2015. [14] Furthermore, the U.S. Energy Independence and Security Act of 2007 has set a mandatory Renewable Fuel Standard (RFS) requiring fuel producers to use at least 36 billion gallons of biofuel in 2022 – creating substantial market potential for catalysts in the long term.[15]

Markets can also be described in terms of the basis for competition (best technological performance, best value or the price/performance tradeoff that best matches the end-users' preferences, lowest cost, or best availability or the ability to get the product quickly). This dimension helps to define the context in which a commercialization strategy must be developed.

Basis for Competition in the Arena	
Today	***Trend***
Best Value	Best Value

The market for catalysts appears to be driven by best value, as "high energy prices help support increased catalyst demand as a means of improving productivity. Average prices will also continue to advance due to a combination of underlying support from strong demand, and a shifting product mix toward higher cost/ more efficient products."[16]

This trend is likely to continue as further development of catalysts has focused on improved lifetime, activity and selectivity.[17] Furthermore, even though "the production costs of BTL fuels is likely to be higher than conventional oil-derived fuels in the near to medium future, the cost benefit analysis based on a combined market realization of fuels, non-energy products (waxes, lubricants, kitchen oils, etc.), power and heat promises to make it a viable proposition in future."[18]

In each market there may be stakeholders and companies with significant market share that will influence the introduction of your technology. Some organizations or companies that will likely influence the introduction of this technology are the following:

Examples of Major Competitors in the Arena		
Competitor	***Relevance***	***Web site***
Syntec Biofuel	"Syntec Biofuel Inc is a creative	http://www.syntecbiofuel.com/

[14] "Syntec Acquires Access to Catalyst Technologies for Converting Biomass Waste to Diesel and Jet Fuel." Gulf Oil & Gas, July 2008. http://www.gulfoilandgas.com/webpro1/MAIN/Mainnews.asp?id=5709 (accessed May 1, 2009).
[15] Ibid.
[16] "Global Value of World Catalyst Demand will reach $16.5 billion in 2012, predicts New Report." M2 Presswire. 2008. HighBeam Research web site (subscription required). http://www.highbeam.com (accessed May 1, 2009).
[17] "Strategic Analysis of Second Generation Bio-feedstock." April 2009. Frost & Sullivan web site (subscription required). http://www.frost.com/ (accessed May 1, 2009).
[18] "About BTL." Biomass to Liquids web site. http://www.btltec.com/about-btl/ (accessed May 1, 2009).

	renewable energy company that is developing and commercializing proprietary second-generation biofuel technology and processes to convert waste cellulosic biomass into ethanol and other high-value alcohols. The company's unique Biomass-to-Alcohols (B2A) thermo-chemical process can utilize virtually any organic feedstock, such as woodchips, corn stover, sugar bagasse, wheat straw and so forth, to produce highly sustainable and renewable fuel."[19]	
Sud-Chemie Catalyst Division	"Süd-Chemie AG is a highly-innovative, specialty chemical company operating on a worldwide scale, its catalysts and adsorbents divisions offering products and technical solutions to facilitate effective use of resources in customer value chains."[20]	http://www.sud-chemie.com/scmcms/web/page_en_5639.htm
Oxford Catalysts Group	"Oxford Catalysts produces specialty catalysts for the generation of clean fuels, from both conventional fossil fuels and renewable sources such as biomass."[21]	http://www.oxfordcatalysts.com/
BASF Catalysts	"BASF Catalysts, part of the BASF Group, offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics, adsorbents and other products."[22]	http://www.catalysts.basf.com/main
Catalin Inc.	"Catilin, Inc. is a technology based company that is revolutionizing biofuel production. Catilin has developed a unique, new technology for biodiesel production that greatly reduces the cost of producing a gallon of biodiesel while creating a superior quality biodiesel and glycerin by-product. Catilin's patent-pending, non-toxic technology is	http://www.catilin.com/

[19] "Home Page." Syntec Biofuel web site. http://www.syntecbiofuel.com/ (accessed May 1, 2009).
[20] "Catalyst Division." Sud-Chemie Group web site. http://www.sud-chemie.com/scmcms/web/page_en_2991.htm (accessed May 1, 2009).
[21] "About Us." Oxford Catalysts web site. http://www.oxfordcatalysts.com/about/overview.php (accessed April 29, 2009).
[22] "About Us.' BASF Catalysts web site. http://www.catalysts.basf.com/Main/aboutus (accessed May 1, 2009).

	centered on a family of solid heterogeneous catalysts that can be easily utilized within existing production facilities, can be reused multiple times and works with virtually every biodiesel feedstock source."[23]	

Examples of Key Stakeholders or Networking Channels with Contact Information		
Stakeholder	***Relevance***	***Contact Information***
International Service for the Acquisition of Agri-Biotech Applications	"The International Service for the Acquisition of Agri-biotech Applications (ISAAA) is a not-for-profit organization that delivers the benefits of new agricultural biotechnologies to the poor in developing countries. It aims to share these powerful technologies to those who stand to benefit from them and at the same time establish an enabling environment for their safe use."[24]	417 Bradfield Hall Cornell University, Ithaca New York 14853, USA Tel: 607-255-1724 http://www.isaaa.org
The International Energy Agency (IEA)	"The International Energy Agency (IEA) is an intergovernmental organisation which acts as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major consumers and producers of energy like China, India, Russia and the OPEC countries."[25]	9 rue de la Fédération 75015 Paris Tel: +33 1 40 57 65 00/01 E-mail: info@iea.org http://www.iea.org/
Biomass Energy Research Association (BERA)	"BERA's mission is to encourage biomass energy research in both the public and private sectors, and to facilitate information exchange, education, transfer of research from the laboratory to commercial use, and	901 D Street, S.W. Suite 100 Washington, DC 20024 E-mail: beraorg@yahoo.com http://www.beraonline.org/

[23] "Home Page." Catalin web site. http://www.catilin.com/ (accessed May 1, 2009).
[24] "Home Page." International Service for the Acquisition of Agri-Biotech Applications web site. http://www.isaaa.org/ (accessed May 1, 2009).
[25] "About Us." The International Energy Agency web site. http://www.iea.org/ (accessed May 1, 2009).

	international cooperation on all facets of biomass energy (bioenergy)."[26]	
The Biomass Power Association (BPA)	"The Biomass Power Association is the only organization working nationally to expand and advance the use of clean, renewable biomass energy. Biomass energy (or "biopower") uses natural materials like tree trimmings, harvest waste, scrap lumber and other organic materials to generate electricity, using a process that's cleaner and far more efficient than most other generation techniques. BPA represents 80 biomass-fueled power plants in 16 states, and advocates at the state and federal level on a wide range of energy-related issues."[27]	100 Middle St PO Box 9729 Portland, ME 04104 http://www.usabiomass.org/

Users' abilities to buy the technologies they want are constrained by relevant government regulations and by relevant industrial standards and certification requirements. These requirements indicate test and evaluation procedures that can speed market acceptance if incorporated into concurrent engineering.

Examples of Regulations, Standards, and Certifications		
Identifier and Promulgator	***Description***	***Comments***
BSR/ASABE S564-200x American Society of Agricultural and Biological Engineers	"Standard Methods Applicable to Properties of Solid Fuels from Biomass of Plant Origin used for Direct Combustion in Stationary Heat and Power Systems"[28]	"The proposed standard will provide approved developed standard methods that are applicable to properties of solid fuels from biomass of plant origin used for direct combustion in stationary heat and power systems."[29]
ASTM E869-93(2006) ASTM International	"Standard Test Method for Performance Evaluation of Fuel Ethanol Manufacturing Facilities"[30]	"This test method covers the determination of performance characteristics of fuel ethanol manufacturing facilities. This test method is applicable for all starch, sugar, and combination starch/sugar based fermentable feed stocks."[31]

[26] "About Us." Biomass Energy Research Association web site. http://www.beraonline.org/ (accessed May 1, 2009).
[27] "About Us," Biomass Power Association web site, http://www.usabiomass.org/pages/about.php (accessed May 4, 2009).
[28] "Detail Results." NSSN Search Engine for Standards web site, http://www.nssn.org/search/DetailResults.aspx?docid=574269&selnode= (accessed May 1, 2009).
[29] Ibid.
[30] "Detail Results." NSSN Search Engine for Standards web site, http://www.nssn.org/search/DetailResults.aspx?docid=482346&selnode= (accessed May 1, 2009).
[31] Ibid.

ASTM E873-82(2006) ASTM International	"Standard Test Method for Bulk Density of Densified Particulate Biomass Fuels"[32]	"This test method covers the procedure for the determination of bulk density (or bulk specific weight) of densified particulate biomass fuels with a maximum particle volume of 16.39 cm3 (1 in. 3)."[33]
ASTM E870-82(2006) ASTM International	"Standard Test Methods for Analysis of Wood Fuels"[34]	"These test methods cover the proximate and ultimate analysis of wood fuels and the determination of the gross caloric value of wood fuels sampled and prepared by prescribed test methods and analyzed according to ASTM established procedures. Test methods as herein described may be used to establish the rank of fuels, to show the ratio of combustible to incombustible constituents, to provide the basis for buying and selling, and to evaluate for beneficiation or for other purposes."[35]

Entry barriers are obstacles that remove customer segments from the market for some period of time. They limit the size of the addressable market in general or the market share that can be captured. These barriers must be overcome or avoided to have a successful market entry. Our work to date suggests the following entry barriers may prevent customer segments from buying this type of technology for some period of time.

Market Entry Barriers	
Name of Barrier	***Description/Why***
High Material Costs	High capital investment is necessary and is likely as a major constraint to new market entrants. Catalytic "enzymes used to extract glucose and other sugars from cellulose are currently too expensive to make the process competitive for creating cellulosic biofuels."[36]
Hazardous and Complex Chemicals	The common catalyst "sodium methoxide is highly explosive; its formation is the most perilous part of biodiesel production. Even without combustion, the mix can be a serious health hazard to humans upon contact. From a process perspective, separating the methanol from its sodium hydroxide emulsions illustrates one more hoop that producers need to jump through to achieve proper ester conversion."[37] To be successful new entrants must developed innovative and novel catalyst alternatives to the hazardous products currently available.

[32] "Detail Results." NSSN Search Engine for Standards web site, http://www.nssn.org/search/DetailResults.aspx?docid=482350&selnode= (accessed May 1, 2009).
[33] Ibid.
[34] "Detail Results." NSSN Search Engine for Standards web site, http://www.nssn.org/search/DetailResults.aspx?docid=482347&selnode= accessed May 1, 2009).
[35] Ibid.
[36] Patel, Prachi. "New Route to Hydrocarbon Biofuels." Technology Review, September 2008. http://www.technologyreview.com/Energy/21395/ (accessed May 1, 2009).
[37] Kotrba, Ron. "A Catalyst for Change." Biodiesel Magazine, 2005. http://www.biodieselmagazine.com/article.jsp?article_id=379 (accessed May 1, 2009).

Lack of Large Scale End User Infrastructure	In the short term the catalyst market will likely be constrained by the lack of large scale biofuel processing plants and infrastructure, as plants are expensive, take a long time to build, and require substantial technical expertise.[38]

Although catalyst technology has been in use for some time and there is a strong track record of catalyst research and understanding in the petroleum and petrochemical industry, these current catalyst technologies are not as effective for biomass feed stocks."[39] This potentially poses a barrier to entry from traditional catalyst produces as end user specifications will likely vary significantly from the chemical and biofuel industries.

Market drivers are forces that strengthen or weaken the importance of end-user needs over time. Practice level drivers are micro-economic; they affect the end-user directly. They influence the selection of substitutable goods and thus affect market share. Arena level drivers affect the organizations and industrial sectors in which the end-users work. They influence the overall demand for goods like this technology and its substitutes. They affect when and how much of the total addressable market is actually going to be in the market and buying.

Market Drivers	
Name of Driver	***Why Significant***
Growing Biofuel Industry; Efficiency Gains from Catalysts	'"The use of these new catalysts will allow operators of high technology reactors such as microchannel reactors to operate with productivities (bbl product/litre of catalyst) that are orders of magnitude higher than for conventional systems."[40] Growing demand for biofuel will spur further growth and development of more efficient and effective catalyst systems.
Need for Better and Cheaper Fuels	"The wild fluctuations in oil prices over the past year has set off a quest for both better fuels and improved efficiencies for manufacturing established fuels and chemicals. Many believe that catalysts will play a key role in this quest as refining and petchem producers look for ways to reduce energy consumption, improve yield and process selectivity, as well as ways to produce alternative fuels. In light of this environment, the market for such catalysts is expected to grow rapidly over the next few years."[41]
Technological Innovation	"Developing cost-effective ethanol production from ligno-cellulose via enzymatic hydrolysis would therefore increase the variety and availability of feed stocks and hence expand the production of biofuels."[42] Technological innovation is likely to enable the use of cheaper and more abundant feed stocks and drive

[38] Jones, Alan. "Biofuel Infrastructure: Regional Needs and Barriers." Emerging Fuel Issues Workshop, December 2006. http://www.biotenn.org/altfuels/pdf/biofuelsinfra.pdf (accessed May 1, 2009).
[39] Ebert, Jessica. "Breaking the Catalytic Barrier to Biofuels." Ethanol Producer Magazine, August 2008. http://ethanolproducer.com/article.jsp?article_id=4456&q=&page=1 (accessed May 1, 2009).
[40] O'Driscoll, Cath. "Fast work from biofuel catalysts.(Fischer-Tropsch)." Chemistry and Industry. 2008. HighBeam Research web site (subscription required). http://www.highbeam.com (accessed May 1, 2009).
[41] "Opportunities for Catalysts in the Refining and Petrochemical Industries: An Eight-Year Forecast." Nanomarkets, January 2009. http://www.nanomarkets.net/products/prod_detail.cfm?prod=9&id=277 (accessed May 1, 2009)
[42] Rinaldi, Roberto. Schüth, Ferdi. "Design of Solid Catalysts for the Conversion of Biomass." Energy and Environmental Science, April, 2009. http://www.rsc.org/delivery/_ArticleLinking/DisplayHTMLArticleforfree.cfm?JournalCode=EE&Year=2009&ManuscriptID=b902668a&Iss=Advance_Article (accessed May 1, 2009)

	the market for biofuels and biofuel catalysts in the long term.
Growing Demand from Transportation Sector	"Producing transportation fuel from biomass feedstock (BTL) is considered an important means of reducing carbon emissions and increasing energy security while providing an alternative to fossil fuels."[43] This is likely to drive market growth for catalysts as biofuel use becomes more desirable.

The transportation sector will likely be a major driver of catalyst technology as "biomass is the only renewable alternative to fossil energy sources in the transport sector in the short to medium term, and as such the BTL process with its efficient use of biomass, is of central importance."[44] Growing concern over oil supply also appears to be a major driver of the catalyst market, as "the current and projected situation regarding fossil fuels and the potential need to expand the utilization of syn gas from alternative, renewable sources, improved FT catalysis could make a major contribution."[45]

Here is some additional data and sources that can help you better understand the market.

Name	*Description*
European Biofuels Technology Platform	"The Mission of the European Biofuels Technology Platform is to contribute to the development of cost-competitive world-class biofuels technologies, a healthy biofuels industry supplying sustainable biofuels in the European Union, through a process of guidance, prioritization and promotion of research, development and demonstration."[46] For more information see the following URL: http://www.biofuelstp.eu
Canadian Biomass Innovation Network	"The Canadian Biomass Innovation Network (CBIN) coordinates the Federal Government's interdepartmental Research, Development and Demonstration (RD&D) activities in the area of bioenergy, biofuels, industrial bioproducts and bioprocesses."[47] For more information see the following URL: http://www.cbin.gc.ca
Ethanol Producer Magazine	"Ethanol Producer Magazine is the oldest, largest and most read trade publication in the ethanol industry. Published by BBI International Media, Ethanol Producer Magazine is the source for in depth ethanol industry news."[48] For more information see the following URL:

[43] LePree, Joy. "Cleaning Up With Catalysts: as Worldwide Regulations Grow More Stringent, Catalyst Development Focuses on Providing Cleaner Energy Sources and Cleaning up Air Pollution.(Newsfront)." Chemical Engineering. 2008. HighBeam Research web site (subscription required). http://www.highbeam.com (accessed May 1, 2009).
[44] "Oxford Catalysts Group." Clean Equity Monaco Conference, 2009. http://www.cleanequitymonaco.com/CompanyPresentations/OxfordCatalystsMonacoMar09.ppt#692,1,Oxford Catalysts Group PLC (accessed May 1, 2009).
[45] O'Driscoll, Cath. "Fast work from biofuel catalysts.(Fischer-Tropsch)." Chemistry and Industry. 2008. HighBeam Research web site (subscription required). http://www.highbeam.com (accessed May 1, 2009).
[46] "Home Page." European Biofuels Technology Platform web site. http://www.biofuelstp.eu/home.html (accessed May 1, 2009).
[47] "Home Page." Canadian Biomass Innovation Network web site. http://www.cbin.gc.ca/index-eng.php (accessed May 1, 2009).
[48] "About Us." Ethanol Producer Magazine web site. http://ethanolproducer.com (accessed May 1, 2009).

	http://ethanolproducer.com