T2+2™ Market Overview

Carbon Fiber Composites

April 7, 2009

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Carbon fiber composites are becoming widely adopted in the transportation, sporting goods and wind energy sectors, among others. This is because "carbon-fiber composites weigh about one-fifth as much as steel, but can be comparable or better in terms of stiffness and strength, depending on fiber grade and orientation."[1] While market sizes are hard to estimate, the following provides our figures on the global carbon fiber composites market.

Market Niche Size			
Market Size in Dollars	***Growth Rate***	***Base Year***	***Detailed Basis for Estimate***
$6.86 Billion	13%	2007	This market estimate is derived from figure in a report published by the American Ceramic Society. The report states that the carbon fiber composite industry is expected to reach $9.9 billion in 2010 based on annual growth of 13%. Discounting that projection to 2007, the date of the report's publication, yields our $6.86 billion figure.[2]

The aircraft and aerospace segment of the carbon fiber composite market appears to be especially significant. Our research shows that "production of finished composite components and structures for new aircraft" was valued at $5.5 billion in 2006. However, only "most" of these composites were said to be carbon fiber composite, placing the market estimate for that segment somewhere below that overall estimate.[3]

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.[4]

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

[1] "Carbon Fiber Composites for Cars." *Oak Ridge National Laboratory Review*. vol. 3, no.3 (2000). Oak Ridge National Laboratory web site, http://www.ornl.gov/info/ornlreview/v33_3_00/carbon.htm (accessed April 7, 2009).
[2] "Carbon Fiber Manufacturers Increase Production as Composites Market Expands." September 5, 2007. The American Ceramic Society web site. http://www.ceramics.org/news/ceramic_tech_today/ct2007/20070905carbon_fiber.aspx (accessed April 7, 2009).
[3] "Aerospace composites market will quadruple by 2026." January 1, 2007. *High Performance Composites*. Zoltek web site. http://www.zoltek.com/industrynews/4 (accessed April 7, 2009).
[4] 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).

Based on the publically available information, it appears that the carbon fiber composite market is in an atypical situation in that it is growing quickly but is also dominated by an "oligopoly" of seven large companies that have built their dominance by supplying the aircraft and aerospace market.[5] The growth rate of 13% as noted in the above section, combined with analyst comments like "this industry is ready to explode,"[6] indicates a growth market, but growth markets are rarely as concentrated as the carbon fiber composites market. As a result, we believe it is between a growth and mature market, exhibiting characteristics of both, and is likely to remain so for the foreseeable future.

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

Although the primary ingredient of carbon fiber composites, carbon fiber, is a commodity (with a market price that has been steadily dropping from $150/pound in the 1970's to $20 in mid-2007),[7] our research indicates that the players in the carbon fiber composites industry compete based on value. This is because there is a very wide range of products on the market, and many have been developed for specific applications such as aircraft,[8] which require extremely high performance and therefore can not choose suppliers based solely on the lowest price.

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***
Toray	Based in Japan. Their carbon fiber composites "business segment is underpinned by Toray's strengths,	http://www.toray.com

[5] "Good growth projected for aerospace composites." December 12, 2008. ICIS web site. http://www.icis.com/Articles/2008/12/15/9178930/good-growth-projected-for-aerospace-composites.html (accessed April 7, 2009).
[6] "Market Trends: This industry is ready to explode." March 27, 2008. *High Performance Composites.* Zoltek web site. http://www.zoltek.com/industrynews/91/ (accessed April 7, 2009).
[7] "Aircraft orders put carbon fiber prices in steep climb." June 4, 2007. *USA Today*. Zoltek web site. http://www.zoltek.com/aboutus/news/60 (accessed April 7, 2009).
[8] "Carbon Fiber Composite Materials." Toray web site. http://www.toray.com/businesses/carbon/index.html (accessed April 7, 2009).

	including: (1) global operations with production bases in Japan, the United States, and Europe; (2) vertical development of prepreg, woven and other intermediate materials and composite materials in addition to carbon fibers; (3) a superior lineup of carbon fiber products of the highest quality; (4) a technological competitive edge attributable to the stable quality of its prepreg products; and (5) Toray's solid position in aircraft applications."[9]	
SGL Group	"The composite materials from the SGL Group encompass high-performance products made from carbon and glass fiber, as well as materials for industrial insulation and high-temperature materials. These products are mainly used in the wind energy and automotive industries, in aerospace and in sports equipment." Products include textiles, CFRP components, and carbon fiber filled EPDM.[10]	http://www.sglgroup.com
Zoltek	"Our objective as a company is to lead the commercialization of carbon fiber as a primary composite building material. It is our goal to help others achieve new levels of performance across a range of products. Carbon fiber reinforced composites are remarkable in their performance characteristics and properties that include high strength, low weight, high stiffness, corrosion resistance, heat resistance, and electrical conductivity."[11]	http://www.zoltek.com
Hexcel	Hexcel is "the largest US producer of carbon fiber; the world's largest weaver of reinforcement fabrics; the number one producer of composite materials such as honeycomb, prepregs, film adhesives and sandwich panels; and a leading manufacturer of composite parts and structures."[12]	http://www.hexcel.com
Cytek	"Cytec Engineered Materials produces high-performance, pre-impregnated	http://www.cytek.com

[9] Ibid.
[10] "Composite Materials." SGL Group web site. http://www.sglgroup.com/cms/international/products/product-groups/cm/index.html?__locale=en (accessed April 7, 2009).
[11] "Company." Zoltek web site. http://www.zoltek.com/aboutus (accessed April 7, 2009).
[12] "About Hexcel." Hexcel web site. http://www.hexcel.com/about (accessed April 7, 2009).

	composites and adhesives, ablatives, carbon-carbon materials for high-temperature applications, high-temperature silicone-based sealants, a variety of specialty thermoplastic materials, and PAN and pitch-based carbon fibers. The company also offers a range of vacuum-only-cure prepregs that enable the manufacture of large aerospace parts—without the use of autoclaves. Cytec Engineered Materials' exclusive toughened resin transfer molding (RTM) materials offer engineers greater design flexibility over traditional materials as well as the option to use low-cost fabrication techniques for structural parts."[13]	
Mitsubishi Rayon	"The Mitsubishi Rayon Group possesses a product chain stretching from PYROFIL carbon fiber -- made from polyacrylonitrile (PAN) filaments produced in-house -- to intermediate materials and molded products based on carbon fibers. Our carbon fiber products are also used in a wide range of applications. The Mitsubishi Rayon Group has obtained the JISQ9100 quality assurance system certification for the aerospace industry, and we are continuing to work to raise our quality control levels still further."[14]	http://www.mrc.co.jp/english/index.html

Examples of Key Stakeholders or Networking Channels with Contact Information		
Stakeholder	***Relevance***	***Contact Information***
Advanced Composite Manufacturers Association (ACMA)	"ACMA represents 850 of approximately 3000 composites manufacturers and suppliers to the industry." It has started the Composites Growth Initiative (CGI), the mission of which is to "promote and expand the use and understanding of composite materials."[15]	1010 North Glebe Road Suite 450 Arlington, VA 22201 Tel: 703-525-0511 http://www.acmanet.org
Japan Carbon Fiber Manufacturers Association (JCMA)	An organization formed by the seven largest Japanese carbon fiber and carbon fiber composites	Not available in English. A contact form is available by going to the URL below and clicking on "Inquiry" from the left-hand menu

[13] "Engineered Materials." Cytec web site. http://www.cytec.com/engineered-materials/index.htm (accessed April 7, 2009).
[14] "Specialty Products." Mitsubishi Rayon web site. http://www.mrc.co.jp/english/products/special/index.html#01 (accessed April 7, 2009).
[15] "About ACMA." Advanced Composite Manufacturer's Association web site. http://www.acmanet.org/about/index.cfm (accessed April 8, 2009)

	producers.	and clicking on the link for "Inquiries to JCMA." http://www.carbonfiber.gr.jp/english/index.html
Oak Ridge National Laboratory	Oak Ridge has initiated a number of projects aimed at reducing the cost of carbon fiber and carbon fiber composites. They are also researching ways to increase to volume production of carbon fiber, in anticipation of future mass use in automobiles.[16]	P.O. Box 2008 Oak Ridge, TN 37831 Tel: 865-574-4160 http://www.ornl.gov/ornlhome/contact_us.shtml
U.S. Department of Energy	"The U.S. Department of Energy (DOE) has developed a new carbon-fiber reinforced polymer composite drill pipe that is lighter, stronger and more flexible than steel, for use in the oil industry. The new composite drill pipe could, according to the DOE, significantly alter the ability to drain substantially more oil and gas from rock than traditional vertical wells. With much of the nation's "easy-to-produce" oil gone, many U.S. companies are looking for lower cost ways to recover oil and gas that may have been bypassed when the fields were first opened."[17]	1000 Independence Ave., SW Washington, DC 20585 Tel: 800-342-5363 http://www.energy.gov

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***

[16] "Carbon fiber cars could put U.S. on highway to efficiency." March 6, 2006. Oak Ridge National Laboratory web site. http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20060306-00 (accessed April 7, 2009).

[17] "U.S. Department of Energy Develop Flexible Carbon Fiber Composite Drill Pipe." May 17, 2004. *Advanced Materials and Composites News.* AllBusiness web site. http://www.allbusiness.com/energy-utilities/utilities-industry-electric-power/8187925-1.html (accessed April 7, 2009).

Standard Test Method for Constituent Content of Composite Prepreg by Soxhlet Extraction ASTM C613/C613M-97 ASTM International	"This test method covers a Soxhlet extraction procedure to determine the matrix content, reinforcement content, and filler content of composite material prepreg. Volatiles content, if appropriate, and required, is determined by means of Test Method D 3530/D 3530M."[18]	Full standard available for purchase from the American National Standards Institute at http://webstore.ansi.org/RecordDetail.aspx?sku=ASTM%20C613/C613M-97(2008).
Fibers, Carbon Tow and Yarn, For Structural Composites SAE AMS 3892B Society of Automotive Engineers (SAE)	"This specification and its supplementary detail specifications cover carbon fibers in the form of continuous multifilament tow and yarn. This product has been used typically as reinforcement in composites for structural applications, but usage is not limited to such applications."[19]	Standard was reaffirmed in 1997 and 2005 by SAE.[20]
Cloth, Carbon Fiber, Resin Impregnated SAE AMS 3897 Society of Automotive Engineers (SAE)	"This specification and its supplementary detail specifications cover continuous multifilament carbon tow woven into fabric and impregnated with uncured resin. Primarily for fabricating composite parts where the characteristics of woven fabric are desired. The requirements specified herein and in the applicable detail specifications define each cloth by fiber, resin, style, and type of weave."[21]	Full standard can be ordered from SAE by calling 724-776-4841.[22]

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 Price of Carbon Fibers	The price of carbon fiber has fluctuated between $8[23] and $20/pound[24] over the

[18] "Search Results." NSSN web site. http://www.nssn.org/search/DetailResults.aspx?docid=591444&selnode= (accessed April 7, 2009).
[19] "Search Results." NSSN web site. http://www.nssn.org/search/DetailResults.aspx?docid=340908&selnode= (accessed April 7, 2009).
[20] Ibid.
[21] "Search Results." NSSN web site. http://www.nssn.org/search/DetailResults.aspx?docid=340927&selnode= (accessed April 7, 2009).
[22] Ibid.
[23] "Carbon Fiber Composites for Cars." *Oak Ridge National Laboratory Review*. vol. 3, no.3 (2000). Oak Ridge National Laboratory web site, http://www.ornl.gov/info/ornlreview/v33_3_00/carbon.htm (accessed April 7, 2009).
[24] "Aircraft orders put carbon fiber prices in steep climb." June 4, 2007. *USA Today*. Zoltek web site. http://www.zoltek.com/aboutus/news/60 (accessed April 7, 2009).

	last several years, and while that is cheap enough to make carbon fiber composites attractive to certain industries, it is still twenty times as expensive as steel and far too expensive for potentially lucrative markets such as the automotive industry.[25] In order to become viable for the automotive market (i.e. in order to incorporate carbon fiber composites into cars and trucks on a large scale), the price of carbon fibers must fall to $3-$5/pound.[26]
High Capital Costs	"High capital costs and very long-term payback have traditionally been barriers to entry for new fiber players… The seven major manufacturers known investment in 2007 totals more than $1.4 billion."[27] Furthermore, it can take "three years to build a carbon fiber advanced composites plant from design to commission."[28] Such costs generally make it difficult for new players to enter the market.
High Concentration of Competitors and Customers, Especially in Aircraft and Aerospace	As has been already mentioned, there are only seven real players in the carbon fiber composites market, and they have built their businesses by supplying materials for aircraft and aerospace, the largest market segment. This makes it difficult for new market entrants to gain market share. Furthermore, contracts in the aircraft and aerospace industry are generally very large and long-term (for example, Hexcel was recently awarded a $4 billion contract through 2025 to supply carbon fiber composites for the Airbus A350), and there are only three dominant customers: the Department of Defense, Airbus and Boeing.[29] These market dynamics present real barriers to potential new entrants looking to compete.

While the concentration of competitors and customers is certainly a problem for potential, it may become less so in the future. If carbon fiber composites become cheaper and more applications are found, it is likely that new companies will be able to get started with less capital and be able to find customers in industries outside of defense and aerospace.

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***

[25] "Advances in Carbon Fibers for the Composites Industry (Technical Insights)." December 31, 2008. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed April 7, 2009).
[26] "Carbon Fiber Composites for Cars." *Oak Ridge National Laboratory Review*. vol. 3, no.3 (2000). Oak Ridge National Laboratory web site, http://www.ornl.gov/info/ornlreview/v33_3_00/carbon.htm (accessed April 7, 2009).
[27] "Market Trends: This industry is ready to explode." March 27, 2008. *High Performance Composites.* Zoltek web site. http://www.zoltek.com/industrynews/91/ (accessed April 7, 2009).
[28] "Good growth projected for aerospace composites." December 12, 2008. ICIS web site. http://www.icis.com/Articles/2008/12/15/9178930/good-growth-projected-for-aerospace-composites.html (accessed April 7, 2009).
[29] Ibid.

Production of Next Generation Transport Aircraft	The Airbus A380 and Boeing 787 Dreamliner, the new flagship planes of the world's dominant aircraft manufactures, are making an "increased use of composites," and carbon fiber composites are also being used more in a number of other aircraft. This means that "over the next two decades, transport aircraft production will drive overall market growth."[30] Toray has already expanded its Washington State production facility specifically to accommodate the demand resulting from its contract with Boeing. [31]
Demand for More Fuel Efficient Automobiles	"CFCs [carbon fiber composites] are capable of reducing an automobile's weight by almost 60% (as compared to steel), and thereby a fuel consumption of 30%."[32] As a result, as global demand for cars and trucks that use less gas increases, it is very possible that increased use of carbon fiber composites will result.
Market Growth in Asia	Many developing countries in Asia, including China, India, Bangladesh and Vietnam, have begun using carbon fiber composites, and Asia is also expected to be a hotspot for new airplane purchases from Airbus and Boeing.[33] Thus, Asia appears poised to be a significant market driver for carbon fiber composites.

The development of "buckypaper," a variant of carbon fiber composites that uses carbon nanotubes, could also become a significant market driver, as buckypaper has the potential to be ten times lighter and 500 times stronger than steel. However, buckypaper is still experimental, and there is no existing market for it.[34]

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

Name	*Description*
Toray Carbon Fiber Overview	The Toray web site has an interesting overview of carbon fiber and their applications. See it at http://www.toray.com/ir/individual/ind_012.html.[35]
Graph on Carbon Fiber Price and Use	Market research firm Lucintel has an interesting graph depicting the history of carbon fibers in the introduction to one of its reports. See it at http://www.lucintel.com/marketcarbon.asp.[36]

[30] "Aerospace composites market will quadruple by 2026." Januеary 1, 2007. *High Performance Composites*. Zoltek web site. http://www.zoltek.com/industrynews/4 (accessed April 7, 2009).
[31] "Boeing, Toray in talks to expand 787 carbon fiber agreement." January 1, 2008. *High Performance Composites.* CompositesWorld web site. http://www.compositesworld.com/news/boeing-toray-in-talks-to-expand-787-carbon-fiber-agreement.aspx (accessed April 7, 2009).
[32] "Advances in Carbon Fibers for the Composites Industry (Technical Insights)." December 31, 2008. Frost & Sullivan web site (subscription required). http://www.frost.com (accessed April 7, 2009).
[33] "Market Trends: This industry is ready to explode." March 27, 2008. *High Performance Composites.* Zoltek web site. http://www.zoltek.com/industrynews/91/ (accessed April 7, 2009).
[34] "Superstrong 'Buckypaper' Could be Dream Material." October 17, 2008. Discovery web site. http://dsc.discovery.com/news/2008/10/17/buckypaper-material.html (accessed April 7, 2009).
[35] "Carbon fiber market." Toray web site. http://www.toray.com/ir/individual/ind_012.html (accessed April 7, 2009).
[36] "Growth Opportunities in Carbon Fiber Market 2006-2011." November, 2006. Lucintel web site. http://www.lucintel.com/marketcarbon.asp (accessed April 7, 2009).