PikeResearch
Cleantech Market Intelligence

Research Report

EXECUTIVE SUMMARY:
Green Chemistry
Bio-based Chemicals, Renewable Feedstocks, Green Polymers, Less-toxic Alternative Chemical Formulations, and the Foundations of a Sustainable Chemical Industry

NOTE: This document is a free excerpt of a larger report. If you are interested in purchasing the full report, please contact Pike Research at sales@pikeresearch.com.

Published 2Q 2011

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Section 1

EXECUTIVE SUMMARY

1.1 Introduction

> *Green chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products.*
>
> – *Green Chemistry: Theory and Practice*[1]

Green chemistry encompasses a broad area of endeavor. It is not covered by a narrow definition and does not offer a "silver bullet" type solution because it is essentially a reaction to a complex variety of issues. Ranging from dangerous and wasteful production processes and a heavy reliance on increasingly expensive petroleum to the persistence in the environment of toxic substances with far-reaching (and increasingly well-understood) effects on human and animal health, these problems call for equally diverse solutions. Green chemistry is the expansive discipline that is evolving in response to this wide array of challenges.

The field of green chemistry emerged from the interaction of industry, government, and academia in the early 1990s. One key milestone was the passage in the United States of the Pollution Prevention Act of 1990, which sought to broaden the focus of regulation from cleaning up pollution that had already been emitted to changing industrial practices and processes to prevent or minimize the creation of pollution. In 1991, the U.S. Environmental Protection Agency (EPA) declared the elimination of pollution at its source as one of its objectives.

Perhaps the most challenging aspect of assessing the green chemistry industry is that green chemistry is less a description of a discrete industrial segment than it is a way of carrying out industrial activity, from design to manufacturing. As an end-to-end process, green chemistry includes the following elements:

- Modifications to chemistry and chemical engineering educational curricula
- Choices of chemical feedstocks and process design
- Awareness and use of the information and tools that are available
- Integration and firm anchoring in existing and proposed regulatory regimes

For the purposes of this report, Pike Research has narrowed the major themes of green chemistry to the following:

- Waste minimization in the chemical production process
- Replacement of existing products with less toxic alternatives
- A shift to renewable (non-petroleum) feedstocks

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[1] *Green Chemistry: Theory and Practice*, P.T. Anastas and J.C. Warner, Oxford University Press, New York, 1998.

These themes are reflected in three major market segments:

- A segment centered on process improvements in conventional chemical synthesis
- A segment featuring chemical formulators
- A particularly dynamic (but still nascent) segment focused on chemical manufacturing

1.1.1 The Value of Green Chemistry

The worldwide chemical industry is valued at approximately $3 trillion. Thus, even small improvements in efficiency can have a very large absolute impact. The greatest opportunity for near-term positive financial and environmental impact comes from waste minimizing improvements to existing, conventional chemical production processes. Pike Research estimates that it is possible to capture over $40 billion in process cost savings and avoided environmental and social liabilities – just by bringing laggard companies up to the baseline standard of the chemical industry as a whole.

One of the core tenets of green chemistry is the minimization of waste. In this sense, the opportunity for process improvements through the application of green chemistry is reminiscent of the lean production imperative to drive waste out of discrete manufacturing processes that has helped to transform the automobile (and other) industries. Certainly, green chemistry typically represents a significant source of cost savings. In contrast to the consumer market, where we are trained to pay a premium for green products, greener is cheaper in industry.

On the consumer (e.g., household cleaning chemicals) side, a number of large public companies have recently introduced overtly green brands into a market formerly dominated by small, closely held companies. For example, The Clorox Company's Green Works brand, introduced in December 2007, has grown rapidly and is estimated to now generate approximately $200 million per year in revenue for the company. Moreover, this growth appears to be the result of taking share from conventional chemical preparations, rather than existing boutique green product lines such as Seventh Generation.

1.1.2 Evolution of the Green Chemical Market

There has been a great deal of activity in the development of renewable feedstocks for a wide range of chemical processes, both replacements for commonly used "merchant molecules" and new compounds with interesting and commercially valuable properties. Claimed advantages for renewable feedstocks over conventional derivations from petroleum include lower greenhouse gas emissions, reduced toxicity, and lower costs. Most renewable feedstocks are produced through biological processes (primarily fermentation of plant sugars into the desired compounds or their intermediates) or thermal and chemical processes applied to cellulosic materials such as wood, agricultural waste, or non-food plants like switchgrass.

The evolution of the green chemical market is being driven by a combination of technical, regulatory, consumer preference, and economic factors. Improved chemical screening technology and advances in the science of mechanistic toxicology have improved our understanding of the effects of manmade chemicals on humans, animals, and the environment. The rapid advances in biotechnology achieved over the last several decades have created powerful, new toolkits for the manipulation of organisms (bacteria, yeasts, and algae) such that they produce industrially useful compounds with great efficiency and minimal waste.

While regulatory regimes at the federal level in the United States do not appear likely to become increasingly stringent soon, several states have imposed strict new regulations on hazardous chemicals, as has the European Union. Consumers are becoming increasingly aware of the potential effects of the chemicals used to produce common materials (recall the BPA controversy of recent years) and are demanding green alternatives. Companies are being forced to meet not only end-user demand, but also the demands of powerful retailers, which can dictate product specifications to their suppliers by virtue of their vast sales. Finally, the rising (and highly volatile) price of petroleum – crucial both as a source of process energy and as a feedstock for many chemical processes – is driving interest (and investment) in finding alternative, renewable feedstocks for key chemical products and intermediates.

1.1.3 Competitive Landscape

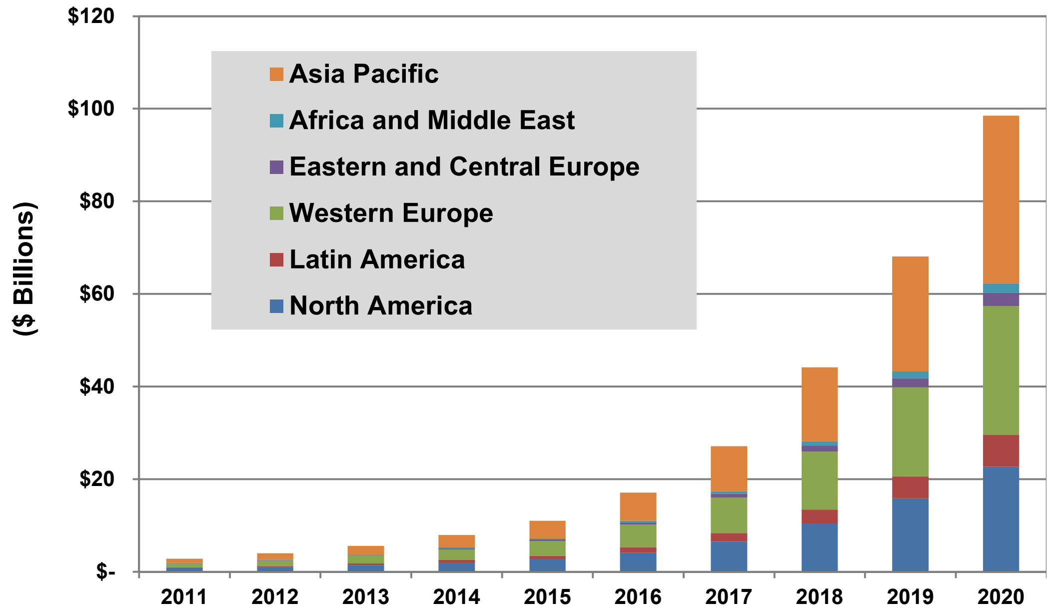
Green chemical industry players run the gamut from vast multinationals that have been in operation for over a century to tiny startups. Much of the bio-based segment, which perhaps has the greatest long-term potential to revolutionize the chemical industry, is nascent. Technologies are just a few steps beyond the laboratory and production facilities are a few years from reaching their modest full production levels. The bio-based segment of the market excluding biofuels is liable to grow slowly over the next few years. Issues of scale are never simple. Also, in the chemicals and materials business, the adoption cycle often requires long lags for extensive customer testing before new products are introduced.

As is the case with many nascent markets, the green chemical market will grow through several clearly defined stages: a profusion of small companies based on exciting technologies will gradually coalesce (through failures, acquisitions, and mergers) into a functioning ecosystem. Many of these small companies will choose to follow a model that is common in the biotechnology industry, whereby small, innovative companies partner with industry incumbents to obtain capital and distribution channels. Established companies have the luxury of choice. They can either establish their own green operations, or watch the startups as they develop and acquire those that are the best fit for their own businesses once some of the technology and market risk has been wrung out.

1.1.4 Market Forecast

Pike Research estimates the current size of the green chemical industry at approximately $2.8 billion worldwide. It will likely grow to about $11.0 billion in 2015 and nearly $100 billion in 2020. These estimates could be dramatically affected to the downside by another significant reversal in the world economy, or to the upside by prolonged, dramatic increases in the price of petroleum. Chart 1.1 graphically illustrates the size and growth of this market by geographic region.

Chart 1.1 Green Chemical Market by Region, World Markets: 2011-2020



(Source: Pike Research)

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SCOPE OF STUDY

Pike Research has prepared this report to provide participants in the chemical and materials industries, in addition to stakeholders, with a study of the commercial impact of green chemistry principles. The report examines the effects of these principles on process optimization in established companies, as well as on the creation and adoption of new materials and new means of production. Its major objective is to identify and evaluate the significant opportunities and challenges facing these industries and to forecast the nature and magnitude of likely future growth. Pike Research also analyzes the major market drivers and barriers, along with key industry players within the competitive landscape.

The report's purpose is not to provide an exhaustive technical assessment of the technologies and markets covered, but rather, a strategic examination from an overall business perspective. Pike Research strives to identify and examine new market segments to aid readers in the development of their business models. All major global regions are included and the forecast period extends through 2020. Note that many of the technologies covered are still at a very early stage of development and are likely to show their greatest impact in the later years of the forecast.

SOURCES AND METHODOLOGY

Pike Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Pike Research's analysis is primary research gained from phone and in-person interviews with industry leaders, including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Pike Research's analysts and the firm's staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Pike Research's reports. Great care is taken in making sure that all analysis is well supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

Pike Research is an independent market research firm whose goal is to present an objective, unbiased view of market opportunities within its coverage areas. The firm is not beholden to any special interests and is thus able to offer clear, actionable advice to help clients succeed in the industry, unfettered by technology hype, political agendas, or emotional factors that are inherent in cleantech markets.

NOTES

CAGR refers to compound average annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/steps)}$ – 1.

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2011 U.S. dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

Published 2Q 2011

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