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Shifting To Green Chemistry: The Need for Innovations in Sustainability Marketing

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ABSTRACT
This article analyzes how chemical manufacturers can develop stronger business advantages for green chemistry by rethinking sustainability marketing approaches. Green chemistry is a package of technologies, design principles and tools to reduce the toxicity, resource and energy use, and pollution of chemicals. Using research into US chemical industry efforts, this article introduces green chemistry, and discusses existing weak market signals, ways to market green chemistry and key obstacles to sustainability marketing. It concludes that companies need to generate more information internally, build new relations across supply chains and provide more information externally. Copyright © 2006 John Wiley & Sons, Ltd and ERP Environment.

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GREEN CHEMISTRY PROMISES TO TRANSFORM INDUSTRY IN THE NEXT TWO DECADES. GREEN chemistry can be defined as the design of chemicals, processes and reactions to reduce environmental and health hazards at source and to enhance sustainability, particularly through the molecular design of chemicals (Anastas and Warner, 1998). Potential outcomes include reducing toxicity, pollution and waste, improving energy efficiency and resource use, using renewable feedstock instead of petrochemical inputs and developing products that are readily metabolized in biological and ecological systems. The technical and scientific capability to introduce green chemistry on a large scale already exists.

Nonetheless, green chemistry faces many difficulties in achieving inroads into the chemical industry and the many downstream industries that depend on chemicals. While many research and development activities are underway in industry and university laboratories, companies have implemented relatively few green chemistry technologies and products (Woodhouse, 2003). A combination of reasons explains this situation. They include a lack of regulatory standards demanding prevention of waste and pollution, weak customer demand, the failure to internalize the environmental and health impacts of chemicals,

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flawed organizational practices for designing chemicals and inefficient dispersion of innovations across industry (Nissen, 2003; Wilson, 2006).

However, one vital part of the problem is that companies have not yet developed business strategies to make green chemistry actions commercially valuable. The Porter hypothesis suggests that companies can win business advantage from seeking resource efficiency (Porter and van der Linde, 1995). Companies could market green chemistry as a means of achieving this efficiency. Sustainability marketing has developed in the past decade as a way to expand markets for environmentally attractive products (Wasik, 1996; Charter and Polonsky, 1999). Sustainability marketing is 'building and maintaining sustainable relationships with customers, the social environment *and* the natural environment' (Belz, 2005). Creating environmental value helps provide customer value. Based on ongoing research into how US chemical manufacturers are adopting green chemistry,[1] this article argues that a key business strategy is to rethink the marketing of green chemistry in terms of laying down the cognitive, social, technical and institutional infrastructure needed to make the Porter hypothesis work.

First, the article defines green chemistry and briefly reviews developments in green chemistry and discusses their potential impact on industry. It summarizes the business case for green chemistry and shows that this case is currently far from being established. Using the automotive paint supply chain as an example, the article analyses two types of sustainability marketing that manufacturers can undertake and the key obstacles to sustainability marketing. Finally, it presents three steps that companies can undertake to overcome the obstacles and strengthen the business case for green chemicals under conditions where regulation does not play a central role.

The Scope of Green Chemistry

Green chemistry encompasses a range of scientific and technical developments aimed at ameliorating the chemical industry's environmental and health impacts. The US Environment Protection Agency defines green chemistry as an effort 'to promote innovative chemical technologies that reduce or eliminate the use of generation of hazardous substances in the design, manufacture, and use of chemical products' (EPA, 2005). Many proponents have focused on toxicity reduction, namely making molecules less poisonous and using less toxic chemicals in manufacturing processes.

Increasingly, chemists and corporations now view green chemistry as including broader concerns such as energy conservation and higher resource efficiency. Chemists developed the Twelve Principles of Green Chemistry to guide their work (Anastas and Warner, 1998). For instance, chemists should 'design chemical syntheses to prevent waste, leaving no waste to treat or clean up' and 'minimize waste by using catalytic reactions'. Most attention has centered on designing chemicals, but researchers are gradually adopting a life cycle approach: targeting raw materials, pre-manufacturing and design, manufacturing, processing and formulation, product delivery and retail, product use and end of life (Clark, 2005). Different green chemistry techniques can be used in different life cycle phases.

Green chemistry is still in the early stages of industry take-up. Most green chemistry work remains in the research phase and is principally done in academic laboratories (Ritter, 2002). However, scientific and business leaders argue that green chemistry has the potential to transform many industries

[1] The companies are Dow, Dupont, Invista (formerly Dupont Textiles and Interiors), Kodak, BASF America, Air Products, and Rohm and Haas. Ten interviews with environmental and product stewardship managers took place during May–October 2003, January–March 2004 and July 2005. The interviews were transcribed. They asked about company green chemistry policies and practices, as well as challenges in reaching and marketing to customers. All unattributed quotes in this article are from these interviews. The interviews were triangulated against corporate environmental reports, product offerings and chemical industry news such as *Chemical and Engineering News*.

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(Fitzpatrick, 2004; Poliakoff *et al.*, 2002). Chemicals are used in numerous process industries such as steel and petroleum. They are used in – or in making – products ranging from electronics, furniture, paper and clothes to automobiles (Spitz, 2003). Plastics are used in countless products. Chemicals are sold as cosmetics, cleaning agents, paints and other consumer products.

The extent to which green chemistry can change industrial production is uncertain but potentially vast. Many older chemical processes have not been updated with environmental impacts in mind (Jenck *et al.*, 2004). Thousands of chemicals used in everyday products have not been evaluated for their health risks, if any (Wilson, 2006). The pharmaceutical industry is notoriously wasteful because of its use of numerous manufacturing steps and batch operations. Generally, companies did not consider energy consumption when developing new processes and products. The ways in which green chemistry can propel changes can be summed up in the following major categories.

- *Raw materials*. Companies can change the materials that they use to manufacture chemicals. Instead of relying on petrochemicals, they can use renewable biomass feedstocks, develop new chemical building blocks based on biomass or copy chemicals that already exist naturally (Matlack, 2001). Industry can also harness biological processes such as fermentation to make chemicals, and ensure that safe and responsible extraction methods are used, as in mining raw materials.
- *Production*. Manufacturers can achieve significant change in their production efficiency, costs and impacts by using alternative reaction pathways, solvents, catalysts, reactor technology and solventless systems (Clark, 2005). In particular, they can gain dramatic decreases in energy use and waste output. Such changes are the most established green chemistry practices because of prior industry interest in pollution prevention.
- *Products*. Targeting products can help create green chemistry changes that propagate across the production system. Manufacturers can reformulate chemicals, or redesign consumer products or introduce new ones so that less toxic chemicals are incorporated into products (Matlack, 2001). They can also plan products to use different intermediates, additives, solvents and chemicals in the manufacturing process. Products can be designed to be biodegraded, use less packaging and be recycled and reused at life's end.

Making the Business Case for Green Chemistry

In theory, as many analysts have pointed out, manufacturers can gain significant business benefits from green chemistry. According to the Porter hypothesis, corporations can become more competitive by developing innovative resource productivity solutions. 'Such innovations allow companies to use a range of inputs more productively – from raw materials to energy to labor – thus offsetting the costs of improving environmental impact' (Porter and van der Linde, 1995). Thus, the British Royal Society of Chemistry states 'By improving resource efficiency, green chemistry should provide financial benefits from lower material usage, energy and capital expenditure costs in addition to the environmental benefits' (RSC, 2002).

Benefits can be defined for each life cycle stage and for specific participants in the supply chain (including raw material suppliers, chemical manufacturers, downstream manufacturers and users, retailers, consumers, citizens and governments; Clark, 2005). Benefits can also be grouped according to different vectors of pressures and opportunities, including production, markets for products, regulation and investment. Many pressures and hence incentives for green chemicals already exist.

In production terms, companies can acquire the ability to improve production yield and achieve cost savings by using fewer raw materials, making more product and generating less waste and pollution.

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By designing reactants and products to be easily separated, accelerating reactions and reducing temperature, pressure and solvent conditions, companies can consume less energy. In an era where oil and natural gas prices are increasing rapidly, corporations perceive that energy and feedstock are a greater cost factor (Wilson, 2006).

In regulatory terms, companies find that European Union product regulations are emerging as important drivers of change (Veleva, 2005). EU cosmetics, car and electronics regulation are forcing the elimination of materials such as lead, polybrominated flame retardants and phthalates. In addition, VOC emission concerns have forced downstream manufacturers and users to demand lower VOC-containing solvents and paints to comply with US and EU laws. Manufacturers may achieve faster movement of new products to the market and cost savings from more efficient product design. Registering new chemicals in the US, for example, can be costly (Votta and White, 1999). Air Products says that it can spend $150 000 on a design process, only to find EPA rejecting its registration because of risk concerns, hence losing its investment.

In market terms, consumers may increase their demand for green chemistry products, or avoid products that are seen as risky or exposing them to health problems. Environmental NGOs have become more active in targeting chemicals in products. Their efforts are only nascent but will expand in the next decade. In Britain, Friends of the Earth, Greenpeace and WWF have led campaigns to pressure retailers and downstream manufacturers to screen their products for a number of toxic chemicals and to request that upstream manufacturers remove the chemicals (ENDS, 2003). The European Social Investment Forum states 'Over the next 5–10 years, "green" chemical innovation could be a significant source of competitive advantage for companies manufacturing chemicals used in consumer products, particularly in markets where brand or product differentiation based on "green" credentials is a key component of value for the final customer' (ESIF, 2005).

In investment terms, the attractiveness of corporations to investors may come to depend on whether a company has implemented green chemistry policies and practices. In the US, shareholders have tried to pass resolutions demanding that Baxter International, Avon and JC Penney review their products for hazardous substances (Liroff, 2005). Several sustainable investment advisors, such as Citizen Funds Inc., are evaluating whether manufacturers are adequately addressing chemical regulatory demands.[2]

However, the benefits of green chemistry are not self-evident. As in other sectors, making the business case for sustainability is more complicated than expected (Wagner and Schaltegger, 2003). For green chemistry, the Porter hypothesis is not yet proven. Despite apparently strong incentives, companies do not find green chemistry attractive enough to begin making investments, scrutinizing processes and providing products.

In industry's eyes, customers – whether consumers, retailers or downstream manufacturers – are not yet demanding or buying most types of green chemical product on a large scale. US chemical companies complain that there is no market for specifically 'green' products. Even when Rohm and Haas, a leading manufacturer, seeks to sell green chemistry products, it has frequently not succeeded commercially. A product stewardship manager states 'We were doing some things that were greener products proactively and have not seen a lot of financial success. In fact in our history, it's easy to quote the cases when we took the formaldehyde out and nobody bought it or we made a biodegradable polymer for laundry detergents and the customer wouldn't buy it'. The company's anti-fouling TBT marine paint won the 1997 Presidential Green Chemistry Award but has 'not been a great commercial success'.

Even though green chemistry promises much, it still has far to go before there is widespread industry take-up. In part, this is because the Porter hypothesis remains incompletely stated. Companies do not yet perceive viable markets or major benefits, even from resource efficiency. According to a con-

[2] See http://www.citizenfunds.com

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sultant who works with companies to reformulate cleaning chemicals, Lauren Heine, a strong disconnect currently exists between customers and manufacturers (Heine, 2005), but this is because of a lack of information about chemicals, weak infrastructure for evaluating the greenness of products and poor understanding of how supply chains can provide competitive advantages. The Porter hypothesis is likely to work only if companies invest in these elements; this can occur through considering how to market sustainability.

Marketing Sustainability

Sustainability marketing activities are not novel developments. A growing literature provides many insights into business efforts to prosper from sustainability marketing. The evidence that this marketing can succeed is mixed. In some situations, consumers and businesses may willingly pay a price premium for 'green' products, or may avoid products and manufacturers seen as unethical or environmentally damaging (see, e.g., Meyer, 2001). In other cases, customers may be price sensitive and may prefer green products only when key factors (cost, performance and accessibility) are equal with those of other products (see, e.g., Peattie, 2001). Particular marketing outcomes depend on the industry sector, specific product category, supply chain characteristics and participants being targeted.

However, much of the literature focuses on marketing to consumers as key audiences, rather than on other supply chain participants. It centers on branded products and producers that are highly visible to consumers. It also assumes that product environmental content can be readily delineated and communicated. In contrast, most chemical manufacturers are invisible to consumers since they supply downstream companies that are identified as the source in the market. As in the automotive supply chain, most chemicals are used as ingredients in products or in processes and are hidden from public sight. They are often not branded or associated with companies, or are branded only for industry users such as paint makers. Consumers may only look at the overall product, not at what it contains. Even so, consumers associate paints with the car brand. Consumers may therefore not be the major actors demanding greener chemicals. Instead, retailers, institutional buyers and downstream manufacturers may be far more important participants in shaping chemical use.

Hence it is important to distinguish between marketing to other businesses and marketing to consumers or users (Charter and Polonsky, 1999). Reaching the latter may entail different approaches and problems compared to the former. Businesses are often much more sophisticated in dealing with product issues than consumers because of their greater resources and knowledge. In practice, the distinction can be blurred for chemicals because businesses are also consumers or users that do not necessarily know much about what they are using. This is especially the case for smaller businesses or for large corporations using numerous suppliers and making no effort to inventory their chemicals. Thus I discuss business-to-business and consumer marketing together, while stressing that they can have different considerations.

Marketing sustainability can be a key strategy – if the Porter hypothesis is completed – in boosting the transition to green chemistry by helping create demand for green chemistry among workers, managers, downstream manufacturers, retailers, users, consumers, investors and citizens. This section examines two key marketing areas that a chemical manufacturer can pursue for green chemistry, namely sustainability properties and supply chain advantages. (Other areas include marketing to investors and phasing out chemicals to reshape markets.)

I use the automotive paint supply chain as an example. The chain is one of the relatively few to have faced environmental pressures on chemical use, yet still struggles to make a transition to green chemistry. Automotive manufacturing has hundreds of supply chains feeding into final consumer products.

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Inherent Toxicity	
	Less toxic, persistent, bioaccumulative
	Compatibility with biological and ecological metabolism
	Biodegradability
Impact on Environment	
	Reduced pollution and waste
	Reduced mining or extraction impacts
	Reduced greenhouse gas emissions
	Reduced biodiversity impacts
Resource Efficiency	
	Less materials use
	Energy efficiency
Impact on Human Societies	
	Fewer worker and resident exposures
Bioinspiration	
	Biological production processes
	Biomass feedstocks

Table 1. Examples of sustainability properties

Automotive paints comprise a specialized supply chain but global sales were $6.6 billion in 2001 with North America accounting for $2.5 billion (Tullo, 2002). Chemical companies such as Rohm and Haas, BASF, PPG and DuPont make coatings themselves, or sell components to paint manufacturers. They provide the coatings to car component makers that supply parts to car makers, or to paint contractors working within car assembly plants. Occasionally, chemical companies do the painting themselves. Marketing is largely business to business, but involves substantial selling to customers.

Marketing Sustainability Properties to Users

Consumers, institutional buyers, downstream manufacturers and retailers may preferentially buy green chemicals, or use them in making their products, but to do so they need to know which products can be reckoned as 'sustainable'. Information costs are central. The information may not exist or be in an accessible format. Searching for sustainability data can be a time-consuming process, particularly if data are spread across many sources and scientific disciplines ranging from toxicology to public health. Customers may face constraints on resources, time and attention.

Moreover, customers may have no experience with how products perform on environmental grounds or what the outcomes are. They may not even have thought about inherent toxicity or resource use. As Porter and van der Linde (1995) state, 'Customers, too, are unaware that resource inefficiency means that they must pay for the cost of pollution'. Sustainability may be difficult to discern in a product. Because consumers and businesses do not know what they can demand, market pressures for green chemistry are heavily attenuated.

Companies can help overcome information deficits, simplify the search for data, and build customer experience with products through defining sustainability properties that products have. Such properties include those in Table 1. Highlighting these properties reflects the history of making environmentally sound product claims, such as 'rainforest-free paper' or 'shade-grown coffee'. These claims seek to establish that the product is inherently less polluting or resource depleting, or has been produced without damaging the environment (de Boer, 2003). Determining what sustainability properties mean can be subjective. People can diverge in their views and values of what to expect from green chemistry.

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When defining sustainability properties, it is important to distinguish between three categories: production conditions (how the product was made); product characteristics and performance (what the product contains and what it does) and exposures and risks (e.g. products as pathways of exposing people to chemical risks). Each category calls for different things to be made more transparent and, perhaps, to different customers. Different customer groups within the automotive supply chain may be more interested in different categories than others because of their concerns. For production, it is the history of how coatings are made. For products, it is their features; for exposures, it is what exposures are associated with coatings when used.

It is exposure that most distinguishes green chemistry from other sustainable industry areas. Green chemistry is associated with changes in the risks to which different groups of humans are exposed (Woodhouse, 2003). It aims to reduce the toxic risks that chemicals pose, whether in manufacturing, consumer products or waste, and the exposures of workers, consumers, residents, the public and others to these risks. Consumers may be attentive to claims that they can avoid or mitigate their exposures to toxins by choosing paints designed on green chemistry principles. Downstream manufacturers and workers may also worry about their own exposure risks because of using paints. Automotive painters face significant health problems from breathing VOCs and heavy metals (Wilson, 2006). Corporations face growing litigation for failure to warn and provide protection to workers and residents. Thus, chemical companies can specify how they are reducing exposures for various groups.

Marketing Across Supply Chains

Manufacturers can also define the benefits of green chemistry for different participants across supply chains. A Dupont environmental manager says '[Green chemistry is] much more likely to happen presently if there's an opportunity to solve your customer's environmental problem' in the supply chain.

One opportunity is to market the idea of anticipating and relieving customer needs to comply with regulation. Automotive makers must comply with increasingly stringent regulatory standards, endure registration or licensing scrutiny, test chemicals and products and introduce handling and storage conditions for hazardous materials (Votta and White, 1999; Fitzpatrick, 2004). Companies such as Rohm and Haas and Dow already face some pressures from downstream manufacturers close to consumers, such as car makers, to eliminate heavy metals, volatile organic compounds and persistent, bioaccumulative and toxic substances from automotive paints. Thus, Air Products, PPG, and Rohm and Haas have reformulated coatings to use water solvents or eliminate solvents completely.

Chemical companies can observe regulatory developments in key markets such as the European Union and redesign chemicals or products that automobile or paint manufacturers need to enter, or retain access to, the markets. Such efforts can benefit these downstream manufacturers by being better placed to win market share as regulation becomes increasingly global. They can also decrease the risks that products may be unexpectedly restricted or removed from the market. For example, in 2002, Sony experienced a costly debacle when regulators forced the recall of Playstation game consoles in the Netherlands because the electronics contained excessive cadmium (Liroff, 2005). A far-sighted supplier could have screened components for prohibited chemicals before supplying downstream manufacturers.

Another opportunity is to market the idea that downstream manufacturers or institutional customers can benefit economically from resource efficiency, better environmental performance or technology changes. This can be important in automotive paints, where car makers continually seek cost reductions. By eliminating toxic constituents, chemical manufacturers can help increase production efficiency and cut energy use for their customers. Enhancing the physical and reaction properties of chemicals may create considerable value for customers. Changing paint spraying technology may eliminate energy and resource-intensive production steps. Car makers may use less paint in powder coatings that have

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higher solids content due to functional oligomers, a recent industry innovation. They may also save on energy costs by cutting out the need to dry paints in ovens. PPG has developed the DuraPrime technology that applies the final coating straight to an electrocoat layer, thus avoiding two coatings (Tullo, 2002). In some cases, the reformulated paint may provide superior performance.

Corporations can also market green chemistry as leading to better automotive supply chain performance. Chemical service contracts promise significant cost savings to automobile manufacturers in return for letting chemical makers such as BASF and PPG take more oversight over chemical use and having guaranteed access to markets (White *et al.*, 2001). These contracts reward companies for reducing chemical use and maximizing efficiency in supply chains.

Obstacles to Marketing Sustainability

In trying to market sustainability in chains such as automotive paints, chemical companies face several major obstacles. The most basic obstacle is the relative absence of methods to 'see' and communicate green chemistry in paint manufacturing and paint products. This makes it much more difficult to identify and market sustainability properties. Corporations lack tools and systems for collecting information, discerning problems and costs and attributing these to manufacturing activities or products.

Green chemistry can yield environmental and health gains that are difficult to identify and quantify in business terms. It may also be challenging to link economic and competitive benefits to specific technical changes. Does using a solvent instead of another solvent lead to a better business outcome? Does changing molecular structure to make a chemical less toxic improve the bottom line? Many green chemistry actions can be inscrutable. The environmental impacts of changing a reaction step, adjusting a molecular structure by eliminating one chlorine atom, using a different catalyst or switching between solvents may not be easy to recognize. Some actions may not be visible in the final product but be hidden in the manufacturing, and in the infrastructure, intermediates, raw materials and supply systems on which manufacturing depends.

Much research currently focuses on developing sustainability metrics to help companies, chemists and regulators choose between technologies, evaluate the environmental performance of promising chemicals and processes and determine the extent to which chemistry is 'green' or 'sustainable' (Curzons *et al.*, 2001; Constable *et al.*, 2002). A few emerging metrics summarize the economic benefits of adopting green chemistry in terms that managers, investors and workers can understand. Most do not yet have significant business salience because they concentrate on scientific and toxicological aspects. They are not understood as means of internal and external marketing. Therefore, industry is less motivated to pay attention to green chemistry even though the environmental and health advantages may be obvious.

For business-to-business marketing, the nature of chemical supply chains is another obstacle. Companies face challenges in learning about, and interacting with, downstream customers. Rohm and Haas, for example, seldom sells chemicals direct to ultimate manufacturers. Instead, it provides chemicals to many downstream manufacturers that successively make what becomes a final product such as cars. A product manager says 'We have less ability to know what's happening at the consumer end and to influence it'. The manager adds 'Sometimes we can't talk to the downstream customer because in between us and them is a very sensitive direct customer who's afraid we may steal that business'. Chemical manufacturers can struggle to identify green chemistry marketing possibilities toward the end of supply chains, and to train customers to demand sustainability properties that their chemicals can provide.

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A challenge is to show customers why and how green chemistry can improve a product, particularly in other industry sectors. Companies, even if as vast as Dow and Dupont, may not have specific chemical sales significant enough for automobile customers such as General Motors to think it worthwhile to talk with them. Thousands of chemicals, including tens of paints, from many manufacturers, may be used in making cars. If manufacturers are geographically separated, supply chain distances can be great, exacerbating the breakdown of information flows. For example, a PPG vice-president for automotive coatings says that paint providers are not usually allowed inside assembly factories. Customers 'believe they are effective at their operations, they understand the products, and it is in their best interests to manage them directly' (Tullo, 2002).

Still another challenge in business-to-business marketing is to show that green chemistry does not threaten the stability or reliability of automotive supply chains. Rohm and Haas, PPG and DuPont have encountered significant resistance by automobile makers to the introduction of greener paints. These customers fear that their manufacturing will be undermined, or performance will deteriorate, if they switch to new paint technologies. PPG's PowerPrime system failed because it could only be used on new assembly lines, despite promising significant efficiency gains. 'Drop-in' chemicals are important because they can replace products without impeding existing production lines. If customers face cost penalties or disruptions to their products, they will not be interested in green chemistry. A Rohm and Haas product stewardship manager says 'Most times a customer would have to qualify, requalify that tweak or that new product . . . you are opening the door to your competitors to come in with their products'. Product changes always need research and may be expensive. Even proving that a green chemical is a drop-in product can be costly.

Different types of obstacle exist when looking at marketing to consumers, institutional buyers and other businesses. Another basic obstacle is that there is a pervasive lack of information about chemicals and product environmental content on the market. Customers cannot readily discriminate between automotive paint chemicals unless they perform extensive scientific, technical and business research to trace a chemical's production history, risks, exposures and impacts (which they may not have the capacity to). Not can customers identify what substances specific products contain. They cannot determine whether a Ford car coat has fewer toxics compared with a Toyota coat, so they cannot choose one or the other on this ground.

Downstream manufacturers may not be fully aware of what chemicals they receive from suppliers. A 3E consulting firm study of 300 companies in California discovered that they were unaware of the presence of about 55 carcinogenic chemicals and over 200 'extremely hazardous substances' in products (Wilson, 2006). Lauren Heine, at the GreenBlue thinktank, states that chemical companies typically provide poor toxicity and sustainability data to their customers (Heine, 2005). For instance, the material data sheets that manufacturers supply to automotive companies are seldom detailed enough to enable analysis of the chemicals, particularly on a cumulative scale.

Producers have little incentive to invest in green chemicals because customers have no means of identifying these, yet institutional buyers are increasingly interested in greening the chemicals that they use. For instance, Kaiser Permanente, California's largest private health care system, has struggled to collect information about the thousands of chemicals used in its health care products and workplaces (Wilson, 2006). In April 2004, the company's environmental stewardship council decided to avoid 'the use of carcinogens, mutagens and reproductive toxins and persistent, bioaccumulative and toxic chemicals'. Kaiser is one of a few US companies (none in the automobile industry) to introduce such a chemicals policy. The company recognizes a lack of reliable public data on toxicity and impacts on health and ecosystems. It therefore has pressured its suppliers to produce the data that manufacturers hold but seldom release to customers, let alone the public. These obstacles are not unique to the chemical industry, but they are particularly acute because of the widespread use of chemicals across many industries.

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A related obstacle is that customers may not know what specific sustainability properties for automotive paints mean; these properties are not self-evident. Most customers are likely to be unfamiliar with the technical phrase 'PBT' (or persistent, bioaccumulative and toxic). It assumes some basic knowledge about toxicology and environmental effects. Similarly, compatibility with ecological and biological metabolism is a technical concept that may not make much sense outside biologist communities at first. Customers may be confused as to the meaning of different properties, such as toxicity, heavy metals, persistent organic pollutants and bioaccumulation.

In turn, customers face heavy challenges in trying to understand the impacts of green chemistry technology changes. Can the consumer on the street evaluate how a functional oligomer makes a paint more sustainable? Can a downstream manufacturer determine whether adopting a new solvent means that the paint will not be contaminated? Conversely, industry experience suggests that energy efficiency is easily grasped because energy savings can be turned into cost savings on the bill. Dupont provides dry powder systems that can reduce energy use. A Dupont environmental manager says 'We don't have any trouble getting the customer to see that benefit but they don't see it in terms of reduction in the demand for energy. They see that in terms of reduced energy bills'.

Customers are frequently overwhelmed with information. They may not have the time or cognitive capacity to search for complex information. Some may still have the desire to decide whether they will buy green chemistry, but have no standardized or agreed-on signposts for identifying what is sustainable, to help overcome the information overload or complexity. It may not be clear whether sustainability claims can be authenticated, or whether they are indeed relevant to chemicals. Many sustainability properties cannot be compared against each other because they reflect different scales of societal and environmental impacts. It may also be uncertain what part of the product or production cycle is sustainable. Thus, manufacturers and customers alike can struggle to see whether they need to act, hold chemical companies accountable for design choices or trace 'green' products upstream to corporate actions.

Innovations in Marketing Sustainability

Chemical manufacturers may overcome the obstacles by rethinking their marketing approaches in terms of laying down the cognitive, social, technical and institutional infrastructure needed to complete the Porter hypothesis where regulation has not been imposed. Rather than looking at what to market, industry can consider what tangible changes would be needed for customers to recognize and accept green chemistry. These include the following.

Generate More Information About Chemicals

Companies often operate under conditions of poor knowledge about their chemicals. They may not know what chemicals they use, how much, where from and what design alternatives exist. Before businesses can work with supply chains, provide information externally or give credence to sustainability properties, they need to generate information about their chemicals.

Manufacturers can apply information tools to production lines and products to determine their environmental and health effects. Since 1995, BASF has used eco-efficiency tools to survey and quantify the life-cycle impacts of its chemicals and processes (ENDS, 2004). Some other chemical makers, such as Dow, use life cycle assessment to choose between different processes for making a given chemical. Databases and design tools may also aid employees (and outside stakeholders). For instance, the GreenBlue NGO recently released CleanGredients™, a database that supports the design of green cleaning

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chemicals.[3] The database 'is designed to serve formulator needs for more environmentally friendly ingredients while showcasing and helping market such ingredients for suppliers'. It has toxicity details for ingredients used in cleaners that designers, janitor unions, NGOs and regulators can match against. Companies can help develop similar databases for automotive paints and other product categories.

Corporations can change their operating practices and introduce new institutions. They can instigate screening programs that review all products for the presence of hazardous chemicals. Retailers such as Marks & Spencer and Boots in the UK have already begun studies of what their products contain (Liroff, 2005). Companies can also require their suppliers to do similar audits and to meet corporate product specifications as a condition of serving as a supplier. This practice has become increasingly common in the electronics sector as HP, Sony and Sharp have tightened controls on product content (following European Union and Japanese regulations requiring the phase-out of a few chemicals, but expanding the scope considerably). One way to generate data is to provide and demand product declarations (such as those required under the new European REACH chemical law) along supply chains.

Build New Relations Across Supply Chains

Companies need to build new relationships and information flows along their supply chains upstream and downstream. They can evaluate the influence and needs of different customer groups within supply chains (Cashore *et al.*, 2004). Consumers are increasingly targeted, but retailers, governments, institutions and downstream manufacturers are also critical customer groups. Collectively they can wield much more power than consumers. If retailers and manufacturers switch to green chemistry products, they can change what consumers find available, without depending on consumer demand or willingness to pay premiums. Therefore developing new ways of learning about customers through two-way processes are needed.

Corporations can develop software to model how green chemistry changes can make a difference to downstream manufacturers in terms of economics, regulatory pressures and other business factors. They can hold joint work sessions with customer employees, in which the latter use the software to test for themselves claims of cost savings and supply chain improvements. An example is total cost accounting at Rohm and Haas. The company is experimenting with tools and institutional mechanisms to identify what customers much further down the supply chain gain from products, what problems they encounter and what functions a product serves. The focus is on the whole system of use because the company can then envisage how to modify the system.

In addition, companies engage in little post-manufacture monitoring apart from listening to customer complaints about poor product performance. Few data collection systems and information flows exist that feed into upstream design and business strategizing processes. Hence most corporations lack insight into the conditions and impacts of customer use, which could inform their green chemistry strategies. US chemical makers have not yet paid much attention to what scientists, NGOs and consumers are saying about chemicals in products. Enhancing post-manufacture monitoring would be beneficial.

Companies can work jointly with customers to anticipate regulatory and supply chain pressures. Issues such as the rapid growth in electronic wastes, technological developments such as hybrid cars, the greater use of plastics in cars, urban heat effects and housing trends may suggest new market niches. These are all important drivers for innovative green chemistry products at Rohm and Haas (Fitzpatrick, 2004). Companies can identify these opportunities for customers through information networks and

[3] See www.cleangredient.com

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problem scoping processes. They can position themselves as providers of key information that meets customers' needs.

Companies can also develop strategic alliances with institutional, retail and government customers based on implementing green chemistry. Institutional customers include health care systems, schools and public transportation agencies. Some retailers, closer to customers and more concerned about their reputation, are already demanding green chemistry by using what Dow calls 'X-lists', or lists of undesirable chemicals such as VOCs, heavy metals and PBT chemicals. Most such actors are oblivious to green chemistry possibilities. Hence institutional, government and retail buyers, particularly in the US, have not yet created purchasing or supplier criteria that require the use of non-toxic substances.

Provide More Information About Chemicals to Customers

Companies (and governments) can provide far more information externally than is currently available. Existing chemical regulations do not require companies to generate complete health and environmental data for chemicals, or to detail fully the contents of consumer and industry products. Chemical companies fear that they might lose commercial confidentiality, be less innovative or become susceptible to lawsuits. They are accustomed to designing and producing chemicals with relatively little scrutiny from societal actors.

To be much better placed to benefit from coming regulatory changes and consumer demands, companies can start addressing information costs. They can reduce the difficulty of searching for information, and enable customers to understand green chemistry outcomes under conditions where they have little experience (Belz, 2005). To do so, companies can help define sustainability properties that businesses and customers recognize and accept as meaningful and credible, through collaboration with governments, scientists, citizen groups and other businesses.

A critical step is to establish institutional processes for defining and giving credence to sustainability properties. Given the chemical industry's history of being less than transparent about its risks and problems, customers are likely to regard corporate logos or product information that companies directly control as problematic. In Europe, the German giant BASF is developing the first sustainable chemistry eco-label, based on its eco-efficiency data, 'to open up new markets or bolster existing ones for BASF products while allowing customers to claim that they are using "green" raw materials' (ENDS, 2004). Several chemicals have already received the label, including propylene carbonate used to coat wires. This corporate eco-label lacks external verification and customers may regard it as less credible.

Conversely, customers often regard third-party certification and eco-labels as more credible and meaningful than corporate labels (Cashore *et al.*, 2004). California's Proposition 65 regulation (which requires manufacturers and retailers to provide warnings on labels or notices if their products contains any of 700-plus carcinogenic or toxic substances that the government lists) is an early example of chemical labeling (Dahl, 1995). Far more information-rich approaches can be devised. Industry can help create certification systems for chemical products along the lines of existing food, seafood and forestry schemes. These are important because they can verify production conditions and can signal sustainability to consumers, institutional buyers and businesses. Certification can also support insitutional purchasing decisions. However, all existing successful schemes have involved industry in their design and roll-out.

Generally, simply outlining the sustainability advantages of green chemistry may not make sense to many managers, workers, financiers and investors. The Porter hypothesis assumes that revealing resource efficiency gains will convince strategic managers and corporate marketers. Yet these actors rarely find such a narrow view of sustainability very enticing. Expanding green chemistry's advantages to include company social responsibility may resonate better with managers. Green chemistry may be much more than products and markets. Companies can use green chemistry to protect actively their

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workers, the neighborhoods around factories, their reputation, access to capital and ultimately shareholder investment. Chemical companies may succeed better if they speak to other businesses about responsible business, rather than simply sustainability.

Conclusions

In the next few decades, the chemical industry worldwide faces the challenges of making the transition to sustainability. These challenges include the transformation of chemical technologies, products and infrastructure to use less energy and matter, be less toxic and draw on renewable energy and feedstocks. In the absence of regulation requiring green chemistry changes, finding ways to make green chemistry more commercially attractive are important. To date, rather more attention has focused on the technical aspects of green chemistry than on the business aspects. This situation is beginning to change. At a green chemistry conference, the Rohm and Haas CEO, Michael Fitzpatrick, declared 'Directly or indirectly [our customers] are beginning to call for more sustainable products, or at the very least, are willing to change their purchasing decisions to new technologies so long as the price is right and it's marketed in a way that resonates with them' (Fitzpatrick, 2004).

However, this shift will not succeed unless companies generate more information internally, build new relations across supply chains and provide more information externally. Business needs to consider the concrete steps needed to make marketing green chemistry more viable. By rethinking how sustainability can be marketed in terms of supply chains, information needs and different customer groups, manufacturers can make green chemistry more commercially valuable. As a result, they may put more resources into implementing already feasible green chemicals and technologies. Marketing approaches will likely work best in some situations. They are not a panacea for all of green chemistry's birthing problems. Nonetheless, focused attention to innovative marketing can help advance green chemistry's entry into industry.

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