Sustainability
Special Issue

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Doing well by doing good

Karen Peabody O'Brien makes the business case for green chemistry

IN 1941, Henry Ford (of the US Ford Motor Company) unveiled what was called a “field-grown” plastic car. Although using plastic in auto bodies is not uncommon today (and the use of bio-based plastics is on the rise), this particular car was extraordinary from a sustainable design perspective even by current standards. The body was made of plastic which was 70% derived from wheat straw, the other 30% was from soy. The timing gears, horn buttons, gearshift knobs, door handles and accelerator pedals were derived from soybeans. The tyres were made from goldenrod bred by Ford’s close friend Thomas Edison. The fuel tank contained a blend of about 85% petrol and 15% maize-derived ethanol.

Ford came up with the idea for the field-grown car in the 1930s, when the Depression, drought and debt were driving US farmers from their land. With the onset of World War II and heightened uncertainty of access to foreign resources, the idea of plant-based plastics made even more sense. But the end of the war opened unfettered access to foreign oil supplies and the subsequent dawning of the petrochemical age. This era brought with it an increasing reliance on petrochemical industrial inputs which today are coming under increasing scrutiny due to environmental, health, cost and security concerns.

The concept of greener materials and methods opens up wide vistas for product innovation and broad market shifts. Green chemistry is a vital innovation tool in this emerging market. Green chemistry can benefit both the bottom-line (more income) and top line (more sales). Many companies understand that bottom-line gains can be made through cost reductions and product/process improvements, or through environmental efficiency policies. There are many valuable ways to reduce costs in materials, waste streams, and energy usage; additionally, companies can avoid risk and regulations by greening their processes. But efficiency improvements and risk reduction are just the tip of the iceberg. There are profound top-line gains to be made by companies who employ green chemistry as an innovation tool to help design and create new products and processes. This innovation-oriented perspective offers considerable opportunities for competitive advantage over rival firms.

Bottom-line benefits of green chemistry:
• Improved manufacturing capacity utilisation (more throughput per unit of time).
• Improved E-factor/Increased product yield.
• Lower energy and water consumption.
• Waste reduction: hazardous waste elimination.
• Waste (esp toxic) disposal fee avoidance/reduction.
• Lower material procurement costs (reduced feedstock volumes and processing materials).
• Lower inventory costs (fewer materials required on site).
• Fewer environment, health and safety overheads (less handling risks, safety equipment; monitoring, data, gathering and reporting overhead).
• Liability risks lowered (contingency set asides avoided).

green chemistry
By definition, green chemistry is “the utilisation 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” (Anastas and Warner, Green chemistry: principles and practice). Toxicity is deliberately prevented at the molecular level. Chemicals and chemical processes are designed to eliminate waste, minimise energy use and degrade safely upon disposal. Green chemistry products are often derived from renewable feedstocks; processes are streamlined for maximum efficiency; and hazard and its inherent costs are designed out of both products and processes as much as possible. Green chemists and engineers employ lifecycle and biological systems thinking in the act of creating the chemicals that form the foundation of products, and ultimately the global economy.

The science is rigorous and many specific applications are now emerging in industry and academia. Green chemistry design principles are being used in a range of global companies including chemical giants Dow, DuPont, and Rohm and Haas; and consumer product producers SC Johnson, Shaw carpets and Merck & Co pharmaceuticals; among many others. Merck & Co is one of a group of leading pharmaceutical companies engaged in defining industry best practices in green chemistry — see article on p50. Small businesses also play a leading innovative role, for example AgriQuest and Metabolix, who outlined their renewable plastics business in tce 781, July 2006. Green chemistry design and innovation is being applied to a range of applications including adhesives, pesticides, cleaning products, fine chemicals, pharmaceuticals, plastics, fuels and renewable energies, pulp and paper, nanotechnologies, textiles, paints and...
bottom-line benefits

One essential green chemistry bottom-line tool is the idea of the "atom economy", which would have manufacturers make as full use as possible of every input molecule in the final output product. If you consider that on average 94% of the resources that go into making a product is discarded as waste, this principle has profound system-wide ramifications.

The pharmaceutical industry, an early adopter of green chemistry principles in industrial processing, uses a metric called "E-factor" to measure the ratio of inputs to outputs in any given product. In essence, an E-factor measurement tells you how many units of weight of output one gets per unit of weight of input. This figure gives companies a sense of process efficiency and inherent costs associated with waste, and energy and other resources. By applying green chemistry principles to pharmaceutical production processes, companies have been able to dramatically lower their E-factor and significantly raise profits.

Merck & Co, for example, discovered a highly innovative and efficient catalytic synthesis for sitagliptin, which is the active ingredient in Januvia – the company's new treatment for type 2 diabetes. This revolutionary synthesis creates 99.8% less waste for each kg of sitagliptin manufactured and increases the overall product yield by nearly 50%. Over the lifetime of Januvia, Merck hopes to eliminate formation of at least 150,000 t of waste, including nearly 50,000 t of aqueous waste (www.epa.gov/greenchemistry/pubs/pgcc/winners/gspa06.html). The bottom-line benefits of this green chemistry process innovation are clear.

top-line benefits

Imagine how it would feel to show up Monday morning, check your email and find that Wal-Mart – the ultimate supply chain captain in the US – was going to begin sourcing your product? Not a bad start to the week. All the more so if you are CEO of a relatively small company (though in this example owned by a large parent firm) struggling to make a profit by producing a relatively unknown commodity: plastic made from maize.

This Monday-morning scenario actually happened at NatureWorks. Born of a joint venture between US agricultural processing giant Cargill and Dow Chemical, NatureWorks had been struggling to realise the vision of its original founders for ten years. Employing 230 people, carrying some $750m of capital investment by Cargill, in 2005 the company was operating at a lower capacity than expected. NatureWorks was not yet profitable and the refrain "make the bleeding stop" was beginning to sound like a broken record. Then Wal-Mart called – and many others followed suit, seeking to source NatureWork's renewable plastic. Today, NatureWorks' production facilities are unable to meet rising demand, though they are operating on a 24/7 production schedule. The company has witnessed a 100% increase in customer base in 30 months and 45% average growth-rate over four years.

NatureWorks' polymer – polyactic acid (PLA) – has the potential to revolutionise the plastics and agricultural industries by offering biomass-based biopolymers to substitute for conventional petroleum-based plastics. NatureWorks resins were named and trademarked NatureWorks PLA, for the polyactic acid that comprises the base plant sugars. In addition to replacing petroleum as the material feedstock, PLA resins have the added benefit of being compostable (safely biodegraded) or even infinitely recyclable, which means they can be reprocessed again and again. This provides a distinct environmental advantage, since recycling, or "downcycling", post-consumer or post-industrial conventional plastics into lower-quality products only slows material flow to landfills. Moreover, manufacturing plastic from corn produces 30–50% fewer greenhouse gases when measured from field to pellet. Additional lifecycle environmental and health benefits have been identified by a thorough lifecycle analysis. PLA resins, virgin or post-consumer, can be processed into a variety of end-uses.

Companies such as NatureWorks are discovering that they can increase top-line benefits with sustainable innovation practices such as green chemistry. The mechanisms here are through increased revenue and market share. Companies and new products can differentiate themselves and gain preferred access to markets which were previously inaccessible to them. Green chemistry can help companies design next-generation products and help one beat the competition to market. Green chemistry can serve as an impetus for innovation; the company that figures out how to comply, and even be in advance of, regulations and does so better, faster, and cheaper will have a competitive advantage. Additionally, companies can achieve preferential purchasing status through being first to market with a greener option for customers. There are growing numbers of companies working in partnership with suppliers to use green chemistry approaches to develop greener inputs such that they can meet rising consumer demand for cleaner products.

Last, but not least, there are additional measures of success emerging that companies employing green chemistry innovations are experiencing: benefits which require us to think up new categories beyond top or bottom lines. These are often the result of changes in a company's soft assets, such as brand recognition, company reputation, consumer trust, etc. Examples include:

- process patents;
- brand enhancement/protection;
- enhanced community reputation;
- corporate sustainability report indices – attract investors; and
- preferred supplier status.

To summarise, green chemistry links company profits and human and ecological health at the very heart of product design and manufacturing. It uses the creativity of nature's biological processes to create molecules, materials and processes that are safe and high-performing. It calls for an increased reliance on renewable inputs, and a mechanism of shifting to a bio-based economy. Green chemistry has profound consequences for a wide range of issues, from product innovation and enhanced productivity to environmental health, worker safety, and even to international security. Green chemistry provides the means for companies to do well while doing good; green products can be made at a profit. While no one science supplies all the answers, green chemistry plays a foundational role in enabling companies to see concrete benefits from greener design. tce

Karen Peabody
O'Brien
(kpbrien@advancinggreenchemistry.org)
is executive director of the US non-governmental organisation Advancing Green Chemistry

further information