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Sustainable Solutions for Modern Economies

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Sustainable Solutions for Modern Economies

RSC Green Chemistry

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Edited by

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Foreword

There's a funny thing about design. You can't do design by accident. If you wind up with a wonderful new product through serendipity, you can say all kinds of things about it but you can never claim that it was designed. This is important because what we face today is the greatest design challenge of all time. How do we design the products and processes that are the basis of our society and our economy so that they are benign to humans and the environment and are sustainable? It is a difficult challenge for many reasons.

First, we have designed things so wrong for so long, we have many old, bad habits to break. As we look across the Twelve Principles of Green Chemistry, one could view them as common sense. However, common sense is not common in chemical design. The amount of waste generated per kilogram of product is often of higher magnitude than the production volume. Our feedstocks are usually depleting finite resources, our reagents are often toxic and our products persistent and bioaccumulating. The good news is that many of the best practitioners in the world have recognized the shortcomings of our chemical design and their work is featured in this book.

Second, we don't view hazard as a design flaw. We are very good at designing for performance. The past 150 years of chemistry can be viewed as nothing short of a technological miracle in the development of new medicines, dyes, materials and catalysts. However, adverse consequence to humans or the environment was never considered as a design criterion. In part, this was due to the fact that we didn't have the molecular basis of understanding hazard in a way that would inform design. However, with the advancement of the science, we have insights that allow us to design intrinsically less hazardous products and processes as can be seen in this volume.

Third, we don't think in terms of systems. Even when we approach some of the big sustainability challenges, climate change, renewable energy, pure water, food supply, toxics, *etc*., we approach these challenges in a fragmented manner. We often forget that climate change is inextricably linked to energy, and energy to water purification, and water to food, *etc*. We often wind up doing the "right things, wrong". We purify water with acutely lethal substances. We make energy-efficient bulbs with neurotoxins, and solar energy with scarce, depleting and toxic metals. The Twelve Principles of Green Chemistry have supplied a framework by which to recognize how to do the "right things, right". In other

words, to know when your solutions to sustainability challenges are themselves sustainable.

This book is a collection of work by thoughtful designers who have approached their work with sustainability in mind; who recognize the errors of our past and are designing new systems that reduce or eliminate intrinsic hazard wherever possible. It is one of the great scientific challenges that we face and we need to face it with creative, rigorous design. We cannot count on accident or serendipity to get us off the unsustainable trajectory that we are on currently.

The achievements of the field of Green Chemistry and sustainable design in its short life are truly amazing. They span every molecular sub-discipline. The achievements can be found across virtually every industry sector that chemistry touches from electronics to aerospace, to chemicals, pesticides and medicines, to paints, plastics and cosmetics. However, the most remarkable thing about the accomplishments of the field of Green Chemistry thus far is that collectively they are just a small fraction of the power and the potential of the achievements yet to be realized. The achievements in this book are yet another glimmer of how thoughtful design can lead us towards a sustainable civilization.

Paul T. Anastas
Teresa and H. John Heinz III Professor
In the Practice of Chemistry for the Environment
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Preface

Apocalypse now? Was the financial crisis which erupted in 2008 the "writing on the wall", the Menetekel for the Industrial Age? Is mankind approaching the impasse of Easter Island, Anasazi and Maya societies shortly before collapse – "which followed swiftly upon the society's reaching its peak of population, monument construction and environmental impact"? Or will mankind be capable of a new global common sense? After 200 years of industrial development largely based on easily available, abundant, and hence cheap fossil raw materials, will there be a concept and an agreed-upon action plan to preserve these more and more precious materials, because they are finite, fossil resources and substitute them with renewable raw materials, enforcing sustainable development on a global basis and bringing global warming to a halt?

This introduction to *Sustainable Solutions for Modern Economies* has been written in the first week of April 2009, after the G20, NATO and EU-USA summits in London, Kehl-Strasbourg and Prague, which have created hope that such a vision might become a reality. There is no doubt, however, that concepts for energy savings on a global basis and a fair value for finite fossil resources need to be part of such reality.

Sustainable Solutions for Modern Economies is not meant as a political pamphlet. However, the very concept of sustainability and its social, economical and ecological aspects have been established and accepted at the Earth Summit in Rio de Janeiro as a political initiative obligating the signatory states to implement Agenda 21, the wide-ranging blueprint for action to achieve sustainable development worldwide. *Sustainable Solutions for Modern Economies* is meant as an essay to reflect the aspects of sustainability in the different sectors of national and global economies, to draft a roadmap for public and corporate sustainability strategies, and to outline the current status of markets, applications, use and research and development for renewable resources.

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Besides history of the sustainability concept, Chapter 1 brings up philosophical aspects of the relationship between man and nature and highlights the key sustainability initiatives of the chemical industry, *i.e. The Responsible Care® Global Charter* and the *24 Principles of Green Chemistry and Green Engineering*.

Chapter 2 depicts the position and the systemic role of the financial market in the economic circuit on the one hand and, on the other, recently developed key performance indicators for the sustainability rating of companies used as criteria for socially responsible investments and asset management, and to analyze and measure the non-financial enterprise value on a normative basis. A normative basis necessary to comparatively measure sustainability in industrial products, processes and applications is provided by the eco-efficiency analysis. Chapter 3 describes the eco-efficiency analysis as a management tool incorporating economic and environmental aspects for the comprehensive evaluation of products over their entire life-cycle from concept development, design, implementation and marketing to end-of life issues like recycling or disposal. For the first time, Chapter 4 describes a holistic approach to define sustainability as a guiding principle for modern logistics, *i.e.* throughout the process that plans, implements and controls the effective, efficient, forward and reverse flow and storage of goods, services, finance and/or information between the point of origin and the point of consumption in order to meet customers' requirements.

Consumer behaviour and expectations, indeed, are crucial aspects to be considered when dealing with further development of the sustainability concept. This is done in Chapter 5 for consumer goods, taking detergents as an example with the life-cycle of the washing process acting as indicator, while Chapter 6 specifies the achievement of food security at a global level as a key element of sustainable development and details the importance of, and attention attributed to, the food and nutrition industries to consumer expectations throughout the value chain starting with green agriculture, animal husbandry and fishing followed by sustainable food production and processing, packaging, retailing and service.

Key challenges for society at the beginning of the twenty-first century are energy economy and alternative energies. Tens of millions of years ago, biomass provided the basis for what we actually call fossil resources and biomass again is by far the most important resource for renewable energies today. The actual status and the potential of biomass as well as biomass conversion technologies to provide green energy in the form of heat and/or power are detailed in Chapter 7, while Chapter 8 summarizes the manufacturing and usage of first-generation biofuels and gives an outlook to biomass-based second- and third-generation transportation fuels.

Together with the increasingly efficient utilization of fossil resources for heat and power generation and as fuel for transportation of people and goods, the chemical industry has established the basis for more or less all modern industries. Machinery wouldn't work and cars and trucks wouldn't move without synthetic lubricants. The chemical industry provides dyes and pigments which

make our world bright and colourful. Hunger has been a problem throughout history until chemical fertilizers and pesticides made efficient agriculture and plant protection possible. Lightweight and shock resistant plastics guarantee the safe transport and storage of goods. Modern communication and information storage systems depend on liquid crystals, printed circuit boards or ultrapure silicon wafers. Human population growth, increased life expectancy and reduced risk of physical infirmity (as well as voluntary birth control) only became possible when the chemical industry emanated into the pharmaceutical industry, and when synthetic detergents ensured hygiene in personal care, laundry care and institutional cleaning. It needs to be noted, however, that organic molecules are composed of small molecular building blocks predominantly derived from coal, natural gas and crude oil. The efficient complementation and eventual substitution of these raw fossil materials by biomass is the subject matter of green chemistry and is comprehensively described in Chapter 9, which comprises lipid-based biomass (natural fats and oils, Chapter 9.1), industrial applications of carbohydrate-based biomass (starch, Chapter 9.2, and sucrose, Chapter 9.3), wood (Chapter 9.4), natural rubbers (Chapter 9.5), natural fibres (Chapter 9.6) and plant-based biologically active ingredients for cosmetics (Chapter 9.7).

The notion of sustainability in highly specialized markets where specifications and performance are key requirements is discussed in Chapter 10 (green solvent alternatives for fine chemicals, for metal treatment, for coatings and for crop protection formulations) and in Chapter 11 (sustainable solutions for adhesives and sealants).

Last but not least, White Biotechnology (Chapter 12) is largely regarded as a particularly promising gateway to a sustainable future. Reduction in greenhouse gas emissions, energy and water usage are examples of the benefits brought about by greener, cleaner and simpler biotechnology processes. White biotechnology can contribute to the reduction in the dependency on fossil resources through the utilization of renewable raw materials. An especially notable feature of white biotechnology, though, is the ability to perform specific biochemical reactions without by-product formation or waste generation, which synthetic chemistry is not able to provide.

As an employee of Henkel and Cognis I have had the chance to follow, observe and contribute to the successful implementation of sustainability as a guiding principle and business model for the company and for relations with our customers. I would like to thank my colleagues Benoît Abribat, Carsten Baumann, Manfred Biermann, Joaquim Bigorra, Paul Birnbrich, Christoph Breucker, Wolfgang H. Breuer, Stefan Busch, Dieter Feustel, Matthias Fies, Roland Grützmacher, Bernhard Gutsche, Jochen Heidrich, Uwe Held, Karlheinz Hill, Klaus Hinrichs, Ronald Klagge, Alfred Meffert, Harald Rößler, Thorsten Roloff, Setsuo Sato, Harald Sauthoff, Jörg Schmitz, Ulrich Schörken, Markus Scherer, Heinz-Günther Schulte, Alfred Westfechtel, Andreas Willing and Guido Willems, who have accompanied this enterprise and, in one way or another, have framed the concept and the content of this book.

I would like to thank all the authors for their commitment and for bringing in their knowledge, their professional experience and their expertise.

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Rainer Höfer
Düsseldorf

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