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Theories, Concepts and Industrial Examples for Achieving Sustainable Chemical Products and Processes from a Non-Technological Viewpoint

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Contents

Preface

Chemical products make an irreplaceable contribution in every aspect of our modern day lives. Chemical processes and products play an essential role in industrial sectors as diverse as agriculture, automotive, clothing, communication, construction, food, health, leisure, mobility, plastics, space, transport, and so on. We can easily observe that our advanced society depends on the wealth-creating aspects of industrial chemistry.

Nonetheless, societal expectations and the depletion of natural resources are pushing toward chemical processes becoming cleaner, more efficient, less consuming, safer, and more secured. The ecological footprint of chemical products needs to be decreased.

Sustainable chemistry being concerned with the development of sustainable chemical products and processes and thereby integrating economic, environmental, and social performance, can provide an answer to these major challenges.

To achieve sustainable industrial chemical processes and products, companies, research centers, and academia tend to focus mainly on technological solutions such as cleantech, green technology, process intensification, new catalysts, new membranes, ecofining, and so on. However, nontechnological approaches are essential as well to succeed in adequate sustainable chemistry. Integrated management systems, cluster management, business models, measuring criteria and methods, sustainable supply chain management, chemical leasing, transition management, societal expectations, and so on are all important nontechnological aspects of sustainable chemistry. To date, most of the know-how and expertise on nontechnological issues is developed on individual company or academia basis and in a fragmented way. An overview of management principles, theories, concepts, and so on from a nontechnological holistic (People, Planet, and Profit) perspective has, to the best of the Editors' knowledge, not yet been discussed in one book volume.

The objective of writing a book from a managerial viewpoint consists in leveraging the search for truly sustainable chemical products and processes, and to disseminate the available knowledge to captains of industry and to leaders of the public sector, as well as to company management (within all organizational levels and from all different departments, and disciplines). It is crucial for the vision of sustainable chemistry to be realized that not only novel technology is conceptualized and

developed but also that innovative management models, intraorganization models, and interorganization models are elaborated, promoted, and implemented within the chemicals using industries.

We are convinced that a clear interdisciplinary approach within technological areas, supported by cross-cutting managerial actions, is required for truly successful tackling of these new chemistry challenges and paradigms.

Antwerp
May 10, 2012

Genserik L.L. Reniers, Kenneth Sörensen, and Karl Vrancken

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Part I
Introductory Section

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First Edition. Edited by Genserik L.L. Reniers, Kenneth Sörensen, and Karl Vrancken.

1
Editorial Introduction

Genserik L.L. Reniers, Kenneth Sörensen, and Karl Vrancken

There has been an ever-growing worldwide interest in sustainability in all industrial sectors since the Rio declaration two decades ago (UN, 1992). Especially in industries using chemicals, topics related to sustainability are gaining importance by the year. Sustainability should be seen as an ideal. It is an objective of perfection that will never be completely achieved. It is a target of continuous improvement. It should be a business imperative. The interconnectedness of organizational actions and decisions should have an impact on the social, ecological, and economic sustainability of the community in which it operates. To achieve this ideal, and all its accompanying aims, technological as well as a nontechnological innovations and operations should be strived for and implemented. This book specifically deals with the nontechnological path that should be taken within the chemical industry to achieve sustainability in business needs.

However, these are rather vague concepts. All this wisdom about sustainability, the awareness, and information, does not suggest concrete actions and tactics needed to change an organization for the better. This book describes how to significantly enhance the sustainability of chemical plants from the management's perspective.

By taking into consideration the needs for nontechnological advancements toward sustainability, the present book, whose structure is illustrated in Figure 1.1, aims at covering all aspects and all principles leading to truly sustainable industrial chemistry from a managerial perspective. The first introductory section provides a description of the history and importance of sustainability in the chemical industry and of the evolution in managerial themes and models leading to a steady transition toward sustainability. The second section discusses the management system requirements and the needs to build corporate social responsibility within one plant, and provides tools and methods to measure sustainability within a chemical company or a part thereof. The third section investigates the managerial needs to improve cross-plant management and collaboration at the same level of the supply chain, for moving toward ever more sustainable chemical products and processes. The fourth section provides insights into some innovative managerial approaches with respect to collaboration and cooperation between organizations not situated on the same level of the supply chain, leading toward so-called vertical

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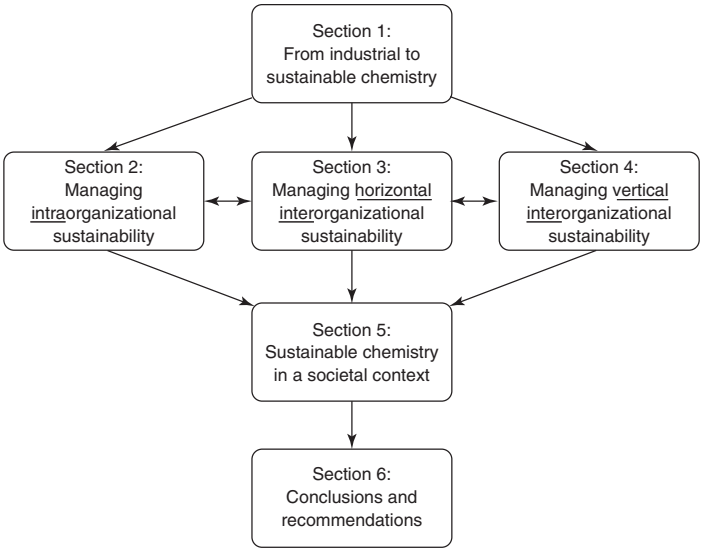

Figure 1.1 Structure of the book.

interorganizational sustainability. The fifth section presents and elaborates on the societal context of sustainable chemistry.

The following paragraphs offer an outlook of the 13 contributions that constitute the various sections of the book. In order to provide an introduction to the various chapters, a description of the main themes that are dealt with in each one is given.

1.1 From Industrial to Sustainable Chemistry, a Policy Perspective

This first, introductory, section contains three contributions. The first one, History and Drivers of Sustainability in the Chemical Industry, provides a brief description of the chemical industry's path toward sustainability. The incentives and drivers for a step-by-step advancement, from the Responsible Care® program to the various corporate sustainability initiatives, are listed out and expounded.

The second contribution of this section, From Industrial to Sustainable Chemistry, a Policy Perspective, clarifies the policy developments that could be observed over the past decades in relation to chemistry on an industrial scale. The contribution clearly demonstrates that there has been a shift in focus over the last two decades from strict rule-driven regulations and authorities toward performance-based and stakeholder-based governance. This shift has initiated and empowered a shift of industry – such as the chemical industry – toward new managerial and governance approaches.

The third contribution of this introductory section, Sustainable Industrial Chemistry from a Nontechnological Viewpoint, briefly discusses what is understood in this book by ''sustainable chemistry'' and what constitutes a ''nontechnological viewpoint.'' The foundations are laid for the further chapters by elaborating on

the different managerial topics for achieving sustainable chemistry in a simple, nontechnological manner.

1.2 Managing Intraorganizational Sustainability

The second section of the book is composed of four chapters. The first one, *Building Corporate Social Responsibility* – Developing a Sustainability Management System Framework, deals with the creation of a conceptual sustainability management system, mainly on the basis of the umbrella guideline ISO 26000. The proposed coherent and systematic framework contains five inherent and consecutive features of sustainability. The current overload of standards makes organizations uncertain how to translate the idea of sustainability optimally into a management system, and this section provides an answer to this organizational need.

The second chapter of this section, Sustainability Assessment Methods and Tools, discusses a sustainability assessment framework and impact indicators and assessment approaches from both a uni- and a multidimensional perspectives. The chapter argues that harmonization and standardization of knowledge in three dimensions (environment, economic, and social) should be pursued for the chemical industry.

The third contribution of this section, Integrated Business- and SHESE Management Systems, takes a closer look at the added value of integrated management systems and the required steps to successfully implement an integrated management system approach. The chapter provides arguments for treating sustainability as a holistic, organization-wide objective, to be achieved by an integrative generic framework that leaves space for specificities wherever and whenever needed.

The last contribution is concerned with the identification of relevant impact categories and suitable KPIs for sustainability performance. How the KPIs should be interpreted and aggregated is explained, amongst others. The method elaborated in this contribution helps decision makers in the design for sustainability within chemical process plants.

1.3 Managing Horizontal Interorganizational Sustainability

The third section of the book is contains two chapters. The first chapter, Industrial Symbiosis and the Chemical Industry: between Exploration and Exploitation, explains industrial symbiosis and compares different chemical clusters from the Netherlands in this regard. The advantages and hurdles of realizing cross-plant collaboration initiatives to advance environmental symbiotic linkages are discussed.

The second contribution in this section, Cluster Management for Improving Safety and Security in Chemical Industrial Areas, proposes a framework and an approach for chemical plants situated within the same chemical cluster, to transfer knowledge, know-how, and best practices, and a more intensive collaboration on safety and security topics.

1.4 Managing Vertical Interorganizational Sustainability

The fourth part of this book has three contributions. The first contribution, Sustainable Chemical Logistics, investigates the status of sustainability in chemical logistics, and argues that organizational aspects have an important role to play in this area. Furthermore, different ways to improve sustainability of chemical logistics are discussed: optimization in logistics, coordinated supply chain management, horizontal collaboration, and intermodal transportation.

The second contribution, Implementing Service-Based Chemical Supply Relationship – Chemical leasing® – Potential in EU?, explains ''chemical leasing'' as a new business model that aligns economic incentives in the chemical supplier–user relationship toward reduced material use on the one hand and waste prevention on the other. The contribution clarifies this novel business concept and shows its innovative nature and possible role in ''servicizing'' the chemical supply chain. Furthermore, the synergy that exists between chemical leasing and several relevant legal frameworks, such as REACH, is addressed.

The third contribution deals with the needs as regards sustainable warehousing. It is evident that adequate risk management policies and -procedures and risk treatment strategies need to be in place in warehouses. The different factors important in this regard, are given and clarified. The chapter further discusses sustainable inventory management and vendor management inventory, and their importance.

1.5 Sustainable Chemistry in a Societal Context

The fifth section of the book is based on three contributions. The first one, A Transition Perspective on Sustainable Chemistry: the Need for Smart Governance, offers an exploratory transition perspective on challenges and changes going hand in hand with sustainable chemistry. The author argues and explains that a transition toward sustainable industrial chemistry is not so much a technological challenge as it is an institutional, economic, and political challenge.

The second chapter, The Flemish Chemical Industry Transition toward Sustainability: the ''FISCH'' Experience, discusses the peculiarities and the obstacles and hurdles of developing an initiative in the Flanders' region in Belgium, to advance the chemicals-using industries toward becoming a sustainability-driven and an innovation-driven industrial sector. Factors to be taken into account when developing a similar initiative are given.

The third contribution, The Transition to a Bio-based Chemical Industry: Transition Management from a Geographical Point of View, analyzes the regional characteristics and their influence on bio-based innovation. The chapter discusses the hard and soft influential factors in this regard, and four cases are examined: the port regions of Antwerp, Ghent, Rotterdam, and Terneuzen.

2
History and Drivers of Sustainability in the Chemical Industry

Dicksen Tanzil and Darlene Schuster

This section provides a historical look on the emergence of sustainability issues and awareness in the chemical industry and how the industry has responded to them, especially over the last 50 years. It describes industry's initial reactive response to the rising public and regulatory pressures, and how this has morphed into the more proactive stance taken by leaders in the chemical industry today in managing environmental, social, and economic issues. The history also illustrates how addressing sustainability issues helps business to better manage risks and capture opportunities for new markets and innovations.

2.1
The Rise of Public Pressure

At the birth of the modern chemical industry some 200 years ago with the beginning of mass production of chemicals such as acids and bleaching powder, what we now consider as ''sustainability issues'' were hardly on anyone's mind. Natural resources were thought to be plentiful, the environment was for industries to exploit, and workers' and community safety was little more than an afterthought. This mind-set had stayed for most of those 200 years. While one can point to measures taken by some early chemical manufacturers that benefited the environment or safety, such as reducing products released to rivers or in the workplace, those examples are few and far between.

Through its history, the chemical industry has certainly made important contributions to society. Fertilizers and other agricultural chemicals increase crop production, synthetic polymers make various new industrial products possible, and mass production of medicines saves lives – just to name a few. Nevertheless, the advancement of the chemical industry was accompanied with growing environmental concerns. Early examples include documented cases of water pollution from chemical plants in the early twentieth century, which led to the 1935 listing of the chemical industry as among the most polluting industries in the United States by the country's National Resources Committee (Geiser, 2005). Yet, the state and

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federal governments in the United States remained slow in enacting environmental or public health policies in spite of the growing concerns.

2.1.1 The Environmental Movement

Many would point to the 1960s as the turnaround, with the chemical industry becoming a primary target of a growing environmental movement (Hoffman, 1999). Many attributed the rise of the public pressure on the chemical industry to the publication of the book *Silent Spring* by Rachel Carson (1962) and the controversy that followed (e.g., Gottlieb, 1993). *Silent Spring* meticulously presented the adverse environmental effects from the indiscriminate use of the chemical pesticide DDT and became an immediate best seller in the United States. Beyond questioning the safety of synthetic pesticides, the book brought up concerns on the widespread use of synthetic chemicals without fully understanding their potential impacts to the environment and human health. The discovery of 5 million dead fish in the lower Mississippi River later that year, which was attributed to the insecticide endrin, further exacerbated the public concern. Pesticide manufacturers and others in the chemical industry reacted strongly and negatively to the book and the public concern (Natural Resources Defense Council, 1997). The reaction, however, appeared to have largely backfired and further elevated the issues to a high-profile national discourse on the potential environmental and public safety impacts of synthetic chemicals.

The rising public pressure associated with the environmental movement of the 1960s resulted in the many new environmental bills brought to the floor of the US Congress. The *National Environmental Policy Act* (NEPA) was passed by the US Congress in 1969, and signed by President Nixon on 1 January, 1970. The United States Environment Protection Agency (USEPA) was formed shortly after. It was followed by the proliferation of environmental regulations passed by the US Congress. The *Clean Air Act, Occupational Safety and Health Act, Clean Water Act, Safe Drinking Water Act, Consumer Product Safety Act, Resource Conservation and Recovery Act*, and *Toxic Substances Control Act* were all passed between 1970 and 1976, often with strong bipartisan support in the US Congress.

Many European countries and Japan enacted similar regulations during the same period (Desai, 2002). These regulations affected the chemical industry as well as many other industries. Among these regulations, the *Toxic Substances Control Act* and the similar 1979 Sixth Amendment to the Dangerous Substances Directive of the European Community were particularly directed to the chemical industry. These regulations address the intrinsic hazards of chemical products and provide government agencies with the authority to demand health and safety data on chemical products and restrict the use of chemical substances so as to reduce ''unreasonable risks'' to the public and the environment (Geiser, 2005).

2.1.2 A Problem of Public Trust

A series of industrial incidents and controversies in the late 1970s and early 1980s further elevated the public awareness on the environmental and public safety risks posed by industries in general. These include the Amoco Cadiz oil spill off the coast of Brittany, France, in 1978 and the Three Mile Island nuclear incident in Pennsylvania, United States, in 1979. Three incidents and controversies involving chemical products and processes particularly stood out in their impact on the public perception of the chemical industry: a train derailment in Canada, the Bhopal chemical disaster in India, and the Love Canal controversy in the United States.

The train derailment incident occurred in December 1979 in Mississauga, a major business and residential suburb of Toronto, Canada. While the chemical industry was not directly responsible, the transportation incident drew additional public attention on the environmental and societal impacts of chemical products and the industry that makes them. The train derailment resulted in the rupture of several tankers carrying chlorine, propane, styrene, toluene, and caustic soda and a fireball explosion that rose to a height of 1500 m visible 100 km away (City of Mississauga, undated). Because of concern of a possible spread of toxic chlorine gas cloud, 218 000 residents were evacuated, making it the largest peacetime evacuation in North America at the time.

The Union Carbide incident in Bhopal, India, ignited even greater global public controversy due to its massive impact. Just after midnight on 3 December, 1984, water contamination of a tank of methyl isocyanate (MIC) in Bhopal, India, initiated a series of events that led to a catastrophic toxic release, killing more than 3000 residents and injuring over 100 000. According to Indian Government estimates, the incident resulted in an immediate death toll of over 2500 people. More recent government estimates puts the long-term mortality at of 14 400 people and permanent disabilities to about 50 000 people due to exposure to the MIC toxic cloud (Lapierre and Moro, 2001). Other independent estimates put the figures higher. However, for sure, the Bhopal disaster constituted one of the worst industrial disasters of all time.

Along with these high-profile incidents, other controversies related to chronic chemical exposure also posed problems to the chemical industry. Most infamous among these is the Love Canal controversy toward the end of the 1970s. Residents of the Love Canal neighborhood of Niagara Falls, New York, were found to have unusually high rates of miscarriages and birth defects as well as toxin content in breast milk, which were attributable to the long-term exposure to hazardous chemicals released from a nearby decades-old chemical waste dump. The Love Canal controversy led to the passage of the 1980 *Comprehensive Environmental Response Compensation and Liability Act* (CERCLA, or the ''Superfund'' Act) in the United States. Among others, the ''Superfund'' Act assigns liability for the release of hazardous chemicals from a waste site and provides a trust fund for the cleanup of contaminated areas when no responsible party can be identified.