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Education for sustainability: Developing a taxonomy of the key principles for sustainable process and product design

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ABSTRACT

Design for sustainability as an independent field of study is both multidisciplinary and cross-cutting. It encompasses engineering, natural science, economics, finance, political science, social science and the humanities. It concerns governments, corporations and consumers. Although not normally considered design topics, the effects of manufactured products and energy usage on society and the environment are increasingly impacting process design choices. Because of the numerous groups and constituencies involved, sustainability is a difficult concept to define. However, from a design perspective, professional competency in sustainability is becoming an important prerequisite for the production of economically viable products. This contribution proposes an outline for a sustainability taxonomy, including the key concepts that define professional competency in design and engineering for sustainability. This contribution is an extended version of a paper originally published in the Proceedings of the 8th International Conference on the Foundations of Computer Aided Process Design Conference, Cle Elum, Washington, 2014.

1. Introduction

The effects that manufacturing processes have on society, the environment and the economy have become a significant concern to the general public, corporations and regulatory agencies. The principle stakeholders in a sustainable future include a wide range of constituents – manufacturers, growers, consumers, corporations, governments and regulators – in short, all of us (Seay and Badurdeen, 2014). Issues involving energy, the environment, water, health and nutrition, and social justice are all becoming part of the considerations and decision making process of engineering design. Furthermore, ensuring that the natural resources required to manufacture the products and services needed by society are utilized in a way that preserves their availability for future generations is a key challenge for process and product design. In addition to making the case for sustainability as an integral part of the design process, this contribution will layout the opportunities for the computer aided design community, introduce a taxonomy for the key concepts in sustainable process design, and the educational needs for university students as well as practicing professionals. To begin this discussion, sustainability will be presented as a key component of chemical process design.

1.1. Sustainability in a design context

The design choices that engineers make are more and more being influenced by social and environmental concerns, as much as technoeconomic factors. In its 1987 report titled *Our Common Future*, the U.N. World Commission on Environment and Development, commonly called the Bruntland Commission, addressed these concerns in its definition of sustainable development, as follows:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987)

Although there is no single accepted definition of the term sustainability, the Bruntland Commission definition of sustainable development forms the basis of what sustainability means to the field of engineering. This definition introduces a key sustainability tenet – that development today must not compromise the ability of society to meet its needs in the future. This does not necessarily mean leaving a specific resource, like coal or petroleum, but rather leaving intact the capacity for a future society to meet its needs. For chemical engineers in particular, sustainability has come to refer to the goal of designing, operating and maintaining chemical

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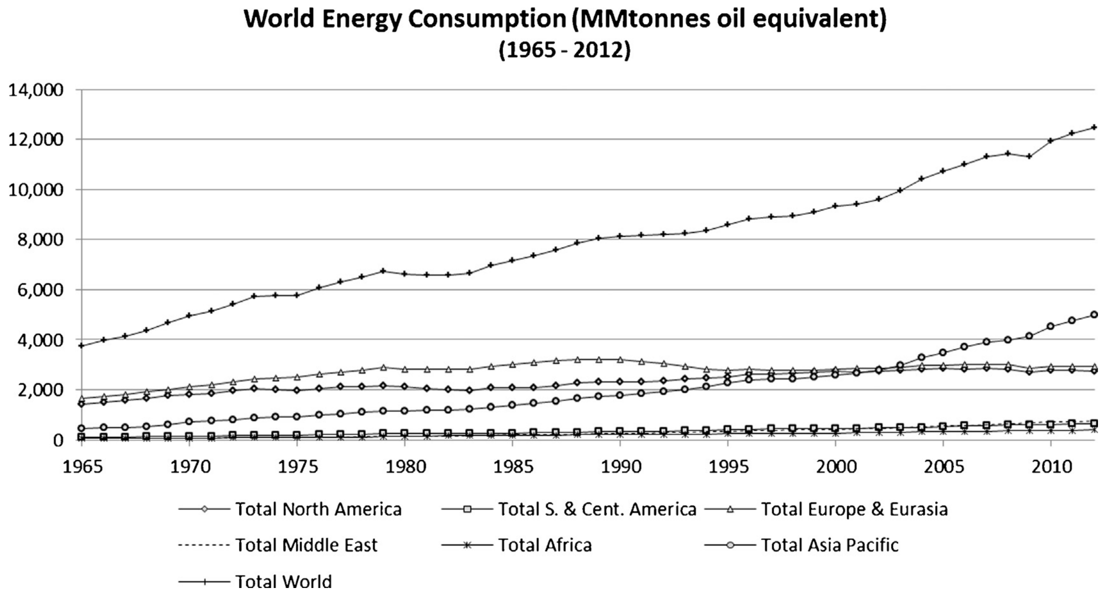

Fig. 1. Global worldwide primary energy consumption.

Source data: BP (2013).

processes in a manner that is economically viable, environmentally benign, and socially responsible. In other words, a sustainable process is one that is designed, operated and maintained to meet the triple bottom line of economics, environment and society, both now and in the future. Determining how to optimize these three competing factors is a skill well suited to the Computer Aided Process Design Community. However, to successfully optimize a manufacturing process, we must know our objectives and constraints. Increasingly, these objectives and constraints will come from consumer demand rather than governmental regulation.

Chemical engineering graduates entering careers in the chemical and manufacturing sectors, as well as current practitioners will increasingly be tasked with job functions that require both an understanding of sustainable chemical engineering principles and competency within a set of sustainable chemical engineering skills. In order to meet this challenge, a common taxonomy for sustainable engineering is required. Sustainable engineering begins at the initial synthesis phases of product and process design, therefore competency in an established body of knowledge in sustainability will be required in order for new graduates and practicing professionals to be competitive in the job market.

How to incorporate sustainability in engineering education is a challenge to the academic community (Davidson et al., 2010; Allen et al., 2006). Additionally, because of the ambiguity in defining the term sustainable engineering, there is little consensus in the education community as to how it should be taught (Allenby et al., 2009). Furthermore, there is no clear consensus as to what educational outcomes define professional competency in sustainable engineering and design. Identifying the key concepts that define competency in sustainable engineering will help in establishing the future direction of process and product design – for students and practicing professionals.

Sustainability as a field of study is generally divided into three broad categories, often referred to as the three pillars of sustainability: economic growth, environmental stewardship and societal impacts. Taken together, these three pillars make up the triple bottom line of sustainability, meaning that the goal of design engineers should be to develop processes and products that are economically viable, environmentally benign and socially responsible. Although perhaps not immediately obvious, meeting the triple bottom line begins in the earliest phases of product and process development. This includes meeting societal and environmental objectives, as well as economic viability. Incorporating the triple bottom line into process and product design provides an opportunity for the computer aided chemical engineering community – particularly in the development of assessment tools that can be integrated into design activities.

The fact that the triple bottom line exists, indicates that there are in fact numerous stakeholders in the results of our product and process design efforts. Not only must manufacturers satisfy shareholders, investors and regulatory authorities, but society as a whole becomes an important stakeholder. As the effects that manufactured products and processes have on society and the environment become more widely recognized, consumers are increasingly demanding more sustainable products that still meet the quality and functional performance standards that they have come to expect.

This consumer driven approach is a pathway that allows societal responsibility and environmental stewardship to coexist with economic competitiveness. This trend among consumers is reflected in the recent shift in advertising where leading manufacturing companies as well as retailers and logistics service providers are touting their improved social and environmental performance as much as their quality and value. This indicates that these companies expect an economic advantage by being perceived by their perspective customers as being more sustainable.

1.2. Driving forces in sustainable product and process design

The first step in developing a taxonomy for sustainable engineering and design is listing and describing the key drivers in sustainability and connecting them to the practice of product and process design. Perhaps the most important driver is global energy utilization. The trend of increasing energy usage worldwide is illustrated in Fig. 1 (BP, 2013). As can be seen, energy usage has increased in all regions since 1965, although a recent drop in consumption since 1990 can be seen in North America and Europe. Globally, society is using more and more energy, leading to volatility in the global energy market over the last few decades. This has had a profound effect on energy prices and raises several critical questions:

- How much higher will our consumption go?
- How will our growing energy demands be met?