Design for Sustainability[1]

I. The Relationship Between Sustainable Production and Consumption and Design for Sustainability

A. Overview of Topic

Design may be thought of as the "glue" that binds together many of the key themes underlying sustainable consumption and production (SCAP). Achieving sustainability will require that we redesign our society and many, if not all, of its sub-components: products, production processes, and the material and energy connections between these processes and products and the natural environment. These redesigned products and processes will both change consumption patterns, and be influenced by consumption patterns.

Some of the interactions between design for sustainability and other key themes underlying SCAP include:

- *Design and consumption* – redesigned products will only be effective if they are able to provide the services of the products they replace (e.g. comfortable shelter, cold beer). However, they must do so in a way that reduces consumption of energy and materials, particularly where the energy and material flows involved are potentially damaging to biological systems. At the same time, changing demands for goods and services will also push design changes.
- *Design and procurement* – products that are well designed must penetrate the market, and replace products that are poorly designed if they are to have an impact.

The principal author of this paper is Tom Armstrong, Senior Associate, IndEco Strategic Consulting Inc. It was prepared as a background paper for Environment Canada's workshop on *Sustainable Consumption and Production* which was held in Ottawa, 25-27 May 1997. Comments on the paper may be directed to Tom at tarmstrong@indeco.com , or by mail to IndEco Strategic Consulting Inc., Suite 302 – 2 Pardee Avenue, Toronto ON Canada M6K 3H5. Prior to finalizing the paper, it was reviewed by Diana Cartwright of the Delphi Group, Kevin Brady and Andie Paynter of Environment Canada, and members of Environment Canada's advisory group. Their input is acknowledged.

- *Design and extended producer responsibility* – increasing acceptance by producers of responsibility for their products after sale will ensure that post-sale management of these products will increasingly come into the design equation. If the producer has no responsibility for reuse, recycling or disposal, there is little incentive to design products that are durable, easily disassembled for recycling, or biodegradable.
- *Design and economics* – many companies have discovered that there are economic advantages to changing designs towards being more sustainable, whether because they are easier to market or cheaper to produce. Better accounting systems that account for the full life-cycle effect of a product or service, and the environmental impacts it creates, can be expected to provide additional information that will influence the design process. Similarly, a carefully constructed set of economic instruments may provide the incentives needed to lead to design changes that help move towards sustainability.

This paper provides an overview of Design for Sustainability by examining the concepts of Design for the Environment, Eco-Efficiency and Industrial Ecosystems, and the specific factors associated with each. Leading-edge examples by government and industry world-wide are provided. Design for sustainability in Canada is then discussed by examining example initiatives by government and industry. The barriers and obstacles in moving towards design for sustainability in Canada are identifieded as are opportunities and issues raised.

B. Definition of Terms

Design for Sustainability (DFS)

Design for Sustainability is the process of designing goods and services that takes into account all the dimensions of sustainable development, and particularly environment, economics, and social factors. As such, it is a superset of the more commonly discussed "Design for Environment". [Note: Some authors have suggested that Design for Sustainability is the subset of Design for Environment that includes Design for Environmental Protection and Design for Resource Conservation (Fiksel 1996).]

Design for Environment (DFE)

Design for the environment is the systematic consideration during design, of issues associated with environmental safety and health over the product life cycle (Fiksel 1996). DFE can be thought of as the migration of traditional pollution prevention concepts upstream into the development phase of products before production and use. The goal of DFE is to enable design teams to create eco-efficient products without compromising their cost, quality, and schedule constraints. It must be integrated seamlessly into the development process, from the analysis of customer needs and

establishment of product requirements to the verification these requirements have been fulfilled.

The development process may be considered as "Design for X" where X represents not only the environment but other parameters such as assembly and disassembly, compliance, manufacturability, reliability, serviceability and quality. There is considerable synergy between some of these parameters, such as assembly and manufacturability, and DFE.

DFE takes many product development aspects into account:

- material selection,
- energy use
- extended component life cycles
- disassembly,
- reuse
- recycling
- reprocessing/remanufacturing
- packaging

DFE is in its infancy and thus standards do not exist. It involves many complex trade-offs with steadfast rules hard to find. A number of companies have developed guidelines to assist engineers in designing for the environment. These guidelines usually contain long checklists which include:

- *Material Recovery and Reuse*-avoid composite materials, standardize materials and fasteners, specify recyclable materials
- *Disassembly*-facilitate means of component separation, avoid permanent attachments of dissimilar materials such as welds
- *Simplicity*- develop common designs for multi-functional parts
- *Waste Minimization*-reduce product size and weight, reduce packaging
- *Energy Conservation*-reduce energy used in production and product power consumption
- *Material Conservation*-design multi-functional products and parts, specify recycled and renewable materials, use remanufactured components, design for product longevity and performance, design for closed loop recycling

While some companies have incorporated these items into software programs, there are limited generic software packages on the market to assist companies starting to design for the environment.

Eco-Efficiency

The term "eco-efficiency" was first coined in 1992 by the Business Council for Sustainable Development in its landmark report, 'Changing Course'. Eco-efficiency was further defined at the first Antwerp workshop on Eco-efficiency held in November 1993, as being 'reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the earth's estimated carrying capacity'.

In other words, eco-efficiency may be seen as the goal, and Design for Environment as the means to achieve the goal.

The purpose of eco-efficiency is consistent with that of sustainability, but it is not as comprehensive or far reaching. Eco-efficiency may be thought of as a stepping stone towards sustainability.

Creating Industrial Ecosystems

The most complex form of sustainable design is creating Industrial Ecosystems. These are characterized as the design of whole systems of processes, industries, products or combinations of these that interact with each other and the natural environment as if they were a natural (sustainable) ecosystem. Creating industrial ecosystems is done using the tools and methods of design for the environment, pollution prevention, and total quality environmental management as a road map for the transformation of industrial systems toward sustainability.

An "industrial ecosystem" may consist of one company or involve many companies. A prerequisite to Industrial Ecosystems in all cases, however, is design for the environment.

II. Background and Overview

A. Understanding the Design Process

There are many questions which must be addressed within the design process. Compliance with legal requirements is a prerequisite. Market research into customer preferences is needed so that products may be designed to be marketable. Technology and accurate accounting of costs must also be part of the design process.

What does the market want?

As outlined in the Sustainable Consumption and Procurement papers, consumers exert considerable influence on the design process through their purchasing decisions. From the design perspective, there is no value in designing and manufacturing sustainable products, even if they are the most desirable from every point of view, if consumers will not purchase them.

What do regulations require?

Regulations may impose certain conditions on design that affect or specify its environmental performance. In particular, some jurisdictions dictate such things as energy performance, recycled content, and maximum allowable emissions. In addition, governments have recently begun to place increased reliance on other policy mechanisms which they hope foster progressive, creative and innovative actions that go beyond compliance. These include voluntary programs and marketplace initiatives. Examples of such programs include the Environmental Choice and Energy Star eco-labeling programs, voluntary programs to reduce toxics, like the ARETs and 33/50 programs in Canada and the United States respectively, and the National Packaging Protocol (Canada). All these programs impinge on the design process.

Are new technologies reliable?

Companies are relatively comfortable with the traditional control technologies needed to meet command and control legislation and regulations, because control technologies are well established and understood. As companies move beyond compliance, however, they are encountering technologies with limited track records and applications. While there are many emerging technologies today for industry to use to design for sustainability, it is difficult for companies to determine which are best suited to their operations. The larger companies have the ability to research the applicability of the prospective technologies, but the small and medium ones may be constrained by limited resources.

What is included in the accounting framework?

One of the reasons companies view environmental action as a net cost item is the lack of comprehensive accounting systems which take all costs into account and allocate them to the proper areas. For example, the costs associated with bringing a new toxic material into commerce, providing worker protection, and then handling and disposing of the material may outweigh the costs of using a less harmful, alternative material and/or process, but wouldn't be recognizable unless the accounting system takes these associated costs into account. This is one of the most important issues for the private sector to develop and implement.

Who really controls the design process?

A prerequisite to the design process, is getting buy-in from senior management who must make the commitment to design their products and processes for the environment. Once this commitment is made, it is then the role of the environmental professionals to translate the company vision and policy into language that design engineers understand and can utilize. Design engineers must address all design criteria, including environmental criteria, concurrently. Of particular importance is the need for ownership and accountability within the product design teams if the design effort is to result in environmentally sound products. The designers consider all stages of the life cycle, from cradle to reincarnation; with multiple life cycles of products, there is no grave.

B. The Driving Forces behind Design for the Environment (DFE)

Companies are receiving strong signals from their stakeholders that environmental stewardship is an essential business function. The driving forces that influence the adoption of DFE include the following:

- *Customer Awareness* - market research shows that customers prefer buying products with environmental integrity from environmentally responsible companies, providing the products are of equal quality to conventional products, and they have the same warranties and guarantees.
- *Eco-Labeling Programs* - many countries now have labels which make it easier for customers to recognize environmentally sound products. Although ostensibly targeted at consumers, these programs also encourage manufacturers to make environmental improvements to their products, if not for market differentiation, then to maintain market share.
- *Profitability Improvement* - a "green" approach to the design of products and processes may have a significant impact on product line profitability through savings in manufacturing and other operating costs, as well as through increased market share.
- *Regulatory Pressures* - government regulations regarding the environmental impacts of products and production processes are becoming more stringent, especially requirements related to the disposal and recycling of products at the end of their useful life.
- *International Standards* - the adoption in late 1996 by the International Organization for Standardization (ISO) of the 14000 series of standards for environment management systems provides a means for customers to differentiate among companies. To become registered to ISO 14001, companies must commit to regulatory compliance and continuous improvement. These commitments are likely to push firms to implement many aspects of DFE.

- *Employee Satisfaction* - employees and their families are increasingly conscious of their responsibility to the environment. Incorporation of such values into business activities contributes to positive feelings about their workplace.

C• Leading Edge Practices by Industry Worldwide

Many designers have explicitly or implicitly taken environmental considerations into account for decades (e.g. Papanek 1971). However, in the 1990s, Design for Environment has emerged as an explicit consideration on a much wider scale than previously. Several examples are briefly described.

Electrolux integrates the environment into business strategy

Electrolux is a leader at integrating the environment into its business strategy. The Electrolux vision emphasizes the design of products for environmental sustainability, and applies to all Electrolux operations worldwide. It is inspired by the life cycle philosophy and systems overview found in the principles for sustainable development put forth by The Natural Step Foundation. These principles are (Robert 1996):

- Nature cannot sustain a systematic concentration of matter removed from the Earth's crust;
- We cannot produce man-made products and compounds to a greater extent than they can be broken down and rebuilt into new quality;
- We must not exploit natural resources more than nature can build up new resources;
- We need a just and efficient economy.

Electrolux operates on the basis that environmental protection is a long-term issue for individuals, companies and society. They sell approximately 55 million products annually (household appliances, garden products, food service, refrigeration equipment, etc.) which are designed to minimize energy usage, reduce noise, phase out CFC's, and reduce the number of parts to facilitate disassembly and reuse. Liquid, solid and gaseous wastes from processing have been reduced significantly. The solar lawn mower typifies the advances made by Electrolux. The mower is powered by 34 solar cells which transform sunlight into electrical energy.

Part of Electrolux's strategy is to capture "niche" markets, such as the market for water efficient appliances in the Middle East, where water is very expensive. The company's expectation is that the demand for such features will become more widespread over time, and they will have a lead over their competitors in designing these features into their products.

Sony designs "green" TVs

Sony learned the hard way the costs of not having state-of-the-art design for environment when its market share for televisions in Europe fell by 13.5% after a Dutch consumer magazine rated the Sony TV as only a "reasonable" buy, in part because its environmental performance was worse than some of the other models tested (WBCSD 1997).

Sony has implemented several programs to improve the environmental performance of its products. These programs incorporate changes to the design and production processes, as well as to the design of the product itself. Some of the specific initiatives introduced include:

- Creation of a "Product Disassembly Evaluation Workshop" to provide input to design and marketing groups;
- Creation of motivation and management projects targeted at the design and marketing groups;
- The introduction of the first version of a TV with easy disassembly/recycling characteristics;
- Marketing of TV sets built using new molding and tool technologies that reduce material usage and varieties of plastics;
- Incorporation of 100% recycled material into the chassis frame, using only halogen-free flame retardants and water-based lacquers for plastic parts, and cutting by more than 50 percent stand-by mode electricity demand (from 10 to 4.5 watts); and
- Development of a program to design a 'green' VCR.

Siemens has made DFE a binding corporate standard

This major world-wide supplier of power generation and transmission systems, and electronic products and systems, was one of the first major European companies to elevate the design of environmentally compatible products to a binding corporate standard. They applied a holistic approach and emphasized reduction of materials, reducing energy consumption, labeling material contents, and disassembly and reuse. The information obtained during the disassembly and recycling process is deemed to be invaluable in the design of new products. Some of the specific design changes Siemans has adopted are typical where DFE is practiced:

- new computer housings are no longer painted since paint renders the plastic non-recyclable.
- assemblers do not rivet fans into housings any more, as they now use clips for easier disassembly.
- each new computer's plastic components are identified by type and additives.

Volvo's design process is driven by its Environmental Priorities System

Environment, safety and quality are three core values at Volvo, where an Environmental Priorities System (EPS) has been established to assess the environmental and human health impacts of products and processes. Features of proposed product designs are put into a computer system that derives a composite score of environmental impacts. On this basis, alternative materials and product configurations can be evaluated to establish an optimum design.

The EPS system assists design engineers in the selection of environmentally preferable materials for product construction. In one case, two technically equivalent constructions for the front end of a car, one using a plastic composite and the other galvanized steel, were compared. Environmental Load Units were calculated for production, product use, and product disposal at end of life for each material. The plastic construction proved to have a lower overall environmental impact. The galvanized steel received a less favourable score because its heavier weight increased fuel consumption during product use.

In addition, an innovative attempt at recycling vehicle components has been undertaken through the commissioning of the ECRIS (Environmental Car Recycling in Scandinavia) facility in 1994. It has been established to develop efficient methods of vehicle dismantling and sorting of environmentally hazardous substances and recyclable materials, test various recycling and recovery methods, and evaluate the market for recycled materials. This information has been instrumental in the development of a design for dismantling to facilitate reuse and recycling of parts. In two test models, the application of life cycle design has driven the reuse and recycling rate to over 90%.

An "industrial ecosystem" Kalundburg, Denmark

The most celebrated example of an Industrial Ecosystem in a multi-plant setting is in Kalundburg, Denmark. Here, there are five core partners: a power station, refinery, plasterboard plant, biotechnical plant, and municipal water and heating system. Over the last two decades these partners have exchanged a number of materials, with the benefit to the environment being reduced emissions (130,000 tons CO2, 3700 tons SO2) and waste residues (135 tons fly ash, 2800 tons sulphur, 80,000 tons gypsum, 800 tons nitrogen). Interestingly, this web of reuse and recycling was not designed but evolved. It grew as a result of close proximity, managers working together, mutually beneficial needs, and a recognition that what benefits the environment also is commercially sound and profitable.

D. Research Institutes

Design for sustainability is being integrated into academic and applied programs around the world, as its value and importance become more apparent. The number of universities and institutes with programs is growing rapidly, and the three presented

here are examples of some of these programs. Other organizations with notable programs include the University of Tennessee, the University of Michigan, Delft University and the University of Amsterdam. In Canada, the University of Windsor has set up the Environmentally Conscious Design and Manufacturing Lab.

National Centre for Design at RMIT, Australia

A DFE program has been funded by the Australian Environmental Protection Agency to facilitate a rapid response from the Australian manufacturing sector to a critical new demand for environmental quality in the international market for manufactured products. The National Centre for Design at RMIT helped develop this research capability through a series of collaborative projects with Australian manufacturers. The manufacturers agreed to commit their resources to a major redesign of an existing product to reduce its total life cycle environmental impact. Participants will assess energy efficiency, waste minimization, resource conservation, design for disassembly and recyclability, and incorporating recycled and/or recyclable materials and components. Other areas of study are reducing or eliminating greenhouse gases, eliminating ozone depleting substances and other hazardous materials, using product design to educate consumers about the environment, and developing strategies for product recovery and recycling.

Rocky Mountain Institute (RMI)

RMI recognized that automobile manufacturing and use leads to a wide range of environmental effects. These include generating 18% of the global carbon dioxide emissions. A team at RMI challenged the automotive industry to radically redesign vehicles to attain dramatic environmental achievements. They called this redesigned vehicle the Supercar. The supercar is an ultralight, highly aerodynamic vehicle powered by a small electricity generating engine. The engine transmits current to drive mechanisms in the wheels, which also recapture energy from braking (up to 70%). Highly energy efficient accessories also reduce energy demand. Body and frame design with strong composite materials provide passenger safety higher than in traditional vehicles at almost one third the weight. Selective use of super-strong carbon fiber and other composites will reduce the number of body parts and simplify production and assembly. The RMI performance models indicate that Supercars would be 100 times cleaner than present cars.

RMI has also done extensive research on buildings, energy-efficient technologies and renewable energy sources. The Institute is noteworthy because its approach to design is comprehensive. It is not interested in small, incremental improvements alone, but has demonstrated that in combination, these can often produce dramatic reductions in resource requirements, ranging from 75 to 90% and beyond.

Carnegie Mellon University, U.S.

Carnegie Mellon has undertaken a research effort to improve environmental quality through green design. Partnerships are being formed with companies, government agencies and foundations to develop pioneering design, management and manufacturing processes that can improve environmental quality and product quality while enhancing economic development. Through the green design initiative, products and processes can be produced which will cost less and pose fewer threats to workers, consumers and the environment.

III. Design for Sustainability Practices in Canada

The following examples illustrate design initiatives in Canada.

A. Government Initiatives

Governments in Canada have adopted a number of initiatives that have affected the design of products and reduced environmental effects, though these have not been officially characterized as Design for Environment programs. Two such programs are Canada's R-2000 Home Program, and the Environmental Choice Program.

The R-2000 Home Program

In the 1970s, Canada was a leader in research into highly energy-efficient homes, such as the Saskatchewan Conservation House. This research eventually led to the development of Canada's R-2000 Home Program. The program has been recognized for leading edge design of energy efficient and environmentally sensitive residential construction. R-2000 homes are designed, tested and certified to meet exacting technical standards that exceed conventional building codes.

R-2000 homes feature:

- continuous ventilation systems;
- environmentally friendly materials and equipment;
- advanced heating and cooling systems; and
- energy efficient appliances, lighting, windows and doors.

The benefits of an R-2000 home include: better air quality, less noise and dust, fewer drafts and cold spots and lower energy bills.

It was logical for Canada to demonstrate leadership in developing energy efficient homes for several reasons:

- Canada was already a leader in residential design and construction,

- the domestic market was served overwhelmingly by a domestic (almost cottage) industry, and,
- with severe winters there exists a significant opportunity for substituting capital investments for operating costs.

The program shows how governments can encourage design changes by working with industry, and sponsoring research and development. However, the impact of the program has been limited; only a small percentage of new Canadian homes qualify as R-2000 homes.

The Environmental Choice Program

The Environmental Choice Program, an eco-labeling program, influences producers, as well as consumers. For example, the reduction in the volatile component of paints in Canada can be attributed, at least in part, to industry competition for Environmental Choice certification. Even where labeling programs do not induce competition, they can encourage producers to revise their designs to meet or exceed the criteria required for certification.

B• Industry Initiatives

Some Canadian industries have adopted DFE principles and practices, including Xerox Canada and Nortel. These industries are leaders in their markets, and their programs are up to the standards of the international programs discussed above.

Xerox Canada

Xerox Canada has moved closer to sustainability through a series of initiatives. First, senior management made a commitment to environmental leadership through the adoption of the environment as a business priority. Products are now designed for the environment, with one of the company requirements being attainment of the Environmental Choice "EcoLogo", for all its new products. Xerox has always subscribed to the principle of reuse and has employed DFE practices to dramatically reduce the amount of material entering the waste stream. An arrangement with Canada Post makes it easy for customers to return spent parts and consumables such as cartridges for reuse and recycling. Equipment is disassembled at the end of each life cycle and the maximum number of components are restored to original equipment specifications and reused in an ISO 9002 certified manufacturing process. The result of these efforts has been to minimize the material entering the waste stream. Currently, they are recycling at a 94% rate at their Mississauga plant. Xerox is also planning to register all their plants worldwide to ISO 14001 in 1997.

Nortel

As the world's leading supplier of digital products and Canada's premier designer and manufacturer of telecommunications products, Nortel is well positioned to demonstrate leadership in design for the environment. They are combining with Environment Canada to undertake a full life cycle assessment (LCA) of a telephone terminal. This joint project will increase Canadian capacity in both LCA and DFE. The goals of the study are to demonstrate how LCA can be applied to design more environmentally preferable products. The baseline analysis examines the existing product system and includes consideration of materials and energy inputs, manufacturing and assembly processes, distribution requirements, product use and end-of-life considerations. Several scenarios were considered to identify product system improvements leading to potential reduced resource requirements, reduced waste and emissions, and efficiency improvements.

IV. Design for Sustainability in Canada-The Future

A. Opportunities for Canadian Business

It is apparent that companies can design products for the environment and achieve economic, social and environmental benefits. The opportunities for Canadian business however, are greatest in the markets which are controlled in Canada, or in situations where Canadian companies collaborate with trading partners elsewhere. This is because many of the manufacturing plants in Canada are part of multi-national companies, which design for markets throughout the world. In these cases, there is no need or opportunity for the design of products in Canada. It follows that the opportunities are in Canadian specific markets such as housing, niche global markets, or through international collaboration.

B. Limitations to Sustainable Design in Canada

Some of the limitations to furthering design for sustainability in Canada are:

- lack of recognition by both consumers and producers of the value of products which have been designed for sustainability;
- pollution prevention technologies are not applicable to a wide cross section of products; and
- the Canadian market is too small (about 4% of global market) to influence designers. Products incorporating DFE will need to be competitive internationally.

C. Issues for Discussion

1) *Integrating sustainability into Core Business Objectives*

While some companies have crossed this threshold, many still view the environment as an added cost of doing business. The leading companies have demonstrated that integrating sustainability into their Core Business Objectives can provide economic benefits.

- How can Design for Sustainability be promoted more within Canada?
- How can business be made aware of the successes companies have had with DFE, and the corporate benefits that have resulted?

2) *Improving design capacity*

Designers and their clients need to be more aware of the tools for Design for Sustainability and the benefits of applying them. The schools in Canada could provide the necessary training for designers if there was a demand for graduates. A prerequisite to increased demand is the commitment of senior business executives.

- How can senior executives be reached?
- Should there be a specific organization with the mandate to promote Design for Sustainability in Canada?

3) *The real cost of designing for sustainability*

True cost accounting procedures have to be instituted for the real cost to be determined. Without the benefit of an accurate cost, an evaluation of the merit of designing for sustainability cannot be established, and may be abandoned for this reason.

- What initial steps could be taken to move business towards true cost accounting?

4) Government and NGO responsibilities

Governments and non-government organizations can promote designing for sustainable. Governments can influence the design process through regulation, by introducing voluntary programs, and by providing economic incentives or

disincentives. A major challenge is to do these in a way that encourages innovation and creativity. NGOs can also encourage innovation and creativity, sometimes by forming partnerships to promote designs that address the goals of both partners.

- Should voluntary agreements just be used as a stepping stone to future legislation, or are they an effective long-term solution?
- How can government policies be formulated which specify performance, without dictating the technological solution?
- How can partnerships between industry and NGOs be encouraged so that win-win solutions can be worked out, while protecting each party's integrity?

5) ***Canadian initiatives***

While Canadian companies may appear to be slow off the mark in the drive to sustainability, the size of their market and demands of their customers are usually the determining factors.

- In what sectors has Canada demonstrated leadership, and how can this be built on?

6) ***The value of niche markets***

Some European companies, like Electrolux are pushing into "niche" markets with products that address specific local environmental issues. By the time these issues are more broadly recognized, they plan to be market leaders, and their competitors will be playing catch-up.

- Which sectors or products offer niche opportunities for Canadian industry?

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