A PRIMER FOR
SUSTAINABLE TECHNOLOGY AND DEVELOPMENT

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A commitment to sustained and sustainable development requires us to reconcile our desire to improve the quality of our lives with the limitations imposed on us by our global context and the need to consider our actions over greater lengths of time. Sustainable development requires innovative solutions for improving our welfare that are derived from practices and technologies that work harmoniously with earth's systems and across diverse groups of people.

Although there is no general agreement regarding the precise definition of sustainable development, most interpretations of the term "sustainable" refer to the availability of natural resources and ecosystem functioning over many generations, and to the enhancement of human living standards through ecologically sound economic development. The United Nations defined sustainable development as (The UN World Commission on Environment and Development, 1987):

… development that meets the needs of the present without compromising the ability of future generations to meet their own needs…

Social Considerations for Sustainable Development

The social dimension of sustainable development involves taking into account the factors that encourage or discourage individuals, businesses and governments from acting in a sustainable way. Some of these factors are integrating scientific and engineering knowledge with private and public decision making and understanding the cultural and political values that affect the creation and distribution of wealth—both in the current generation (intra-generational equity) and in considering the welfare of future generations (inter-generational equity).

A SUSTAINABLE SOCIETY MUST SEEM DESIRABLE—TO ME

Most proponents for sustainable development aren't trying to "save the world". They're trying to help make the world a more desirable place in which to live, today and tomorrow. This implies that some aspects of basic human nature need to be considered in a strategy to promote creation of a more sustainable society. At the most fundamental level, **people need to perceive that the quality of their lives in a more**

sustainable society will be at least as high as it is today. This doesn't necessarily mean that the quality of our lives is defined by material wealth.

This conclusion is borne of practical considerations. According to many social scientists, few rationally self-interested persons would voluntarily sacrifice their own standard of living without some compensating benefit. We don't completely eliminate the possibility of altruism, but a strategy to promote the creation of a more sustainable society needs to be based on meeting individual aspirations more broadly. We need to assure that those who commit to changing their lifestyles perceive the personal benefits that will be associated with their commitment.

Meeting the Needs of the Present

Perhaps the most difficult challenge to creating a more sustainable society is the large difference in living standards between people living in developed versus the developing nations. An agenda that takes into account intra-generational equity presents two types of challenges: providing resources for basic survival for the poorest people in the world and accommodating the aspirations of people for higher standards of living in both developing and developed nations.

When people are concerned for their very survival, and may lack human rights, it is difficult to engage them in a global agenda for sustainable development. Of course, the definition of basic survival is culturally dependent. But in situations where fundamental biological survival is threatened, as it can be in the famine-struck regions of Africa or in our turbulent inner cities, the first step towards intra-generational equity is to improve living conditions.

But conditions which merely support basic, biological survival do not determine what many would call a high quality life. **It has been estimated that if the current world population lived at the standards of the world's wealthiest nations, it would require three times the resources available on Earth.** (Wackernagel and Rees, 1996) Clearly, we cannot afford to do this, but how do we proceed?

Numerous social movements address this question, including those aimed at promoting democratic processes and human rights, redefining progress and prosperity, restructuring commerce and the global economy, and rethinking the design of technologies. Sustainable development is not a political movement; instead it encourages individuals and organizations—whatever their ideology or culture—to take into account a wider range of factors that will help them achieve their goals.

Allowing Future Generations to Meet Their Needs

The term "capital" is traditionally interpreted as the financial and technological resources available to achieve a desired economic outcome. There are other uses of this term relevant to our discussion of sustainable development: natural capital is the stock of natural resources and the productive capacity of ecosystems; and social capital is the intellectual, political, spiritual and other societal resources that support the functioning of our communities.

A strategy to promote inter-generational sustainability needs to **provide capital**

resources—economic, natural and social—so that future generations can determine the best course of action to meet their needs. This doesn't necessarily imply that the exactly identical resources need to be available, but a comparable set. This obligation has been interpreted in various ways in the sustainability literature, ranging from leaving the nonrenewable resource base completely unchanged from its present state, to using nonrenewable resources as necessary provided that adequate substitutes are created.

Progress toward a sustainable society will require great scientific and engineering ingenuity. It also will depend on a more complete understanding of the social systems that decide which technologies to develop and how they will be used. A commitment to pursue sustainable technology and development offers enormous opportunities to advance our knowledge, to create new markets, and to improve the ways that individuals and institutions make decisions about science, technology and development

In the past century, we have witnessed the tremendous capacity we have for adaptation and innovation. While future generations will benefit from the intellectual capital accrued throughout history, **we cannot rely on technological ingenuity to replace all resources**.

TECHNICAL CONSIDERATIONS FOR SUSTAINABLE TECHNOLOGIES

The technological aspects of the challenge to create a more sustainable society—our design considerations—can be explained in terms of: (1) the *quantity* of material and energy resources available; (2) the *balance* in the rates at which those resources are harvested, transformed and recovered; (3) the *quality* of those resources; and (4) the *way* in which those resources will be used. In this section we will discuss the basis for several important factors that need to be considered in the design of more sustainable technologies.

QUANTITY OF MATERIAL AND ENERGY RESOURCES

The quantity of matter that we have on Earth is finite. We cannot create more matter, nor can we destroy it since the application of nuclear technology for waste management is currently impractical. When we throw away our trash, or burn it, the materials are merely transformed into compost, incinerator ash or gases. In simple terms, in a finite system, the more material we discard, the less there is available to use in the future.

Just as the amount of available matter on Earth is finite, the amount of energy available is not unlimited. Currently, most of our energy is derived from the sun. This energy is converted to chemical energy by photosynthesis or is trapped in the atmosphere as heat. Fossil fuels represent energy from the sun which was trapped eons ago in a complex process which would be difficult and costly to reproduce. Thus, the fossil fuels are considered non-renewable resources.

Given the current apathy to the use of nuclear energy, some have stated that a truly sustainable society would live within the "solar budget", using only the current influx of solar energy to sustain ourselves. However, before we can begin living within our solar budget, we need to take actions that improve the performance and affordability of renewable energy sources. During the transition we need to **use nonrenewable resources at rates that accommodate the development and deployment of renewable substitutes.**

So, the first design consideration to be implemented to create sustainable technologies is that they should **satisfy our functional needs by using as few material and energy resources as possible**.

Beyond merely limiting the use of resources, we need to enhance the methods of re-using matter and, where possible, energy. Nature has evolved interlocking systems that enable waste to become the feedstock for a new generation of plants and animals. In the biosphere, carbon, oxygen and other atoms that form the basic building blocks of life, are cyclically structured, transformed, consumed, decomposed and restructured by a variety of natural processes. We need these natural systems to continue to perform their recycling functions so that our finite material resources are made available for use again and again.

We need healthy ecosystems to generate and regenerate the basic foundations of life, and to produce the goods and services that enhance the quality of our lives. Ecosystems produce goods (seafood, timber, fuels, raw materials for pharmaceuticals and other industrial products), purify air and water, maintain biodiversity, partially stabilize the climate, and provide beauty Therefore, we need to be concerned with the ecological impacts of both the selection of materials we use and also the impacts associated with the manufacture and use of the goods produced.

So, another technological challenge is to develop sustainable technologies and methods of manufacturing which, **minimally disrupt or impair ecological functioning**.

There are substances that are very difficult to break down by natural processes. These persistent and bioaccumulative substances move through the food web and result in unanticipated, and potentially harmful, exposures. Many of these substances are agricultural or industrial chemicals, some are unintentional waste products and contaminants. Exposure to such substances, e.g., PCBs and chlordane, can lead to cancer, damage to the central nervous system, diseases of the immune system, reproductive disorders and interference with normal fetal and child development.

There are numerous international programs focusing on the elimination of persistent and bioaccumulative substances from the products and processes we use. In some cases in developing countries, the short-term social benefit gained by continued use of some pesticides requires that a phase-out period be established while viable alternatives are developed. Over the long haul, however, we should ensure that the products and processes we design **do not generate, or unintentionally create unwanted, persistent and bioaccumulative substances.**

IT'S A MATTER OF BALANCE

On a global scale, we often conceptualize the earth's systems in terms of those that describe the atmosphere and the physical climate, the interactions between the atmosphere, oceans and the weather (the hydrogologic cycle) and the interactions between the biosphere, atmosphere and hydrosphere (biogeochemical cycles). The "balance" in these systems refers to the rates at which compounds (such as CO_2) and energy (heat, for example) are emitted, assimilated and regenerated by earth's systems. The many products, processes and practices we use in society need to be designed to **work in harmony with the natural limits of the assimilative and regenerative capacity of earth's systems.**

Let's look at the carbon cycle to explore this further. Carbon, in the form of carbon dioxide in the atmosphere, is taken up by plants and, through photosynthesis, is converted to new plant growth. In turn, carbon dioxide is generated and released to the atmosphere by human, animal and plant respiration, and the burning of plants, trees and fossil fuels.

Scientists and policy makers are concerned because the carbon dioxide generated by our use of fossil fuels may exceed the capacity of forests and other natural systems to assimilate it. Furthermore, the demands of a growing population for settlements and agricultural land may hasten the demise of vital forest ecosystems. The result is a net increase in carbon dioxide in the atmosphere.

This build-up of carbon dioxide in the atmosphere is one of the factors that may cause global climate change. Potential changes in our climate strike directly at the quality of our lives. Among other things, they can result in changing agricultural patterns, changes to coastal areas, and changes in the use of energy in established communities.

Just as the destruction of forests contributes to the imbalance in carbon cycle, we can create other forms of imbalance by harvesting other natural resources, for example timber or fish, at rates that are faster than they can be replaced. Thus another challenge for sustainable development is to **use renewable resources that are harvested at rates no greater than their sustainable regeneration rates.**

The Quality of Material and Energy Resources

Quality matters. The "quality" of matter and energy can be defined in terms of our ability to use them to meet our needs. Utility, in turn, can be related to the degree to which resources are structured or ordered, or that the stored energy they contain is available for our use. For example, the structured chemical energy embedded in an unlit match usually has greater potential utility than an equivalent amount of sound energy in the form of noise.

A fundamental challenge to maintaining the quality of our resources is the natural tendency of these resources to become less structured. We observe such tendencies every day: the cup of steaming hot coffee that gives up its heat to the surrounding area and becomes cold; the refrigerants that leak from our cars' air conditioning systems; or an orderly office which rapidly becomes cluttered. The degree of disorder in a system is usually inversely related to its potential utility.

Every time we expend energy and produce goods, we increase the amount of disorder in the global system. Another way of stating this is that we reduce the quality of the resources available for other uses.

The concept of recycling is not new, but we've only recently begun explicitly designing our technologies, up front, for recyclability. We've seen aluminum cans recycled into more cans and plastic bottles turned into parking lot bumpers. These same plastic bottles could have had their matter and energy reduced in quality by incinerating them to release their energy, but instead they have been used is a way that partially maintains the quality of the plastics which compose them. At any time, the parking lot bumpers can still be incinerated, but meanwhile we have provided an intermediate step in the ultimate degradation of the material which composed the plastic bottles.

The key is not only to recycle the materials, but also design products so that they **preserve the quality of their constituents over their useful lifetimes** and are more amenable to recycling. More sustainable technologies should also be designed so that they **require as little energy as possible for recovery, recycling and reuse of their constituent resources.**

USING RESOURCES WISELY

We began our discussion of sustainable development with an overview of the ethical imperative to use our limited resources to "meet the needs of the present generation without compromising the ability of future generations to meet their needs". We then focused on the scientific underpinnings of the design guidelines for more sustainable technologies. Before we summarize our technical discussion, **we need to remind ourselves that the challenges to creating a more sustainable society go far beyond designing better technologies**.

There's an old saying that a good engineer will design a bridge for you, but a great engineer will ask you whether the bridge needs to be built in the first place. This is an important message for the designers of technologies. Sustainable technologies are not independent of their social context. Their design will reflect individual values and choices made within the larger context of corporate and national strategies to compete for and develop scarce resources. We need to make sure that we always ask whether the products and systems we create are **worth the expenditure of our limited time and resources.**

A Summary: What Can We Do?

What are the design considerations for technologies that support a more sustainable society? In order to assure that the material resources we have on earth are available for generations to come, we need to design products and processes that…

- ✔ use nonrenewable resources at rates that accommodate the development and deployment of renewable substitutes
- ✔ satisfy our functional needs using as few material and energy resources as possible,
- ✔ minimally disrupt or impair ecological functioning,
- ✔ do not incorporate, or unintentionally create unwanted, persistent and bioaccumulative substances

- ✔ work in harmony with the assimilative and regenerative capacity of earth's systems,
- ✔ use renewable resources which are harvested at rates no greater than their sustainable regeneration rates,
- ✔ preserve the quality of constituent resources over their useful lifetimes,
- ✔ use as little energy as possible for recovery, recycling and reuse, and
- ✔ only do those things which are worth the expenditure of our limited time and resources.

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FOR MORE INFORMATION

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Georgia Tech's Institute for Sustainable Technology and Development, http://www.istd.gatech.edu

Second Nature's Starfish Website, http://www.2nature.org/programs/starfish/sfhome.nsf and (Resources for interdisciplinary education for sustainability)