

Second Nature

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Engineering Education for a Sustainable Future

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Introduction

It is a great honor and privilege for me to participate in this important conference on the education of engineers to help society move on a more sustainable path. I wish to thank the World Federation of Engineering Organizations (WFEO), United Nations Environment Programme (UNEP), World Business Council for Sustainable Development (WBCSD) and École Nationale des Ponts et Chaussées (ENPC) for organizing and sponsoring this conference and for inviting me to be involved. I acknowledge with great enthusiasm and admiration the outstanding and relentless leadership that my good friend and colleague, Madame Jacqueline Aloisi de Larderel, UNEP-IE Director, has brought to the international movement for sustainable development, particularly with business and education. I recall with great pleasure, the first international conference on business education and the environment that she initiated at INSEAD in October 1990 along with the Management Institute for Environment and Business and Tufts University where I was serving as Dean of Environmental Programs.

The Need for a New Human Perspective

This conference comes at a critical time in the history of the sustainable development movement and addresses one of its most significant issues – changing the mindset of society's leaders to move on a sustainable path. An unprecedented change in mindset and, therefore, education is **crucial** to implementing all of the recommendations and agreements of international bodies and individuals concerning sustainable development. Moreover, the change must be accomplished in the next two to four decades.

In the last four decades, the population of the world has more than doubled to 5.9 billion people and the world's economic output has increased fivefold.

This unprecedented growth is altering the face of the earth and the composition of the atmosphere. Pollution of air and water, accumulation of wastes, destruction of forests, erosion of soils, depletion of fisheries, and damage to the stratospheric ozone layer threaten the survival of humans and thousands of other living species. Humans are conducting an uncontrolled experiment unprecedented in scope and scale that represents the reversal of natural evolution which produced clean air and water and increasingly complex and diverse ecosystems – systems which made human evolution possible.

These changes, a result of unsustainable and inequitable patterns of production and consumption, are likely to accelerate with the addition of 81 million people to the planet each year. In *Changing Course: A Global Business Perspective on Development and the Environment*, Stephan Schmidheiny, chairman of the Business Council for Sustainable Development, points out that we are a society living off its natural capital, not its income. We are acting like a planet in liquidation. Schmidheiny calls this bad business.

Current strategies to meet human needs are not sustainable. Eighty percent of the world's resources are being consumed by 20 percent of the world's population. The world's poorest 20 percent earn 1.4 percent of the world's income. According to the UN, the income ratio of the richest 20 percent to the poorest 20 percent was 28:1 in 1960; it was 60:1 in 1990. For 30 percent of the world's population, poor sanitation, malnutrition, and air pollution are still the major causes of illness and death. The rural poor will increasingly migrate and be transformed into an urban poor, and environmental health and social problems will multiply. **By the year 2005, for the first time in history, more people will live in urban than in rural areas.**

In the US, air pollution is believed to kill more people than automobile accidents – more than 60,000 premature deaths per year according to the EPA. By the time population growth stabilizes in the next century, a 5- to 7-fold increase in consumption of energy and goods will be needed just to raise the consumption level in the developing world to that in the industrialized world. Agricultural production must increase 3-fold in the next 40 years for all humans to have adequate nutrition – we are already appropriating the most productive 40 percent of the land-based biomass for human purposes. **Simply to maintain the current unhealthy levels of pollution and waste loadings will require an 80–90 percent reduction in pollution generated per unit of economic output.**

The world will need an unprecedented 2 billion jobs in the next 20–30 years to employ the current 800 million underemployed and unemployed people and the new job seekers that will enter the market. This cannot be done with economic activity that substitutes capital for labor (according to Paul Hawken from 1978–1990 in the last twelve years the Fortune 500 companies have eliminated four million jobs), consumes large amounts of materials and energy and creates large volumes of pollution and waste, particularly when we have geometric growth in population. Hawken points out that with a quintupling of population and increasing economic output over 100-fold we have the reverse of the situation at the start of the industrial revolution which was an abundance of natural resources and the ability of the biosphere to assimilate wastes. "Our thinking is backwards: we shouldn't use more of what we have less of (natural capital) to use less of what we have more of (people)."

There is increasing social and political instability worldwide despite the end of the Cold War and the increased globalization of the economy (which many argue contributes to the instability). According to Worldwatch Institute there are 27 million environmental refugees, unprecedented migration of people from East to West and South to North, 68 regional military conflicts, the UN has seen its influence erode and there is increased isolationism on the part of major powers such as the US.

As the astronauts said in Apollo 13, "Houston, we have a problem!" – a societal problem caused by the "design" of an economic and social system which lives off its support system in a degrading, unhealthy and unsustainable manner. We will need a paradigm shift in the relationship of humans to the environment and each other – one in which humans live in harmony with both natural systems and each other. We cannot achieve these results with our current thinking. A psychologist friend once remarked that a definition of insanity is doing the same thing over and over again and expecting a different result. As Einstein observed, "the significant problems we face cannot be solved at the same level of thinking we were at when we created them." In the next 20 to 40 years, society must adopt new strategies that allow the needs of an expanding population to be met in an environmentally sustainable and equitable manner.

We have known for quite some time that a healthy environment is essential to human existence, health and well-being. Humans can live for about four minutes without air, four days without water, and four weeks without food. Plants, animals, and the habitats they occupy provide the food that sustains human life. The earth and all its living organisms supply all raw materials for human activities. All economic, social, and community systems derive resources from, and are a part of, the biophysical system we call the biosphere. A recent study by Bob Costanza et al. of some of the essential ecological services provided by the biosphere indicate their value of \$33 trillion (range \$16 - \$54) annually compared to a worldwide human economy of \$18 trillion. Indeed, economic activity is simply the use of human ingenuity, technology and labor to convert natural and physical resources into goods and services which have more human utilitarian value (in the short run) than leaving them in their natural state. **There is no inherent conflict between protecting the environment and a strong human economy since the environment is the support system for all human activity.** As Peter Dunne said in a *New York Times* editorial, "The environment is not a competing interest; it is the playing field on which all other interests intersect."

Vision for a Just and Sustainable Future

A first step in the transition to a sustainable path is to shift from **problem-solving** to **creating**. **Problems** are negative things which we would like to eliminate. However, eliminating the problem does not necessarily get us what we want. We often frame problems in such narrow ways that the solutions are not lasting and may create other problems later on or in some other place. The way we have dealt with most environmental issues such as air or water pollution is to view them as discrete problems whose solutions end up often moving pollution around rather than getting to the root of the problem and eliminating it. **Creating**, on the other hand, is bringing into existence some thing or situation that we want which is usually a much better motivator for change than a problem we need to eliminate.

How do we create a life that allows all present and future humans to be healthy, have their basic needs met, have fair and equitable access to the earth's resources, have a decent quality of life and preserve the biologically diverse ecosystems on which we all depend? Future scientists, engineers, and business people must design technology and economic activities that sustain rather than degrade the natural environment, enhance human health and well-being, and mirror and live within the limits of natural systems.

The vision of a sustainable future is one in which:

- **The world population is stabilized** at a level that is within the short and long term carrying capacity of the earth's finite resources. This level is of great debate and is probably between 8 and 9 billion people.
- **Resources are used efficiently**. Leading organizations such as the Wuppertal Institute and the Factor 10 Club and a growing number of individuals such as Ernst von Weizsacker, Paul Hawken and Amory Lovins have been calling for a huge increase in **resource productivity** – by a factor of 4–10 in order to increase wealth for 4/5 of the world's population and to decrease environmental impact. This is critical because the industrialized economy is incredibly wasteful in use of resources while the planet has a finite amount of resources and a finite ability to absorb and process wastes. According to a recent report of the World Resources Institute, industrialized countries extract 45–85 tons of materials per person per year. A recent report of the US National Academy of Engineering indicates 93 percent of all the material which enters into commerce becomes waste before the product

reaches the consumer. Paul Hawken estimates that 80 percent of the remaining 7 percent which is imbedded in the products goes to waste within 6 weeks of use. Moreover, Hawken estimates that if one were to include energy, water and biologically-based materials each person in the US consumes their body weight in natural resources daily. For example, only 3 percent of the energy produced by a nuclear or coal-fired power plant to power an incandescent light bulb actually results in light!

In their recently released book Factor Four: Doubling Wealth, Halving Resource Use, Ernst von Weizsacker and Amory and Hunter Lovins call for a revolution in energy and resource productivity and provide over 50 demonstrated examples of factor 4 increases in energy, material and transportation productivity from a variety of institutions around the world. With a few exceptions they all cost less than conventional means of doing business and increased social and economic as well as environmental sustainability.

One of my favorite energy examples illustrates the possibilities and the challenges ahead. From 1973 to 1986, the US economy grew by 40 percent, yet energy consumption did not increase. Higher prices in oil led to industrial conservation and government efficiency standards for automobiles, refrigerators and electric motors. The economy saved \$160 billion a year. And there is still room for improvement. Germany and Japan obtain twice as much economic output per unit of energy consumed as the US and 10-12 times as much as China. Since 1986 the price of oil has fallen to an historical low due to the success of conservation. As a result, in the US, the size (witness the growth in gas guzzling sport/utility vehicles which now make up 45 percent of new car sales) and number of automobiles and the number of miles driven has continued to grow, driving energy consumption up steadily each year. The US now imports more oil just for **gasoline** than the total amount of oil imported during the 1973 oil crisis.

- **We will mirror and live within natural systems.** Humans are the only species on earth that produce waste which is not a raw material or nutrient for another species. Also, we are the only species to produce wastes that can be broadly toxic and build up for long periods of time. As Bill McDonough, Dean of the University of Virginia School of Agriculture, has said, a sustainable society would eliminate the concept of waste. Waste is not simply an unwanted and sometimes harmful byproduct of life; it is a raw material out of place. Waste and pollution demonstrate gross inefficiency in the economic system since they represent resources that are no longer available for use and/or create harm in humans and other species.

A sustainable economy would mirror nature's "circular" method of using matter and employ the concepts of design through which all waste would be the "food" (**waste = food**) for another activity. This idea is illustrated in the concept of **industrial ecology**. Metal extraction and conversion would be replaced by strategies to continuously cycle existing metals through the economy. For example, recycling aluminum rather than using virgin bauxite ore cuts energy use by 95 percent and pollution by 99 percent. When we recycle paper, we cut energy consumption by 40–50 percent and air and water pollution by about 35 percent, while employing more people.

- **We will use renewable resources at a rate less than or equal to the natural environment's ability to regenerate the resource.** This means **living off the income, not the capital**—e.g., practicing sustainable forestry, sustainable fishing and sustainable agriculture. Every ton of paper made of recycled fiber saves 17 trees and cuts air and water pollution 30–50 percent. Organic farming and agricultural production which minimize the use of pesticides and fertilizers while conserving soil and water are safer and more sustainable.

- **We will rely directly on solar energy to drive our economic system.** Over 85 percent of the world's energy comes from fossil fuels. This form of energy use causes major environmental and health problems such as black lung disease, air pollution, acid rain, oil spills and global climate change, to name a few. The desire for a continuing "cheap" supply of fossil fuels has had enormous military and economic costs to keep the oil and gas flowing around the world, especially from the Middle East. Moreover, this fossil fuel dependence is economically unsustainable for more than a few decades—it took 10,000 days for nature to create the fossil fuels that society consumes in one day!

- **We will increase production of durable, repairable goods and eliminate persistent, toxic and bioaccumulative substances.** At the same time, we will eliminate disposable goods as much as possible and detoxify the production process by minimizing the use and discharge of toxic substances. Products would be designed for disassembly so that the materials could be utilized in making new products. For example, several manufacturers (Volkswagen, Volvo, BMW) are redesigning automobiles so that 90 percent or more of the materials can be recycled into new automobiles. In 1993, the Gillette Company, one of the world's leading manufacturers of shaving equipment, had reduced its Toxic Release Inventory (US EPA definition) wastes in the US by 97 percent from their 1987 level. According to Factor Four, between 1981 and 1993, Dow Chemical's Louisiana Division with

2,400 workers implemented 1,000 projects (costing under \$200,000) to save energy or reduce waste. For the 575 projects subsequently audited, the average annual return on investment was 204 percent and the annual savings was \$110 million!

- **We will focus on providing the ultimate ends of products or services not the products or services themselves.** German chemist Michael Braungart and Bill McDonough have invented the concept of "products of service". A key to resource efficiency is to understand products as a means to deliver a **service** to a customer. For example, people do not want energy, they want the service it provides such as heat or light. Similarly, people want access to people, places, things and experiences not necessarily increased transportation. An example of a company that has adopted this idea is Interface, the largest commercial carpet tile company in the world which now **leases** carpet through its *Evergreen Lease*. The lessee gets the service of the product – warmth, softness, acoustic value, and aesthetics for a fee. When the carpet is worn out, Interface takes it back and recycles it into new carpet.

- **All people will understand their connection to the natural world and to other humans.** They will understand their "ecological footprint", i.e., they will know where products and services come from, where wastes go, and what they do to humans and other living species. They will appreciate that driving a car in Ohio may cause flooding in Bangladesh through global warming, or that cutting down forests in Brazil may deprive someone in Hungary of a lifesaving drug. For all people (led by professionals such as engineers) minimizing their ecological footprint and "walking lightly" on the planet will be "second nature".

- **All current and future generations of humans will be able to meet their basic needs, pursue meaningful work and have the opportunity to realize their full human potential personally and socially.** The average American receives 3,000 advertising messages per day oriented toward consumption. The American public is often portrayed as a group of consumers, not citizens. But increased consumption and material acquisition alone has not led to a happier, safer and more secure population in the US, nor has it done so elsewhere.

This June, the prestigious Councils of the Royal Society of London and the United States National Academy of Sciences issued a statement calling for an urgent need for better understanding of human consumption and related behaviors and technologies, so that effective action may be taken to expedite the transition to a sustainable, desirable life for the world's people in the coming century. In the statement they said, "It has often been assumed that population growth is the dominant problem we face. But what matters is not only the present and future number of people in the

world, but also how poor or affluent they are, how much natural resource they utilize, and how much pollution and waste they generate. We must tackle population and consumption together." **Sufficiency** of resource use and accumulation is as important as resource **efficiency** and **productivity**. Beyond meeting basic needs, we must examine **non-material ways** to fulfill our needs for security, belonging, personal development and happiness that transcend materialism – a goal of most major spiritual and religious movements.

- **We will have timely economic and social signals that encourage environmentally and socially sustainable behavior.** The economic measures of success we use today, such as the GNP and consumer price index, discourage conservation and encourage waste, consumption, and the substitution of capital for jobs. The price of goods services reflects all the profits to the producers but does not include all the social, environmental and health costs to society. In a sustainable society we would have more **development**, i.e., qualitative improvement in people and value added to resource use than **quantitative growth** in resource and energy intensive economies. Several national and international organizations and thousands of individuals have called for full cost (including social and environmental) accounting for economic activities, development of macroeconomic indicators which truly reflect societal well-being (e.g., Index for Sustainable Economic Welfare, Genuine Progress Indicator) and taxation which taxes the undesirables (energy and resource consumption) and not the desirable (employment and investment).

- **Nations would act like a Global Family.** We must change the relationship between the developed and the developing countries. Industrial countries must reduce their consumption of the world's resources in the face of the desperate need of developing countries to improve health and to reduce poverty, social instability and population growth. A child born in the US today will consume as much of the earth's resources and produce as much waste as more than 100 Bangladeshi children. We also need new approaches for transferring technology, for training and education, and for providing financial assistance to developing countries. These approaches must address population stabilization, improving the educational and social status of women, the international debt problem, and the need for sustainable economic strategies.

The Role of Higher Education

Such a shift in the thinking, values, and actions of all individuals and institutions worldwide calls for a long term societal effort to make environmental and sustainability concerns a central theme in all education, particularly for engineers, economists and business people. If we are to achieve a sustainable future, institutions of higher education must provide the awareness, knowledge, skills, and values that equip individuals to pursue life

goals in a manner that sustains human and non-human well-being. This is critical since higher education prepares most of the professionals who develop, manage, teach in and influence society's institutions.

Higher education institutions bear a profound moral responsibility to increase the awareness, knowledge, skills and values needed to create a just and sustainable future. Society has conveyed a special charter on institutions of higher learning. Within the United States, they are allowed academic freedom and a tax-free status to receive public and private resources in exchange for their contribution to the health and well-being of society through the creation and dissemination of knowledge and values. These institutions have the mandate and potential to develop the intellectual and conceptual framework for achieving this goal. They must play a strong role in education, research, policy development, information exchange and community outreach and support. Higher education in the United States are significant but largely overlooked leverage points in the transition to a sustainable world – they influence future leaders through their students and current leaders through their alumni. They have the unique freedom to develop new ideas, comment on society, engage in bold experimentation, as well as contribute to the creation of new knowledge.

Several prominent engineering schools are making important strides such as Georgia Tech with its plan to convert to solar power within 20 years and MIT with its Program in Environmental Education and Research (PEER). And there is some excellent leadership by professional organizations such as the WFEO and the WBCSD to make sustainable development a high priority in engineering and business education. Despite these efforts and those of a number of colleges and universities which have active environmental studies programs and train graduate professionals, education and research about the interdependence of and a sustainable relationship between humans and the rest of the environment is not a priority in higher education. As David Orr has said, "The crisis of humanity and the biosphere is a crisis of mind, perception and heart. It is not a problem in education it is a problem *of* education". To date, no engineering school in the US (or, to my knowledge, internationally) has made design for the environment, industrial ecology, pollution prevention or the relationship of technological development to sustainability the **cornerstone** of engineering education.

American medical students receive the equivalent of one day's training in occupational and environmental medicine in four years of medical school. Only 100 out of 700 schools of business and management in the US. have courses on business and the environment; the majority of the courses are electives. Only 9 percent of teachers' colleges require a practicum in environmental education at the elementary level, and only 7 percent at the secondary level.

As a result, the general public has little awareness that a healthy natural environment is essential to our very existence. We see ourselves as separate from the natural world and are unaware that it provides all the resources which make life possible while absorbing our wastes and enriching our lives with its incredible diversity of plants, animals and other species. Much of the population has little idea about where goods come from and where they go and the destructive impact of pollution on human health. We believe that natural and physical resources are free and inexhaustible and that the environment can assimilate all our pollution and waste. The general public has little idea that it is not just industrial enterprise, but the aggregate of all human activities – all the individual and the collective daily decisions – that are irreversibly changing the earth.

A fundamental problem in current education (and in many other sectors) is the underlying assumption that environmental protection should be left to environmental professionals such as environmental engineers. This results in educational systems treating environmental education as yet another specialty, not unlike sociology or biology. But environmental specialists alone will not help us move toward a sustainable path. All humans consume resources, occupy ecosystems and produce waste. We need **all professionals** to carry out their lives and activities in a manner that is environmentally sound and sustainable. In addition, the current education and training of most environmental professionals who will be employed by government, industry, academia and environmental organizations is narrowly focused and incomplete. Most of these professionals are trained in dealing with a subset of environmental problems such as air pollution, water pollution, or hazardous waste, but are not trained to deal with environmental issues in an integrated and comprehensive fashion. The focus of training is on controlling pollution and waste once created and in remediating environmental damage, rather than reducing or eliminating pollution and waste generation at the source.

Several structural aspects of the educational system contribute to the problem. Interactions between population, human activities and the environment, and strategies, technologies and policies for an environmentally just and sustainable future are amongst the most complex issues with which society must deal. These issues cross disciplinary boundaries, making it very difficult to convene the skills necessary for

effective teaching and research in educational institutions that are organized into highly specialized areas of knowledge and traditional disciplines. Specialists are produced with little feeling of connectedness, and little understanding of the workings of natural systems, or even the place of their own discipline in the larger human and non-human

world. Interconnecting patterns and relationships which govern all natural and most human interactions are largely left to the student to discern on his or her own. For example, neoclassical economics views the economic system as separate from the biosphere rather than one of its subsystems. As Herman Daly states "Neoclassical economists look at the relationship between the economy and the biosphere like physicians who view a human body as having only a circulatory system and no digestive tract. Engineers believe that most human based technology is an improvement over "natural technology" and feed economists' assumptions that science and technology can substitute for any resource we deplete or species or ecosystem we destroy. In *Earth in the Balance*, Vice President Al Gore argues that "we organize our knowledge of the natural world into smaller and smaller segments and assume that the connections between these separate compartments aren't really important... (On the other hand) the ecological perspective begins with the view of the whole, an understanding of how the various parts of nature (including humans) interact in patterns that tend toward balance and persist over time."

Curriculum and degree requirements are primarily determined by faculty isolated by department and school of study, and/or designed to satisfy accrediting agencies rather than generating students with skills relevant to society's needs. Learning is fragmented, and faculty, responding to long-established incentives and professional practices, are discouraged from extending their work into other disciplines or inviting interdisciplinary collaboration. Tenure and promotion of faculty are largely based on teaching and research, which is most often in a single discipline. Quality scholarship is usually considered as synonymous with originality in a single discipline, and individual contribution is often encouraged over team efforts. It is extremely difficult to obtain tenure as an interdisciplinary scholar (often not considered a rigorous scholar, by definition) in the overwhelming majority of institutions of higher education. Indeed as many have quipped, God probably would never have received tenure at any major university for several reasons:

- He had only one major publication
- It was in Hebrew
- It had no references
- It wasn't published in a refereed journal

- Some doubt He wrote it Himself
- He may have created the world, but what has He done since?
- The scientific community can't replicate His results
- He never got permission from the ethics board to use human species

- When one experiment went awry, He tried to cover it up by drowning all the subjects
- He rarely came to class and just told the students, "Read the Book"
- Some say He had His son teach the class
- He expelled His first two students
- His office hours were irregular and were sometimes held on a mountain top
- Although there were only ten requirements, most students failed

Future Direction for Higher Education

As Chet Bowers and others have pointed out, universities have departments while society has complex problems. Designing a sustainable future requires a paradigm shift toward a systemic perspective which encompasses the complex interdependence of individual, social, cultural, economic and political activities and the biosphere. This will require comprehensive short- and long-term educational change necessitating unprecedented leadership and commitment by colleges, universities and professional schools, especially engineering schools. (See attached tables on Learning Orientation) These strategies are outlined in detail in a 1995 report to the US President's Council on Sustainable Development entitled "Workshop on the Principles of Sustainability in Higher Education". The workshop included 35 international academic experts on sustainability and education.*

The **content** of learning must embrace an **interdisciplinary, systemic approach** to address environmentally sustainable development on local, regional and global scales over short-, medium- and inter-generational time periods.

The **context** of learning must change to make the human/environment interdependence an integral part of the normal teaching in **all the disciplines** rather than isolated as a special course or module in a program for environmental specialists only. Because the environment provides the basis for life and is a major determinant of the quality of life, it must be a fully integrated and prominent part of all education. All students must understand that we are an integral part of nature and that we are coevolving with all the other species in the biosphere. **All** engineers must learn a number of concepts and skills that I never obtained in engineering school such as

- systems thinking
- how the natural world (including humans) evolved and works
- the interdependence of humans and the environment including the relationship of population, consumption, culture, social equity, health and the environment
- how to assess and minimize the ecological footprint of human economic activity

- technical, design, scientific and institutional strategies and techniques that foster sustainable development, promote energy and natural resource efficiency and conservation, mirror natural system resource use and cycling, remediate environmental problems, and preserve biological diversity
- social, cultural, legal, market and governmental frameworks for guiding sustainable development
- strategies to motivate environmentally just and sustainable behavior by individuals and institutions

Research must lead to the development of economic strategies and technologies that are highly energy and resource efficient, that mirror and live within the limits of natural systems, and minimize pollution and waste production. Higher education must help in the establishment of an ethos to stabilize population, assure the just distribution of the world's limited resources and promote social and economic values and policies that lead to a healthy and sustainable future.

The **process** of education must emphasize active, experiential learning and real-world problem solving on the campus and in the larger community. Educational psychologists tell us that we retain 80 percent of what we do as opposed to 10–20 percent of what we hear and read. For example:

- using the campus as a laboratory for environmental management and sustainability
- confronting actual, real-world problems
- internships in government, industry, communities, K-12 schools and NGOs
- capstone courses oriented toward solving environment and development problems of communities, government and industry
- finding opportunities and giving credit for off-campus work in communities
- encouraging students to work in groups so that they will be able to effectively collaborate as future managers and leaders.

Higher education must "**practice what it preaches**" and make sustainability an integral part of the **operations, purchasing and investments** of higher education institutions. The university is a microcosm of the larger community, and the manner in which it carries out its daily activities is an important demonstration of ways to achieve environmentally responsible living. By focusing on itself, the university can engage students in understanding the "institutional metabolism" and ecological footprint of materials and activities. Students can be made aware of their "ecological address" and the impact of their attending school on the natural environment and the community, and they can be actively engaged in the practice of environmentally sustainable living. Engaging in environmentally just and sustainable practices in its operations, purchasing and

investments, higher education helps reinforce desired values and behaviors in all members of the academic community. Moreover, the annual buying and investment power of the US institutions of higher learning (\$165 billion in purchasing; \$85 billion in endowment) make them important players in creating market demand for environmentally just and sustainable goods and services and in supporting the local communities in which these institutions are located.

Making the Transition Through Higher Education

Many people (including yours truly) believe that society has 20–40 years to make the transition to a sustainable path. Unfortunately, higher education is not likely to change its direction far enough or fast enough without strong outside influence. Historically, this is due to the isolation of higher education from many of society's problems, the overwhelming dominance of the disciplinary approach in learning and research and the tendency to be "producer" driven rather than "customer" driven. In Universities and the Future of America, former Harvard president Derek Bok opines, "When society recognizes a need that can be satisfied through advanced education or research *and* when sufficient funds are available to pay the cost, American universities respond in exemplary fashion... On the other hand, when social needs are not clearly recognized and backed by adequate financial support, higher education has often failed to respond as effectively as it might, even to some of the most important challenges facing America... After a major social problem has been recognized, universities will usually continue to respond weakly unless outside support is available and the subjects involved command prestige in academic circles."

Strong, rapid and largely unprecedented efforts by all of higher education's stakeholders are necessary to motivate the system on a path to sustainability. Students, parents, alumnae, prospective employers, organizations funding research and education (government, industry and foundations), accrediting organizations and the public are all consumers, clients or supporters of higher education's services.

If we are to encourage the educational system to produce the environmentally aware professionals and specialists needed to lead us on a sustainable path, **all stakeholders** must work with the higher education system in creative ways to encourage environmental education and research. For example, there is a growing student demand at colleges and universities in the US and internationally for environmental education and for the institutions to reduce the environmental impact of their own operations.

This effort must be encouraged and expanded. For example, the US government, which provides over 90 percent of the funding for academic research, could gradually

move this research budget over the next two decades toward activities which are environmentally, economically and socially just and sustainable. Both directly and through their hiring practices, prospective employers could expand efforts to communicate with higher education about the need for both environmental specialists and environmentally literate and responsible graduates in all fields. Environmental education could be encouraged or required at the state and local level and encouraged by accrediting organizations. These steps would encourage faculty to make environmental concerns central to their teaching.

Recognizing the need to assist higher education in making this transition, a small group of us led by US Senator John Kerry established Second Nature, a nonprofit organization located in Boston. Its sole purpose is to increase the capacity of higher education to make justice and sustainability "second nature" in its learning, research, operations and community outreach. In its three years of existence it has provided technical assistance, educational materials and helped train over 700 faculty and staff and between 25–30,000 students in 25 universities across the US. Its co-located sister organization, the Consortium for Environmental Education in Medicine (CEEM) is providing similar services to medical schools in Massachusetts, Rhode Island and Texas. We and four other sister organizations – Management Institute for Environment and Business, Center for Respect of Life and Environment, National Wildlife Campus Ecology Program and Association of University Leaders for a Sustainable Future – have formed an Alliance for Sustainability through Higher Education to expand our scope and effectiveness to promote education for sustainability.

These efforts are important but represent a tiny fraction of the effort that is needed to move higher education and society on a just and sustainable path. As we focus on strategies for educational reform we must remember that a sustainable relationship with our life support system is the *sine qua non* of a successful effort.

Active partnerships between the higher education system, the private sector, communities and state and federal governments are urgently needed to accelerate this effort as we approach the 21st century. This conference is another important step for the future of engineering education. I applaud you in this effort and pledge to work with you in expanding and accelerating creative ways to help engineering education move in a direction which is critical to the future of humanity.

I wish to acknowledge the contribution of the work of the following colleagues and mentors to my work and this speech: Robert Ayres, Thomas Berry, Chet Bowers, Michael Braungart, Lester Brown, Robert Costanza, Herman Daly, Jacqueline Aloisi de Larderel, Claude Fussler, Tom Gladwin, Paul Hawken, Tom Lovejoy, Amory Lovins,

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Dr. Anthony D. Cortese is President of Second Nature and was formerly the Tufts University Dean of Environmental Programs and Commissioner of the Massachusetts Department of Environmental Protection.

- * 1995 report to the US President's Council on Sustainable Development entitled "Workshop on the Principles of Sustainability in Higher Education" can be obtained from

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