Engineers and Sustainable Development

Prepared by the World Federation of Engineering Organizations' Committee on Technology, August 2002

Welcome to this CD about engineers and sustainable development. This CD, prepared by the World Federation of Engineering Organizations (WFEO), has three objectives:

1. To describe the roles engineers play in improving human living standards and protecting and restoring the environment.

2. To review the accomplishments engineers have made toward the sustainability goals defined in Agenda 21, the primary action document of the 1992 Rio Summit.

3. To summarize the ways that engineers can more effectively meet the goals of Agenda 21 in the future.

We hope that the innovative approach used in this CD will provide information about engineers in a form that is both interesting and easy to use. Through the use of tabs and hyperlinks, you can get information with several levels of detail.

What is Sustainable Development?

The term "sustainable development" was first proposed by the World Commission on Environment and Development (WCED) in its 1987 report *Our Common Future* (also known as the Brundtland Commission report). WCED, which included 23 members from 22 countries, was formed by the United Nations in 1984, and for three years studied the conflicts between growing global environmental problems and the needs of less-developed nations.

WCED's widely used definition of sustainable development is:

"*Meeting the needs of the present without compromising the ability of future generations to meet their own needs.*"

Since 1987, there have been many efforts to explain and amplify what is meant by sustainable development.

To an engineer, a sustainable system is one that is either in equilibrium, or one that changes slowly at a tolerable rate. This concept of sus-tainability is best illustrated by natural ecosystems, which consist of nearly closed loops that change slowly. For example, in the food cycle of plants and animals, plants grow in the presence of sunlight, moisture and nutrients and are then consumed by insects and herbivores which, in turn, are eaten by successively larger animals. The resulting natural waste products replenish the nutrients, which allows plants to grow and the cycle to begin again.

If humans are to achieve sustainable development, we will have to adopt patterns that reflect these natural processes. The roles of engineers in sustainable development can be illustrated by a closed-loop human ecosystem that mimics natural systems. This model of a closed-loop ecosystem was first proposed in 1990. Other authors have since suggested modifications to this model, one of the most sophisticated of which is described in this attached file (SDProdConsumModel.pdf).[1[1]]

Engineers contribute to all the steps in this systems model:

- By developing, processing and transporting natural resources in closed-loop systems, we can reduce waste and increase the efficient use of resources.

- Harvesting renewable resources such as water, fish and trees within the limits allowed by nature will ensure a continuing supply of resources for humans and natural ecosystems. Minimizing our use of non-renewable resources, such as petroleum and scarce minerals, and replacing them with environmentally friendly substitutes will also help extend the supply of natural resources.

- Processing natural resources efficiently and with little or no waste helps to preserve the earth's finite natural resources. We can further preserve resources by designing products and packaging for reuse and recycling, and we can protect resources through industrial processes and facilities that have minimal adverse environmental impacts throughout their full life-cycles.

- Transporting goods contributes heavily to pollution; to minimize these effects, we can transport resources and manufactured goods efficiently to consumers by pipelines, rivers, railways, roads, ships

[1[1]] These additional documents are available on the Engineers and Sustainable Development compact disk.

and airplanes using technologies that have minimal impacts on the surrounding land use and serve the needs of consumers with little waste.

- How we develop, process and transport resources can improve living standards in many ways. These include providing clean water, energy, housing and commercial buildings and streets and other forms of infrastructure; efficiently storing and distributing food; and meeting acceptable health standards, including high-quality waste management and treatment.

- To allow natural and built environments to be clean and unpolluted, we can reduce waste throughout this ecosystem cycle by continually recycling and recovering residual byproducts of resource development, industrial processing and meeting consumer needs. Some waste in the system is inevitable but should be in forms that have minimal long-term impacts on the natural environment. The impacts from residual waste can be offset by continuing programs to clean up and reuse old waste sites, along with other forms of environmental restoration.

- The effects of developing energy sources on the atmosphere, earth and water can be reduced by more efficient use of power and by production from non-fossil sources.

- As described in other sections of this CD, engineers fill vital roles in each phase of this human ecosystem model.

Engineering for SD

Engineers play a crucial role in creating infrastructure in the world. Engineers are problem solvers who apply their knowledge and experience to building projects that meet human needs, and to cleaning up environmental problems. They work on a wide range of issues and projects, and as a result, how engineers work can have a significant impact on progress toward sustainable development.

Engineers can contribute to sustainable development along the entire chain of modern production and consumption, including the following:

- Extracting and developing natural resources
- Processing and modifying resources
- Designing and building transportation infrastructure
- Meeting the needs of consumers
- Recovering and reusing resources
- Producing and distributing energy

The Roles of Engineers

Approximately 15 million engineers populate the world today. As in many other professions, there are different kinds of engineers, including civil, environmental, mechanical, electrical, chemical, industrial, agricultural, mining, petroleum and computer engineers.

Engineers are involved with two kinds of projects:

1. They design and build projects that meet basic human needs (potable water, food, housing, sanitation, energy, transportation, communication, resource development and industrial processing).

2. They solve environmental problems (create waste treatment facilities, recycle resources, clean up and restore polluted sites and protect or restore natural ecosystems).

Engineers are problem solvers. They use skills or information that include the following:

- The results of scientific discoveries
- Empirical experience gained from centuries of construction
- Innovative approaches gained from recent projects
- Analyses of costs versus benefits over the life of projects
- Evaluation of environmental impacts versus benefits
- Consideration of political, cultural and social environments at project locations

Engineers are involved in many functions in their work. These include the following:

- Baseline studies of natural and built environments
- Analyses of project alternatives
- Feasibility studies
- Environmental impact studies
- Assistance in project planning, approval and financing
- Design and development of systems, processes and products
- Design and development of construction plans
- Project management
- Construction supervision and testing
- Process design
- Startup operations and training
- Assistance in operations
- Management consulting
- Environmental monitoring
- Decommissioning of facilities
- Restoration of sites for other uses
- Resource management
- Measuring progress for sustainable development

Sustainable Engineering

Engineers can play an important role in sustainable development by planning and building projects that preserve natural resources, are cost-efficient and support human and natural environments. A closed-loop human ecosystem can be used to illustrate the many activities of engineers that support sustainable development.

Resource Development and Extraction

Engineers are involved in developing and extracting natural resources in many different ways:

- Discovering and evaluating deposits of industrial minerals such as sand and gravel
- Planning open-pit and underground mining operations
- Petroleum engineering and designing offshore oil platforms
- Water resource planning of all kinds including dams, irrigation systems and wells
- Agricultural engineering in land reclamation, drainage and improved farm operations
- Designing tree plantations and managing forests
- Designing fish farms and supporting aquaculture
- Improved land planning to protect the best farmland and natural resources from the impact of urban sprawl

Processing and Modifying Resources

In the past, many industries generated waste products that were toxic and not easily degraded under natural conditions. In the last 100 years, this has led to environmental pollution and new laws and regulations to help protect the environment. Because of improved measuring and monitoring technologies, pollution has been identified that was previously unknown. Many industries are now making major changes in the ways they use raw materials to produce products—by reducing their waste to a minimum, many are finding that improved processing leads to increased profits.

Engineers play the following roles in processing and modifying resources:

- Developing instrumentation to measure and monitor pollution
- Changing industrial processes to reduce the use of energy and other resources and to eliminate waste wherever possible
- Considering the total input/output of operations over their complete life-cycles

- Designing products and packaging for re-use or resource recovery
- Collaborating with other industries by creating “eco parks” or applied industrial ecology. With this approach, several industries work together so that each industry’s waste products can be used as the raw materials for others. This also makes possible more efficient use of waste heating and cooling water and using combined waste treatment facilities.
- Restoring and modifying old industrial sites for other uses

Transportation

In the past 200 years, engineers have made continuous breakthroughs in developing transportation systems:

- Building canals, locks and improving river navigation
- Designing and building all-weather roads and highways
- Constructing pipelines that move liquid and gas products
- Designing engines and transportation vehicles
- Building bridges and tunnels
- Constructing railroads and high-speed rail systems
- Creating ports and harbors
- Designing airplanes, airports and air traffic control systems

In the future, engineers will design these transportation systems so that they will:

- Be more energy efficient
- Create fewer adverse environmental impacts
- Encourage sound urban and rural planning with less urban sprawl
- Create longer-life facilities that can be maintained at lower costs

Meeting Consumer Needs

By the year 2020, there may be 8 billion people in the world. Over 80 percent of this population will be in countries that we describe as “less developed” or “developing.” About half the world’s population lives in cities today; within 15 years, there may be more than 20 cities with populations of 10 million or more, and 500 cities will have more than a million inhabitants. In the next 25 years most of the population is expected to live in “mega-cities” in developing nations. The engineering profession will be under continuing pressure to help provide the food and other resources to this growing population, and the traditional roles of engineers will be stretched to satisfy the future needs of mega-cities.

The roles of engineers in meeting human needs include the following:

- Creative land planning and development to minimize negative environmental impacts
- In emerging mega-cities, helping to establish local organizations that can provide the necessary infrastructure
- Providing treatment facilities and distribution systems for potable water
- Designing systems to collect and store food and other supplies
- Designing housing and commercial buildings
- Developing streets, utility lines, public transportation and other infrastructure
- Using underground space for recreation and other uses
- Providing technologies and facilities for heating and air conditioning
- Creating high-quality treatments for liquid and solid waste
- Reducing the risks of damage and loss of life from natural hazards such as hurricanes, floods and earthquakes

Resource Recovery and Reuse

According to a World Resources Institute report, the USA currently produces more than 20 billion metric tons of materials per year, about 80 tons per person. The direct input into the built environment is over 3 billion metric tons. A high proportion of the materials used consists of industrial minerals such as sand, gravel and crushed stone.

In 1990 the average North American produced over 1500 pounds of municipal solid waste, compared to about 700 pounds by the average Western European. Eighty percent of all products in the USA are thrown away after one use. For sustainable development to be possible, our human activities will have to be redesigned to reuse our raw materials and consumer products many times over.

Engineers can assist in this process in several ways:

- Improving ways to recycle and reuse domestic waste
- Designing better solid waste collection and storage facilities
- Improving methods to collect and reuse construction materials such as concrete and asphalt from roads, and ways to reuse scrap metal and other natural and synthetic materials.
- Improving treatment facilities for urban organic waste and human waste so that the treated fluids and solids may be used safely for agriculture and other purposes.
- Recovering, reusing and remanufacturing byproducts from resource development and industrial processing

Environmental Restoration

Some environmental pollution is inevitable in the future, resulting from resource extraction, industrial processing and transportation, and from wastes generated by humans wherever we live. In the future, the impacts of residual wastes should be offset by a variety of environmental restoration projects.

Engineers can assist in restoring environments in several ways:

- Treating and restoring old industrial waste sites
- Reclaiming old mine properties
- Treating polluted groundwater, lakes and streams
- Restoring the ecology of lakes and wetlands
- Renewing aging urban areas in large cities
- Reclaiming and restoring eroded or damaged farmlands

Energy Production and Use

We now use 80 times more energy than we did in 1850, with attendant emissions of carbon, sulfur and nitrogen byproducts creating unacceptable levels of pollution. Humans consume more fossil fuels per year than nature produces in a million years. The long-term effects of increased energy use may produce major changes in the earth's climate.

The American Electric Power Research Institute (EPRI) has estimated that energy use in America could be reduced by 50% without any reduction in the country's standard of living. One of the greatest engineering challenges for the future will be to develop less environmentally damaging sources of energy while simultaneously reducing total energy consumption.

In the future, the roles of engineers in energy production may include the following:

- More efficiently extracting and processing remaining petroleum and gas reserves
- Improving the efficiency of electric power stations and using superconductors for power distribution
- Reconsidering the use of nuclear power, assuming that safer facilities can be developed for generating power and handling nuclear wastes
- Expanding the use of hydroelectric, solar, geothermal, wind, and biomass energy

Engineers can also play a role in conserving and reducing the use of energy in the following ways:

- Designing energy-efficient buildings

- Designing industrial processes that are more energy efficient
- Using low-energy lighting systems
- Designing more efficient automobiles and public transportation systems
- Increasing the use of underground construction

Engineering Progress

Soon after the 1992 United Nations Conference on Environment and Development (known as the Rio Summit), a group of engineers made a systematic analysis of the conference's primary action document, Agenda 21 (http://www.un.org/esa/sustdev/agenda21text.htm). They found that of the 2500 issues in Agenda 21, 1700 seemed to have engineering or technical implications, and at least 241 appeared to have major engineering implications. Eminent engineers, scientists and environmental non-governmental organizations met at the United Nations headquarters in 1993 to review these high-priority needs and to discuss possible action programs.

In the 10 years since the Rio Summit of 1992, progress has been slow but encouraging. The accomplishments include the following:

1. International engineering organizations formed a new entity, the World Engineering Partnership for Sustainable Development (WEPSD). Engineering societies also formed environmental committees at both national and global levels to consider environmental issues.

2. Many engineering organizations developed environmental policies, codes of ethics and sustainable development guidelines.

3. Engineering groups contributed to the creation of the Earth Charter.

4. Engineers interacted with the United Nations Commission on Sustainable Development (UNCSD).

5. Engineers worked with scientists to make major breakthroughs in computer technology and communication networks.

6. Educational programs were started to introduce sustainable development concepts to engineering students and practicing engineers.

7. Industrial processes were improved to reduce the use of resources in manufacturing and to reduce waste products.

Engineering Organizations

- Global organizations representing engineers are educating their members about sustainable development and encouraging them to apply it in their work.

Global engineering organizations, working independently and together, provide information and leadership to the engineering profession. Each of these organizations has made progress in encouraging their members to understand and apply the principles of sustainable development.

The primary global organizations representing professional engineers are the World Federation of Engineering Organisations (WFEO), the International Union of Technical Associations (UATI, http://www.unesco.org/uati), the International Federation of Consulting Engineers (FIDIC, http://www.fidic.com/resources/sustainability) and the International Council of Academies of Engineering and Technological Sciences (CAETS, http://www.atse.org.au/international/caets.htm). In addition, many engineers are employed by the companies that constitute the World Business Council for Sustainable Development (WBCSD, http://www.wbcsd.ch/).

In September 1991, the WFEO held a meeting of its General Assembly in Arusha, Tanzania. At this meeting WFEO adopted the Arusha Declaration (ArushaDeclaration.doc) on the future role of engineering, developed from a study of *Our Common Future*, (the report of the World Commission on Environment and Development) and other documents. This declaration provided helpful guidelines that could be used by engineers in their projects.

Following this meeting, WFEO's Environmental Committee began to review the results of preparatory meetings for the UNCED conference scheduled for Rio de Janeiro in 1992. In reviewing drafts of Agenda 21,

it appeared to the WFEO members that the engineering contributions to both developmental and environmental projects were omitted and that these omissions weakened the report.

Independently, FIDIC formed an Environmental Task Committee in 1988 to review environmental trends and to provide recommendations to FIDIC members. They also developed guidelines, policies and training programs. FIDIC members also became concerned by the lack of engineers in the planning of the Rio Summit.

Until 1991, WFEO and FIDIC worked independently in support of sustainable development. However, both organizations began to realize the need for joint efforts if the real contributions of engineers were to be recognized at the Rio Summit. This led to the decision to form a new organization that would be a partnership of WFEO, FIDIC and UATI. A representative group from these organizations met in New York in 1992 during the final meetings of the UN delegation to the Rio Summit. The engineers drafted a Vision Statement and the broad goals for a new World Engineering Partnership for Sustainable Development (WEPSD). The results of this engineering meeting were shared with the UN delegates at an open house at the United Engineering Center, located near the headquarters of the United Nations. Maurice Strong, Secretary General of the Rio Summit, assisted the engineers at this open house, where he told the UN delegates that "the concept of sustainable development would be impossible without the full input by engineers."

The WEPSD organization accomplished a great deal in its five years and successfully laid the groundwork for the many programs in support of sustainable development that are being pursued by WFEO, FIDIC and other international organizations through their members and committees. In addition to activities at the international level, engineering societies in many countries have also been extremely active in considering the implications of sustainable development in engineering practices.

Members of WFEO and WEPSD were present at the 1992 Rio Summit, and WFEO officers were represented at the Rio + 5 conference. In addition, WFEO and FIDIC collaborated in developing a report for the Rio + 5 conference, *The Engineer's Response to Sustainable Development* published by WFEO in February 1997.

Since 1997, the major international engineering organizations have worked together on several projects and are making contributions to the World Summit on Sustainable Development (WSSD) held in South Africa in 2002. In addition, for the first time, engineers and scientists have agreed to be represented jointly at the WSSD. This includes the preparation of a joint paper entitled *Role and Contributions of the Scientific and Technological Community to Sustainable Development* (UNECOSOCpaper.doc).

Ethics, Policies and SD Guidelines

- Many engineering organizations have developed environmental codes of ethics, policies and sustainable development guidelines to help guide their members.

In the last 15 years, many of the international and national engineering organizations have developed codes of ethics that deal with the environment and sustainable development. Environmental policies are similar to codes of ethics but focus on principles of professional practice.

Some of the best examples include the following:

- The WFEO *Arusha Declaration on Environment and Development* (ArushaDeclaration.doc).
- The *WFEO Model Code of Ethics*, (WFEO Ethics.doc) adopted in September 2001.
- FIDIC adopted a powerful set of environmental policies in 1990. These include guidelines on the obligations of the consulting engineer with respect to their projects and clients (http://www.fidic.com/about/statement04.asp.
- The *Melbourne Communique* (MelbourneCommunique.doc) is a statement of operating principles adopted by 20 national organizations of Chemical Engineers.
- In 1992 the American Association of Engineering Societies adopted *The Public Policy on Sustainable Development and Action Principles* (http://www.aaes.org/content.cfm?L1=2&L2=3&OID=18). AAES also developed six action principles (ActionPrinciples.doc) to guide engineers in applying sustainable development.

- *The Code of Ethics* of the American Society of Civil Engineers was a pioneering effort that has far reaching implications; the code is enforceable in requiring consideration of sustainable development principles in civil engineering projects (http://www.asce.org/inside/codeofethics.cfm?strPrinter=1).

- In June 2002 representatives of the National Academy of Engineering in the USA met with representatives of the major American engineering organizations to consider how to unify the American engineers in support of the goals of the 2002 World Summit on Sustainable Development in Johannesburg, South Africa and to work together after this conference. Further meetings are planned and recently the group adopted a powerful statement (EngRoleSD.doc) on engineers and sustainable development.

Earth Charter

- Engineers contributed a technological perspective to developing the Earth Charter.

Beginning as early as 1945, during the formation of the United Nations, discussions began about the need for an earth ethic. In 1972, at the UN Stockholm Conference where the current environmental declarations were initiated, discussions continued about an earth ethic, and, in 1982, The World Charter for Nature was adopted by the UN General Assembly. The 1987 World Commission on Environment and Development report *Our Common Future* also described the need for an Earth Charter. During the 1992 Rio Summit, the Earth Charter was to have formed the ethical foundation upon which Agenda 21 and other Rio documents were to have been based.

A new Earth Charter initiative was begun in 1994 by Maurice Strong, Chairman of the Earth Council, and Mikhail Gorbachev, Chairman of Green Cross International. An Earth Charter Commission was appointed and numerous drafts were distributed and circulated among the nations of the world, resulting in the Earth Charter that was officially launched on June 29, 2000 in The Hague. The Charter will be debated, revised and presented to the UN for consideration at the 2002 UN General Assembly. Governments will be invited to endorse the Earth Charter at the 2002 World Summit on Sustainable Development.

The WFEO contributed to developing the Earth Charter in several ways. In 1997, a USA National Earth Charter Committee was appointed. This committee included James Poirot who, at that time, was a vice president of WFEO and President of the WFEO Committee on Technology (ComTech). Subsequently, WFEO was invited to present its views at an Earth Charter Continental Conference held in Cuiaba, Brazil in 1998, and WFEO participated in a virtual conference to comment on a draft of the Earth Charter. Making a presentation at WFEO's 1999 General Assembly, James Poirot described WFEO's actions in support of the Earth Charter.

In response to the Earth Charter challenge, the WFEO Executive Council adopted its *Earth Charter Resolution* (EC00Resolution.doc) on September 20, 2000. This action followed the WFEO General Assembly's 1999 adoption of four resolutions (EC99Resolutions.doc) supporting the Earth Charter.

The implications to engineers of the Earth Charter (ECPoirotIndia.doc) were explained by WFEO Vice President Poirot at the World Congress on Sustainable Development held in Calcutta, India on January 21, 2000. The current draft of the Earth Charter can be found in the attached file (EarthCharter.doc). This is a powerful document and deserves to be widely read.

Joint Programs

- Several international engineering groups have partnered in sustainable development programs with global organizations.

During the past 10 years, the engineering community has developed closer relationships with the World Bank, the UN and other international agencies that provide programs and funds to meet the needs of people by applying engineering and technology.

In 1996, the World Engineering Partnership for Sustainable Development (WEPSD, a partnership between WFEO, FIDIC and UATI) worked with the World Bank and UNDP to evaluate the feasibility of treating urban wastes for land application in agriculture. The program considered the problems and opportunities of reusing municipal organic wastes and human wastes after appropriate treatment. This joint program demonstrated that properly treated urban organic wastes could help solve two problems: reducing the health hazards of cities, and increasing food productivity through improved crop yields in nearby farms. The

results of this program are highlighted in this 1996 paper (WEPSDWasteConf.doc) and in the final project report (UrbanWasteAgriculture.doc).

Protecting and developing water resources is one of the most critical problems facing the world. The Global Environmental Facility (GEF, http://www.gefweb.org) is a major funding agency designed to address severe environmental problems such as the need for safe water supplies. The GEF, FIDIC and WFEO worked together to develop the International Waters Workshop—CEO Dialogue, held on June 7-8, 2000 at the World Bank in Washington, DC, where international water experts were invited to recommend high priority water projects. The conference outlined a long-term program for consideration by the GEF and private investors, and recommended that follow-up conferences be held to facilitate specific regional projects. The results of the workshop are summarized in this file (IntlWaters.doc), and additional information is available on WFEO ComTech's web site (http://www.wfeo-comtech.org/).

WFEO and FIDIC have agreed to assist the UNEP-GEF Technology Transfer Networks (SANet) program to help disseminate information about environmentally responsible technology. The SANet program (http://www.sustainable alternatives.net) is a partnership of the United Nations Environment Program (UNEP) and the Global Environment Facility (GEF). SANet's mission (TechTransPartner.doc) is to facilitate widespread use of cleaner technology, successful case histories, expert knowledge, planning tools and co-financing of projects.

UN Commission on Sustainable Development

- Engineering organizations have helped advance sustainable development by making presentations to the United Nations Commission on Sustainable Development.

The United Nations Commission on Sustainable Development (UNCSD) (AboutUNCSD.doc) was established in December 1992 to ensure effective follow-up to the United Nations Conference on Environment and Development held in Rio de Janiero in 1992.

In June 1997, James Poirot, then President of WFEO's ComTech, participated in the Earth Summit + 5, Special Session of the UN General Assembly (UNGAS97.doc). Poirot's attendance at this conference led the UNCSD to involve the engineering community in its annual meetings. Since 1998, WFEO has organized and sponsored four panels of experts on important topics. Presentations from these panels can be found on WFEO's ComTech web site (http://www.wfeo-comtech.org/).

- Water Panel, April 27, 1998. Four expert panelists presented case histories to demonstrate how privatization projects can be initiated and structured.
- Production/Consumption Panel, April 28, 1999. Four expert panelists presented case histories featuring cleaner production technologies.
- Panel on Sustainable Practices in Agriculture, May 1, 2000. Three expert panelists presented case studies on natural resource management technologies.
- Energy Panel, April 17, 2001. Three expert panelists presented case histories about technologies that employ renewable energy sources.
- In addition, an engineering officer of WFEO was a member of and advisor to the U.S. delegation to the 1997 UN General Assembly.

Computers and Communication

- Engineers have helped develop breakthroughs in computer technology and communication networks.

In the past 10 years, dramatic advances have been made in computers and computer software. Computers have become exponentially more powerful, smaller and more economical, and the Internet has made rapid communications possible throughout many parts of the world. Computer engineers played an integral role in this progress.

Along with rapid changes taking place with computers and communication networking, software development has evolved to allow enormous amounts of data to be stored, and has provided powerful

technical programs of great help to scientist and engineers. Exchanging electronic information has also allowed existing knowledge, information and technologies to be shared to fulfill public and private needs. Through this exchange of information the engineering profession has been able to provide an engineering dimension to sustainability issues.

However, as technology has expanded rapidly, a gap has developed between the countries with access to technology and those without. This condition is commonly referred to as the "digital divide." WFEO's committees on Information and Communication (CIC, http://www.coi-tn.org/fmoi-cic/cic.shtml) and Technology (ComTech) are working to develop better methods for sharing information (DigitalDivide.doc) among practicing engineers.

In 1999, WFEO endorsed a proposal to establish a virtual engineering library for sustainable development. Virtual engineering libraries can be accessed from the Internet, and range from those that provide titles or abstracts only, to those that provide access and downloads for full text papers or lecture notes. It was envisioned that virtual engineering libraries on the Internet would be useful in supporting engineering education in schools, technical colleges and universities. The Institution of Engineers, Australia and the Institution of Professional Engineers New Zealand agreed to lend support to the development of a prototype of such a system. It is hoped that this prototype, named the Australasian Virtual Library (AVEL) could become the model for a future global system, called the Virtual Environment and Sustainable Systems Engineering Library (VESSEL). This program is described in a paper (VesselFinal6.doc) by William J. Rourke, Special Advisor to the president of WFEO.

The AVEL program has been incorporated into the Australian Virtual Columbo Plan, which is being funded as part of Australia's overseas aid program. Substantial funds are also being provided by the World Bank. The Virtual Columbo Plan is initially being directed towards primary and secondary school teachers and policy makers. In coming years, material will be supplied to university lecturers, including those giving engineering courses.

Educational Programs

- Engineering groups started educational programs for engineering students and practicing engineers on applying sustainable development concepts in their work.

Many universities are beginning to introduce the principles of sustainable development into their curricula. An overview of the progress from 1992 to 1997 is contained in the report *The Engineer's Response to Sustainable Development*, (EngEducation.doc) dated February 1997, published by WFEO. In the USA many engineering colleges have developed extensive programs with special courses on the environment and sustainable technologies. Other institutions have integrated these concepts in their courses.

The Georgia Institute of Technology provides and excellent example. They have created an Institute for Sustainable Technology and Development and have incorporated the principles of sustainable development into the university's strategic plan. Information about the programs at Georgia Tech may be found at http://www.istd.
gatech.edu. This web site describes the history of this effort and describes the courses that the Institute offers.

Other forward-looking university programs include those at the University of Florida (http://www.ees.ufl.edu/), the Systems Engineering Department of the University of Virginia (http://www.sys.virginia.edu/) and the Earth Systems Engineering Program at the University of Colorado (http://ese.colorado.edu/).

Several programs are evolving that will provide financing for students or recent graduates to become interns for a year with environmentally-oriented companies. One such intern program available in Canada is the Institute for Leadership Development**,** (EngInternship.doc) affiliated with York University**.** A similar intern program has been established in Australia as part of the Australian Ambassadors Scheme.

In 1994 an international workshop of invited educators from the Asia Pacific region was convened in New Zealand to examine "Fundamentals of Environmental Education in Engineering Education." Outputs from this workshop have been widely published, and a major follow-up conference was held in Paris, France on September 24-26,1997. This conference was jointly sponsored by the United Nations Environment Program (UNEP), the World Federation of Engineering Organisations (WFEO), the World Business Council for Sustainable Development (WBCSD) and the Ecole Nationale des Ponts et Chaussées (ENPC). Educators and professional engineers from 27 countries attended the Conference. Many recommendations came out

of this conference that still warrant close examination, published in a report entitled, *Engineering Education and Training for Sustainable Development* (ParisReport.doc).

Sustainability is also finding its way into university accreditation procedures. In the USA, for example, each engineering university must be accredited periodically. The organization responsible for coordinating this process (ABET), in their document *Engineering Criteria 2000* (AccreditingCriteria.pdf) states that students must be prepared for professional practice through a curriculum that includes "most of the following considerations: economic, environmental; sustainability; manufacturability; ethical, health and safety; social; and political." (Underlining added.)

International engineering organizations have also contributed to sustainable development education. FIDIC has developed training programs for their members and for industry that provide guidance on how to inventory and analyze environmental issues as well as setting up environmental management systems. These programs have been developed in collaboration with UNEP and the International Chamber of Commerce (ICC), and are described on the UNEP web site (http://www.unepie.org/outreach/business/ems.htm).

A regional program that incorporates sustainable development concepts is described in the article *Report From Africa* (ReportAfrica.doc) by Rafik Meghji, WFEO ComTech's Regional Vice President for Africa and member of the Executive Committee for FIDIC.

Industrial Processes

- Engineering has developed new approaches in industrial processes to reduce the use of resources and eliminate waste products.

Many industrialized nations have adopted laws and regulations in the last 30 years to regulate the generation of toxic wastes. Other laws attempted to regulate the cleanup of old waste sites. At first, industries in the USA struggled to comply with these strict regulations. Over time, many of the leading industries began to realize that removing waste from the process stream could result in significant savings and increased profits.

As industries began to take the initiative in reducing waste improving processing, a group of industry executives decided to share knowledge and cooperate in other ways. The result was the World Business Council for Sustainable Development (WBCSD, http://www.wbcsd.org/). This organization now consists of a coalition of 160 companies united by a shared commitment to sustainable development. These companies represent many engineering disciplines.

The International Institute for Sustainable Development (http://www.iisd.org) also advances policy recommendations, including those for industrial processes.

Future Goals

Engineers believe that many of the problems facing less-developed nations can be solved by using existing knowledge, technology and experience. This, combined with scientific discoveries that can be applied to meeting basic human needs, could make an enormous difference in the next 20 years. The challenges and opportunities for transferring knowledge, building capacity and influencing the decision-making process are stressed in Chapters 31, 34 and 35 of the Rio Summit's Agenda 21.

In the future, engineers can be of even greater help in achieving the goals of sustainable development if they are able to finance and execute programs such as the following:

- Creating a comprehensive program to identify and provide the information that engineers in developing countries need to meet energy requirements, as well as food, health and other basic human needs.
- Expanding global educational programs on sustainable development for students and practicing engineers.
- Encouraging more engineers to become environmental generalists.
- Becoming actively engaged in the full range of decision-making processes in addition to performing projects.

- Improving methods for identifying and considering all of a project's environmental costs and impacts throughout a project's life cycle.

- Creating programs to provide hands-on-help, share knowledge and provide assistance on technically viable, commercially feasible and socially sustainable projects in developing countries.

- Supporting well-crafted policies and creative applications of engineering principles, and committing to partnerships with social and physical scientists and health and medical professionals.

Share Information

- Sustainable development can be furthered by creating a comprehensive program to identify and provide the information that engineers need in developing countries to meet energy, food, health and other basic needs.

At the WFEO Annual Meeting in September 2001, retiring WFEO Vice President James Poirot expressed his concerns about the problems of reaching engineers in less-developed countries and being able to provide information that would help them meet basic needs in their countries. He described the obstacles that exist, such as different languages and lack of access to modern communication devices, and he urged WFEO to consider ways to accelerate two-way communications of relevant technology.

In response to this challenge, Don Roberts, the new President of ComTech and Vice President of WFEO, drafted a comprehensive proposal (CommProposal.doc) that addresses a wide range of problems related to technical communications and sharing of information. This program, if authorized, would consist of five phases and could take 10 years to accomplish. As an example, funding the Virtual Environment and Sustainable Systems Engineering Library program (VESSEL) would help provide Internet access to virtual libraries on sustainable development. Full implementation of the SANet program would also be very helpful in helping to share information.

Global Education Programs

- Expansion of educational programs for students and practicing engineers would make sustainable development more understandable and easier to apply to engineering projects.

At present, most universities seem to be developing educational programs about sustainable development independently. These efforts and courses could be made more efficient and thorough and could be shared widely through a global education program using the Internet and wideband telecommunications.

Practicing engineers also need to be able to learn practical methods of using sustainable technologies in their projects. Guidance documents, such as those under development by the American Society of Civil Engineers (ASCE) and the English Institution of Civil Engineers (ICE) need to be funded and widely distributed. These documents should include successful case histories and simple suggestions on how engineering projects can be made more compatible with sustainable development.

Engineering educators and practicing engineers should also assist in developing educational materials that would introduce sustainable development concepts to students years before they attend universities. Discover Engineering Online (http://www.discoverengineering.org/eweek/) provides a model for how to attract young students to engineering through student-oriented learning experiences.

Engineers as Environmental Generalists

- Encouraging engineers to become environmental generalists will help advance sustainable development by broadening perspectives in engineering.

A 1990 paper entitled *Sustainable Development—A Challenge for the Engineering Profession*, (Challenge.pdf) given at the FIDIC Annual Conference in Oslo, Norway, argued that perhaps 25% of engineers should be trained to become superb environmental generalists. The paper suggested that these students could be recruited early and exposed to a broad education that combines the technical skills of engineering with a wide range of environmental disciplines. These studies could be integrated with a background in economics, law, history and political science, and special leadership training would be mandatory, especially in developing communication skills. The author argued that over time this education,

combined with a variety of assignments as volunteers, would prepare many of these "renaissance engineers" to assume leadership roles in education, industry and government.

Engage Engineers in Decision-making

- Encouraging engineers to become actively engaged in the full range of decision-making processes, in addition to performing projects, can make projects more efficient and effective.

Frequently, engineers will limit their activities to providing technical advice or planning on projects. However, many vital projects face severe delays or cancellation due to opposition from well-intentioned non-governmental organizations or poorly informed politicians. Engineers can help direct the course of important projects—and foster sustainable development—by involving themselves in all stages of a project's decision-making.

Engineers can become involved in local and regional civic activities as volunteers where their knowledge may be vital to sound decisions. If planning studies on projects are properly evaluated, the engineers can seek out different stakeholders, identify their concerns, if any, and incorporate them into the project. Open discussions with concerned stakeholders can be very helpful even before project feasibility studies and environmental impact studies are completed.

As the project develops, the engineer should not shy away from public hearings and should be willing to get involved in resolving controversy. Even during construction and operations of completed projects, the engineer should be sensitive to concerns and disputes and offer to provide object advice whenever it would be constructive.

In a recent speech given in September 2001, Maurice Strong outlined what he believes must be achieved at the 2002 Johannesburg World Summit for Sustainable Development. Engineers can make major contributions to many of his points. His speech is available at http://www.unu.edu/interlink/papers/Strong.doc. In addition, at the annual conference of FIDIC in 2000, Mr. Strong gave a speech that strongly supported engineers.

Environmental Impacts and Costs

- The adverse environmental effects of engineering projects can be lessened by improving methods for identifying and considering all of a project's environmental costs and impacts throughout its life cycle.

Many of the procedures for conducting environmental impact analyses were developed in the USA in the 1960s. Even though the approaches to evaluating potential environmental problems have gradually improved, environmental impact studies can be wasteful and ineffective.

Typically, the environmental studies are performed in the following way. Ecological and other environmental studies are often started after the project site has been selected and feasibility studies have been started or completed. By this time, the project may have already drawn attention from concerned citizens and environmental non-governmental organizations. In these cases, the environmental studies may become a battleground between those who wish the project to go ahead and those who wish to have it stopped. Advocates and project opponents may perform independent studies, creating wasteful investigations, significant legal costs and confrontations that may lead to stopping the project or causing lengthy delays.

If the project is finally approved, there may be little monitoring of construction or the performance of the completed project. As a result, the actual impacts may differ from those predicted in the original studies.

Better approaches to environmental studies on projects would reduce time, money and effort in approving projects, and would decrease the negative environmental impacts of projects**.** Environmental studies should start sooner and continue longer. The potential project should be compatible with the local or national strategic plan and should strike a good balance between serving local populations and protecting the environment. Baseline studies of the regional environment should be made years before projects are considered. In the planning studies, environmental constraints, if any, can be considered more completely when all of the project options are identified. The project cost-benefit analyses should attempt to consider all the direct and indirect environmental costs, and should consider cultural and sociologic issues.

If some form of economic development is needed, efforts should be made to identify all parties who may have a legitimate reason to be concerned about the potential projects. The planning of environmental studies should include as much direct input as possible from all stake-holders when project options are

being considered. By listening to the concerns of everyone early in the planning process, it may be possible to avoid wasting energy, time and money in confrontation and legal action.

Environmental monitoring of the project should be continued during and after construction, and should continue throughout the life of the project. Provisions should be made to modify the design, if necessary, where the environmental impacts differ from those predicted.

Different approaches for accounting for environmental costs and intangibles have been attempted in recent years, including accounting for environmental liabilities in the value of a nation's gross national product. To the best of our knowledge, practical approaches have yet to be developed that would alter conventional accounting practices to factor in the direct and indirect environmental costs of a facility through its life-cycle of operations.

Direct Assistance Programs

- Creating programs to provide hands-on help, share knowledge, and provide assistance can help critical projects in developing countries.

There are several ways that direct assistance could be provided to developing countries in a manner that would be technically sound, commercially feasible and environmentally as well as culturally appropriate. These go beyond just making knowledge available. Hands-on approaches could include the following:

- Creating a network of expert volunteers willing to provide advice, help plan and finance projects and provide help in the field.

- Encouraging engineering firms that have extensive experience to partner with engineers in less-developed countries. This teaming, built into project requirements, could be an effective way to increase the capabilities of local engineering firms.

- Using volunteers with little experience to learn while helping to plan and construct simple projects. Such efforts, naturally, should be appropriately supervised.

- Creating regional development centers that would coordinate regional teams of consulting engineers, international lenders, local university personnel, environmental scientists and other volunteers. Such centers could be used as a substitute for sending students to European or American universities. The centers could be tailored to meet the needs of less-developed countries, including using technology that would be accepted culturally and could be maintained locally.

Several existing programs deserve to be expanded:

- The Water for People program teams experts from the American Water Works Association (AWWA) with local experts and volunteers in less-developed countries. Water for People (http://www.water4people.com) is a non-profit organization that was founded in 1991 and draws volunteers from the 57,000 members of AWWA.

- Engineers Without Borders—USA (http://www.ewb-usa.org) represents a new approach by involving students with their engineering professors to plan and execute small projects in impoverished towns. To date, this program, led by Professor Bernard Amadei at the University of Colorado, has undertaken projects in Belize, Mali, Mauritania, Peru and Haiti.

- Another organization that uses thousands of volunteers each year is the Earthwatch Institute (http://earthwatch.org). This organization has 50,000 members and supporters, and each year 3500 volunteers work with 120 research scientists on projects in over 50 countries. Almost all of these projects involve scientific investigations, but the program could be adapted to include engineering baseline studies and assistance in less-developed countries.

- FIDIC is advocating a program that would pair experienced engineering firms with their peers in less-developed countries. This program would allow mentoring and hands-on help to build capacity in countries where the consulting engineering profession is not strongly developed. Ideally, such a program would be incorporated into projects by international funding agencies. For information on the FIDIC policies regarding the transfer of technology, see their web site at http://fidic.com/about/statement03.asp.

- SANet (http://sustainablealternatives.net/) is a technology transfer knowledge management and support system that aims to replicate successful applications of technology. SANet cuts across country boundaries and economic sectors and supports the implementation of international environmental agreements. The partnership builds on established communication channels of more than 150 national and regional member organizations, including FIDIC, WFEO and other international associations.

Policy, Principles and Partnerships

- Supporting well-crafted policies, creatively applying engineering principles and forming new partnerships will naturally increase efficiency on engineering projects, thereby supporting sustainable development.

Engineers should move beyond their disciplines to evaluate alternatives and to affect policy changes toward sustainable development. They should develop partnerships with other design professionals, economists and social, environmental and physical scientists to arrive at ecologically sustainable solutions. This means that engineers, along with other technical participants, should actively engage in the full life cycle of decision-making processes, including the interdisciplinary process of building the evaluation/decision framework and the infrastructure to realize the required sustainable future. These concepts are elaborated in a speech by WFEO President José Medem (TechnologiesMedem.doc).

About WFEO and ComTech

WFEO and ComTech

The World Federation of Engineering Organisations represents all engineers (estimated to number 15 million worldwide) and provides leadership to the engineering profession. WFEO is a non-governmental organization (NGO), based in Paris at UNESCO.

WFEO was founded in 1968 by the Fédération Européenne d'Associations Nationales d'Ingénieurs (FEANI), Commonwealth Engineers' Council (CEC), Federation of Arab Engineers (FAE), Unión Panamericana de Asociaciones de Ingenieros (UPADI), Switzerland, France, USA, India, Poland and Bulgaria. Its membership (WFEOMembers.doc) currently includes 80 National and 9 International members.

WFEO is:

- The voice of the engineering profession worldwide, endeavoring to have the influence and leadership of engineers recognized
- The expression of solidarity between developed and developing countries
- A way toward increased professional mobility through progressive integration of regional agreements
- The author of a Model Code of Ethics that incorporates principles of sustainable development

WFEO's mission is:

- To provide leadership to the engineering profession on issues of concern to both the public and the profession
- To serve society, and to be recognized by all levels of government and the public as a respectable and valuable source of information on the policies, interests and concerns that relate engineering and technology to both the human and natural environments
- To foster peace and economic security among all countries of the world through the proper application of technology

The organization's long-term objectives are to:

- Develop, through appropriate engineering activities and education, a worldwide understanding and commitment to sustainable development
- Pursue those programs and activities within Agenda 21 of the UNCED World Summit that are applicable to engineering

- Foster and encourage the formation and strengthening of national and international associations of engineers
- Promote social benefits through cooperation among engineering organizations around the world, and with institutions of science and industry, universities and other organizations
- Disseminate engineering information and promote global access to this information
- Foster the transfer, sharing and assessment of technology
- Initiate programs to improve the quality of engineering education and training. To that end, provide assistance for establishing in all member nations procedures for accrediting engineering courses that provide assurance of the quality of engineering education and training of engineering graduates to meet international standards.
- Develop guidelines to facilitate free trade in engineering services and regional and international recognition of engineering qualifications
- Provide for the protection, security and health of the public by developing guidelines to control risk and to prevent and reduce damage from man-made and natural disasters
- Sponsor congresses and other technical meetings of significance to the profession, and disseminate their conclusions and recommendations
- Provide equal opportunity for all to enter the engineering profession, and pursue their engineering activities freely throughout the world

WFEO projects are managed through its committees, (WFEOCommittees.doc) which include the Committee on Technology (ComTech), author of this report.

ComTech's mission is "To lead the engineering profession worldwide in the promotion and application of sustainable technology and, accordingly, disseminate information about sustainable technologies; inform the profession on available databases; encourage research into and education about sustainable technologies; and stimulate thinking, knowledge and action about WFEO Standing Technical Committees by all available means, including conferences, workshops, seminars and the use of information technology."

ComTech's achievements (ComTechAccomp.doc) over the last six years are noteworthy.

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Call for Information

Thank you for taking the time to review this report. We plan to modify this CD over time to provide a more up-to-date description of the ways engineers contribute to sustainable development and the future plans of our profession.

If you have any suggestions or additions, we welcome them; please send them to Jane Alspach, ComTech Managing Director, at the ComTech address above.