Advancing Sustainable Development of Infrastructure Systems

Arpad Horvath
Univ. of California, Berkeley, CA 94720.

H. Scott Matthews

Sustainability is a concept born from the global movement toward better management of resources. A 1987 United Nations World Congress document (called the Brundtland Report) defined sustainability as “management of resources such that current generations are able to meet their needs without affecting the ability of future generations to meet their needs.” This definition of sustainability has led experts in many disciplines—technical and social—to call for an increased concern for environmental and resource management within their fields. However, practical interpretations of this definition are still largely missing. These interpretations are mostly being advanced by academic researchers and have yet to be incorporated into corporate and governmental structures. Indeed, leaders in engineering, chemistry, economics, and philosophy have translated this concept of sustainability into a call for action.

The field of civil and environmental engineering, while not a primary player in the sustainability movement, has not been idle. The ASCE Committee on Sustainability was formed in 2001 and includes a cross section of ASCE’s membership profile. For the past 2 years, there has been one session at the ASCE National Conference on the topic of sustainability in civil engineering, including discussions on the role of sustainability in civil and environmental engineering education. The 2003 ASCE Construction Research Congress had two sessions on sustainability, and more are planned for the 2005 meeting. The May 2004 ASCE Structures Congress included one session on economic and environmental life-cycle assessment. These efforts are a good professional starting point, but should not be seen as sufficient to enable the levels of change needed.

The National Science Foundation—a primary source of funding for engineering research in the United States—has been supportive of sustainable engineering projects, including the Division of Civil and Mechanical Systems in the Engineering Directorate. Programs from the U.S. Department of Energy and the EPA have also been supportive of this area over the past decade.

Current national environmental priorities are not necessarily in line with global sustainability goals. For example, United States policy is currently dubious of the implications and causes of global climate change from greenhouse gas emissions and atmospheric concentrations. The United States is not a player in the official global Kyoto Protocol implementation to reduce emissions to below 1990 levels. This could have the undesirable side effect of undermining our leadership positions in global environmental management, as well as in the development of environmental control technologies. Europe and Asia are poised to take over these leadership positions without further American efforts and incentives for research and technology transfer in these areas.

For many years, the concepts of life-cycle costing (LCC) have been used in the infrastructure management framework to emphasize the need to holistically consider the costs of a project over its useful life, from design to decommissioning. The goals of these approaches are to force asset managers to recognize the costs and benefits of design and construction decisions on the use, management, maintenance, renovation/retrofit, and end-of-life of facilities. But sustainability will have to depend on tools that are broader than LCC.

Overview of Special Issue Papers

This is the first of two special issues we have organized on the concept of sustainable infrastructure. Our view of infrastructure (and the resulting call for papers) is instinctively broad, including transportation, energy, information and communication technologies, and other utilities. The current issue is centered on the concept of sustainable energy systems.

The papers in these two issues should serve to remind us that while the primary focus of research in the area of civil infrastructure systems has been on built public infrastructure like roads and bridges, other comparable public and privately owned infrastructure assets can be studied through the same lens. After all, tools like life-cycle assessment yield results that are applicable across the various domains.

The papers discuss commercial buildings, telecommunications data centers, building energy use and solar photovoltaic (PV) systems, electricity generation, and network use of electricity associated with a wireless handheld device.

Allenby’s forum kicks off the issue with a discussion on how human-centric views and attitudes are transforming the ecosystem of the planet, and its related infrastructures. He discusses the role of earth systems engineering and management for integrating coupled human-natural systems.

Osman and Ries focus on cogeneration systems that offer an opportunity to satisfy a building’s electrical and thermal loads, which could result in an overall energy efficiency improvement and lower environmental impact. They apply hourly energy simulation and life-cycle assessment to evaluate the relative environmental impacts and energy efficiencies of the construction and operation of alternative technologies for providing space and domestic water heating, cooling, and electrical power for equipment and lights in buildings.

Blazek et al. perform an assessment of the electricity consumption and power distribution in an Internet data center, and find that the facility’s efforts to improve energy efficiency offset the energy demand from increased operations. The energy efficiency measures included better optimization of power distribution units/power management modules and computer room air-conditioning units, alterations to operating conditions,
facilitywide reductions in lighting, and improved facility controls.

Matthews et al. discuss the relative cost and environmental implications of using solar PV technology instead of grid electricity at residences in the United States. From a strictly cost-based perspective, PV is generally less costly in New York than Arizona due to differences in grid electricity prices. However, emerging technologies like net metering and real-time pricing could make solar more widely economical.

Ruether et al. use environmental life-cycle assessment to compare the greenhouse gas implications of various electricity generation technologies, and find that the lowest life-cycle emissions are achieved with hydropower and wind farms, while an integrated coal gasification combined cycle plant with 90% CO₂ capture has lower life-cycle greenhouse gas emissions than natural gas combined cycle and solar PV systems.

Filion et al. estimate the life-cycle energy use implications of water distribution assets for several time-based replacement strategies in New York City, and find that a pipe-replacement period of about 50 years yielded the lowest overall energy expenditure in all life-cycle stages.

Koomey et al. disprove widely cited comparisons of energy use of refrigerators and personal digital assistants.

Sustainability research has permeated many academic disciplines and has led to pockets of excellence in the fields just mentioned. Yet, there is no critical mass of researchers on the topic. In addition, there is no single intellectual home or journal that encompasses sustainability, even within engineered systems. One goal of this special issue was to identify the Journal of Infrastructure Systems as an appropriate professional outlet for research related to sustainability of infrastructure.