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EDITORIAL

# Sustainability science: building a new discipline

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## The impetus for this journal

In scientific and academic circles worldwide, the opportunity to develop the emerging discipline of sustainability science has never been greater. This new science has its origins in the concept of sustainable development proposed by the World Commission on Environment and Development (1987) (WCED, also known as the Brundtland Commission). Defining sustainable development as ‘‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’’, the WCED gained worldwide support for its argument that development must ensure the coexistence of economy and the environment. Today, ‘‘sustainability’’ is recognized the world over as a key issue facing twenty-first century society.

It has, however, also been remarked that the idea of sustainable development increasingly seems to be linked to political agendas, raising concerns about the solidity of its analytical basis; as a consequence the scientific and technological underpinnings of the concept remain unclear to many (Cohen et al. 1998). During the 1990s, the International Council for Science (ICSU) initiated studies of science and technology for sustainable development. There were, increasingly, calls for a science of sustainability predicated on recognition of the fundamental link between science and economy while remaining free from political bias of the sort seen, for example, when North–South issues are raised in debates over sustainable development (Kates et al. 2001; ICSU 2002; Clark and Dickson 2003).

At the University of Tokyo, located in Asia, the need for a new academic discipline of sustainability science has become increasingly evident during our ten years of collaborative research and education initiatives through the Alliance for Global Sustainability (AGS) with the Massachusetts Institute of Technology (MIT), the Swiss Federal Institute of Technology (ETH), and Chalmers University of Technology in Sweden. We have been fortunate to receive support from the Special Coordination Funds for Promoting Science and Technology of Japan’s Ministry of Education, Culture, Sports, Science, and Technology (MEXT) for the purpose of forming a sustainability science network in Japan and working toward sustainability from a global perspective, particularly in Asia. In August 2005, the University of Tokyo inaugurated the Integrated Research System for Sustainability Science (IR3S) and invited universities throughout Japan to participate, thus launching a full-scale effort to set up a nationwide research network.

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A process of public announcement and rigorous peer review, including recommendations from an International Review Panel,[1] resulted in the selection of Kyoto University, Osaka University, Hokkaido University, and Ibaraki University as IR3S participating institutions, with the University of Tokyo, Toyo University, the National Institute for Environmental Studies, Tohoku University, and Chiba University as cooperating institutions. In April 2006, IR3S began an active program of research and educational activity addressing sustainability issues on a global scale, but with a special focus on Asia. In the course of the vigorous discussions that accompanied the inauguration of the IR3S network, the participants unanimously agreed that IR3S should establish an open forum for publishing the results not only of its own research and education efforts but also of sustainability science-related activities throughout the globe. This journal was launched to provide such a forum.

*Sustainability Science* is, therefore, not the exclusive domain of the universities and research institutions participating in IR3S. We intend to make it a truly international publication and for this purpose have assembled a roster of associate editors from around the world. Not only do we seek articles and reports on problems affecting sustainability, and their solutions, we also welcome articles identifying and addressing the limitations of existing academic inquiries. We also view as essential the participation of all stakeholders in sustainability: people from all walks of life, including industry and government, and scientists, scholars, and students. To accommodate these different contributions the journal has established several categories for submission: original articles, review articles, overview articles, technical reports, case reports, and notes and comments.

[1] The members of the International Review Panel were Bojie Fu (Chinese Academy of Science), Mogens Henze (Technical University of Denmark), Said Irandoust (Asian Institute of Technology), Olaf Kuebler (ETH), Valdur Lahtvee (Stockholm Environment Institute), Hoesung Lee (Council of Energy and Environment, Korea), Bindu Lohani (Asian Development Bank), Leena Srivastava (The Energy and Resources Institute), Jeffrey I. Steinfeld (Massachusetts Institute of Technology), Jan Eric Sundgren (Chalmers University), Peter A. Wilderer (Institute of Advanced Studies on Sustainability, European Academy of Sciences and Arts), and Itaru Yasui (United Nations University). After the inauguration of IR3S this panel was retained at the request of the Executive Director to serve as an Advisory Board.

## The concept of sustainability science

By discussion among its participating institutions, IR3S has sought to clarify the concept of sustainability science, usually defined as a discipline that points the way toward a sustainable society. In addition to addressing such problems as that of inter-generational equity, as emphasized in the concept of sustainable development, we approach the problem of sustainability at three levels of ''system''—global, social, and human—which we define below. All three systems are crucial to the coexistence of human beings and the environment, and it is our view that the current crisis of sustainability can be analyzed in terms of the breakdown of these systems and the linkages among them.

The global system comprises the entire planetary base for human survival: the geosphere, atmosphere, hydrosphere, and biosphere. The earth sustains human life by providing us with natural resources, energy, and a supportive ecosystem. The global system is capable of great fluctuations in the earth's climate and crust—the subject of the earth sciences—that profoundly affect human activity and survival. Conversely, the rapid expansion of human activity has become a significant factor in fluctuations in the global system. Global warming and the destruction of the ozone layer are two salient examples of this human-induced change.

The social system consists of the political, economic, industrial, and other structures created by human beings that provide the societal base for a fulfilling human existence. ''Fulfillment'' is often assumed to depend on economic growth and technological advancement, but such development also contains the seeds of such social problems as environmental pollution and the growing inequality between rich and poor. These problems, of which environmental issues are representative, exceed the confines of the social system in their impact, extending to the global system. Another social problem, the declining birth rate in developed countries (particularly in Asia) may be said to raise questions about the sustainability of the family, a fundamental unit of the social system. Problems like these challenge us to reexamine our notions of what constitutes a wealthy or fulfilled society.

The human system is the sum total of factors affecting the survival of individual human beings; it is, of course, intimately connected to the social system. The healthy functioning of the human system requires the establishment of lifestyles and values that enable people to live healthily, safely, and securely—i.e. not merely to survive but to experience a fulfilled life. In reality, however, human beings are adversely affected physically and emotionally by diseases, mental illness, and inequities in the social system. An increase in such problems puts pressure on the social system. As this stress increases and the environment deteriorates, the human system itself becomes less healthy. Emblematic of this trend are the problems of extreme poverty—hunger, disease, lack of shelter and exclusion—which are especially prevalent in developing countries and which are targeted by the UN Millennium Project under the framework of quantified Millennium Development Goals (UN Millennium Project 2005). Disparities in values, as seen in religious tensions, are another of the problems that threaten the sustainability of the human system. In the extreme, the weakening of sustainability and the concomitant impact on the health of the human system is manifested in increasing conflict and war.

What types of problem occur on a global scale as a result of the highly interactive relationship among these three systems, and what visions or scenarios do the solutions to those problems demand? Some examples are depicted in Fig. 1. A representative problem arising from the interaction between the global and social systems is global warming, which demands the development of a low-carbon society that embraces systemic and technological reforms leading to significantly reduced emissions of the gases that contribute to global warming. An example of a problem arising from the interaction between the social and human systems is the generation of waste. Here, what is demanded is the construction of a resource-circulating society, i.e. one capable of sustainable production and consumption (Sotherton et al. 2004). This requires the implementation of reduce–reuse–recycle policies, the development of manufacturing processes predicated on resource recirculation, and the fostering of resource-conserving lifestyles. Finally, the interactive relationship between global and human systems involves particularly serious problems that directly affect human survival. Examples include the spread of infectious diseases and other health risks associated with global warming, the effect on human health of increased ultraviolet exposure, because of the destruction of the ozone layer (IPCC WGII 2001; McMichael et al. 2003), and forced evacuations and loss of habitat caused by rising sea levels (Nicholls 2004). Because these problems threaten human security and safety, it is essential to solve them if we are to achieve human well-being and sustainability. Necessary measures include the mitigation of infectious diseases and refugee relief.

Sustainability science must therefore adopt a comprehensive, holistic approach to identification of problems and perspectives involving the sustainability of these global, social, and human systems. The

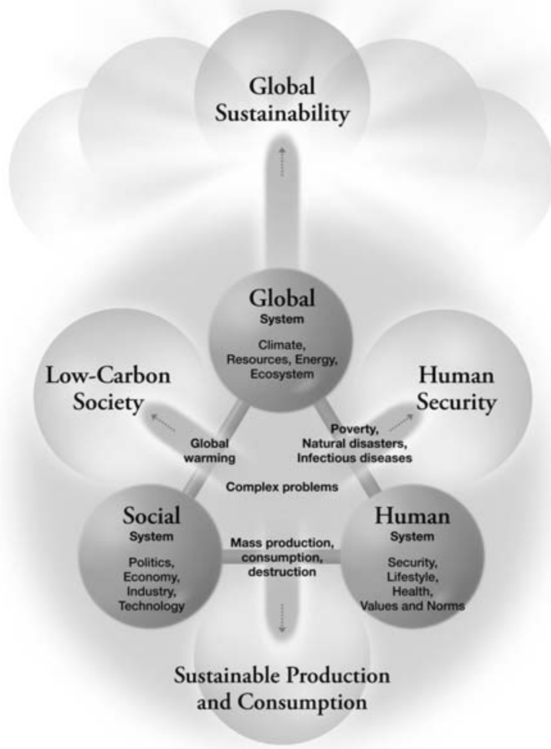


**Fig. 1** Addressing sustainability science through the lens of three systems, and the linkages among them

emerging discipline needs to be a dynamic and evolving field of inquiry that provides visions and scenario analysis pointing the way to global sustainability (Swart et al. 2004). The ultimate purpose of sustainability science is to contribute to the preservation and improvement of the sustainability of these three systems. Although sustainability science has its origins in the concept of sustainable development, we propose that it is, in reality, a much more multifaceted concept.

## Structuring knowledge for sustainability science

Two obstacles that impede efforts to deal with the issues associated with sustainability outlined above are the complexity of the problems and the specialization of the scholarship that seeks to address them. First, the sustainability crisis is caused by a multitude of factors, the complexity of global environmental problems being a classic example. It is, therefore, no easy task to gain a comprehensive view of such problems, let alone solve them. Second, the disciplines that examine these complex problems have themselves grown increasingly fragmented in recent years, so much research is conducted from a highly restricted perspective with regard to both phenomena identification and problem solving.

The fundamental cause of the current crisis in sustainability is the industrialization that followed the industrial revolution and the rapid economic growth it fostered. One result was the burgeoning consumption of fossil fuels and other nonrenewable resources, a level of consumption that has led some to call the twentieth century the ‘‘century of explosive expansion’’. Pollution, which first emerged as a severe problem in specific localities, also grew into the global issue recognized today. As environmental and other problems become global in scale, their causes and effects grow increasingly complex—pollution generated in one part of the world, for example, may do its worst damage in an entirely different region. This complexity hampers both the effort to identify problems and the search for solutions.

For scholars, knowledge structuring is an essential first step in the effort to acquire a comprehensive view of sustainability issues. The problems that sustainability science confronts are not only complex but also interconnected. If we are to find solutions to them, we must first clarify the relationships among them, i.e. engage in problem structuring. Next, we must assemble a platform of knowledge that not only affords an overview of the entire web of problems but also, by systematically organizing disparate fields of inquiry, enables us to replace the current piecemeal approach with one that can develop and apply comprehensive solutions to these problems.

Structuring knowledge in this manner will stimulate existing disciplines and mechanisms, contribute to the development of scenarios for a better future, and point the way to new inventions (Komiyama et al. 2004). Knowledge structuring is thus of critical value in identifying problems and responding to the needs of academia and industry. But nowhere is its effect more likely to be felt than in the field of sustainability science.

One example of knowledge structuring at work is the Tokyo Half Project (Fig. 2), a collaborative international research project by the AGS (Krains et al. 2001). The purpose of the project is to construct a model for computing total carbon dioxide emissions from Tokyo by quantifying the emission processes of the variety of sources of $CO_2$ in the metropolis and compiling data on emissions from these sources on a common platform. This model can also be used to evaluate the effect of efforts to reduce emissions from individual sources on total $CO_2$ emissions from Tokyo. It also serves to identify which measures would be required of consumers and industry to reduce $CO_2$ emissions by half, a target often cited in the post-Kyoto Protocol debate.

By means of this journal we intend to strive for precisely this structuring of knowledge in the field of sustainability science with the objective of achieving a

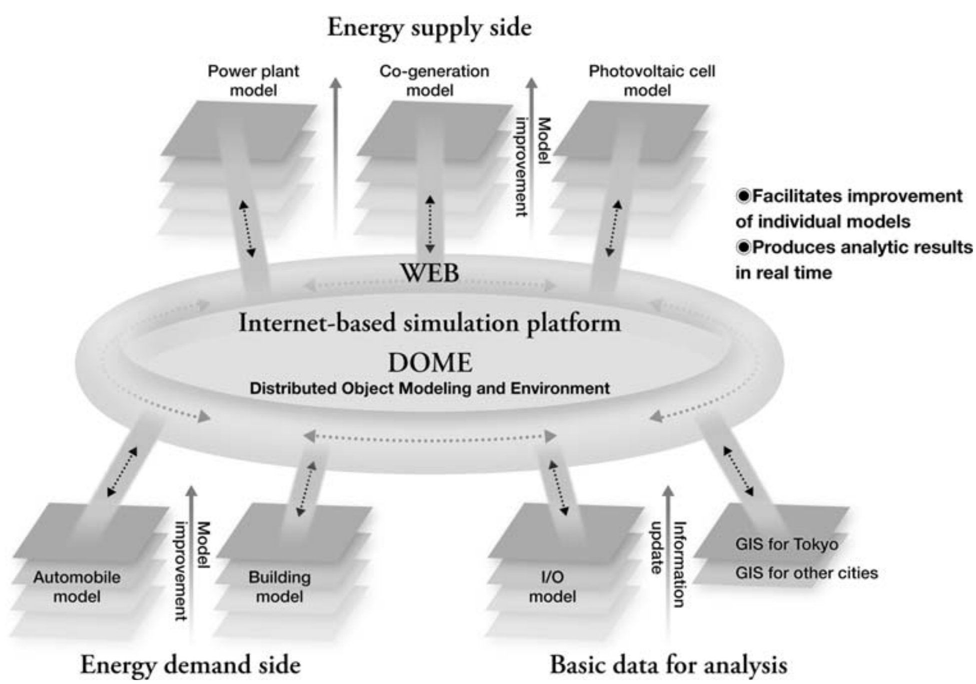


**Fig. 2** The Tokyo Half Project (THP). A system chart demonstrating the potential to reduce $CO_2$ emissions from Tokyo

comprehensive overview of this new discipline. The information technology revolution provides the means for integrating our exponentially growing knowledge base, so we look forward to the publication in these pages of the results of research utilizing such technology. It is our belief that this research can help resolve one of the fundamental dilemmas of contemporary scholarship—the inability of our overly specialized disciplines to offer comprehensive solutions to the conditions that threaten the sustainability of global, social, and human systems.

## A transdisciplinary approach

Precisely because sustainability science includes global, social, and human systems in its purview, and because the problems it addresses involve disparate elements—from science and technology, to politics and economics, to human lifestyles and behavior—this new discipline must necessarily embrace the social and natural sciences (Mihelcic et al. 2003). But as the body of academic and scientific research continues to grow, and as the disciplines engaged in this research continue to fragment, it becomes almost impossible for the individual researcher or research group to gain access to and utilize this vast accumulation of data. We need, therefore, to construct a framework within which individual disciplines can provide quantifiable criteria and indicators related to sustainability. By integrating these criteria we can structure our knowledge, our methods, and our grasp of the issues we confront. This is the first step we must take if we are to progress from identifying problems to solving them.

It is important to note that while these criteria and indicators must conform to scientific standards of objectivity, they must not be expected to yield a singular solution to any given problem. Indeed, a diversity of solutions should be sought in accordance with the particular environmental and cultural conditions of each nation or region. Any attempt to impose uniform solutions of global environmental problems will threaten the diversity of the earth's regions and cultures in the same way that economic globalization does now. Destroying this diversity will, in turn, prevent the realization of a society that is truly sustainable in the sense that it embraces human fulfillment, not merely survival. If the process of structuring sustainability-related scholarship and its knowledge base yields different structuring models for different regions and nations, then structuring itself can be a driving force for greater diversity.

One problem unique to sustainability science lies in the process of shifting from the stage of phenomena identification and analysis to that of problem solving. For sustainability science this process necessarily differs from the conventional transition from basic to applied research, because solutions to problems may have to be sought before those problems have been sufficiently analyzed or even identified. Global warming is the prime example of this dilemma. Future scenarios predicted by various models of global warming remain unverifiable, yet the search for solutions cannot wait.

The principle that must be applied here is the precautionary approach. But acceptance and implementation of this approach requires a framework for gaining the agreement of all sectors of society, and that is where interaction between scientists and the public is of the essence. What is demanded of sustainability science is not only the development of scientifically sound models for predicting future scenarios and evaluating the effects of different countermeasures and solutions but also effective management of the process by which these forecasts and evaluations are accepted by society, to generate the social reforms necessary to ensure global sustainability.

If sustainability science is to contribute practical solutions to the problems we face, cooperation among researchers, industry, and the general public is imperative. Only when society at large is inspired to act on the basis of their research and conclusions can sustainability scientists lay the foundation for construction of a sustainable society. With that in mind, the editors of this journal welcome articles presenting possibilities for major reforms of industrial structures and consumer lifestyles. Examples include the design and implementation of new industrial technology in harmony with the environment, or of other systems of sustainable production and consumption for a resource-circulating society.

In closing we would like to emphasize the key role of education in this process. Sustainability science must nurture a generation of leaders who are capable of appreciating the significance of changes in global, social, and human systems that occur over the extremely long term, and who choose the path of sustainability in implementing policies on the basis of this understanding. It is particularly crucial that concern with sustainability issues and a desire to act on them be instilled in the generation that comes of age in the mid-twenty-first century, when limits on energy and other resources and the global environment in general are predicted to reach crisis point. This journal is therefore also interested in examining the development of educational programs that recognize the need for both global and local approaches to sustainability.

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