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Author(s): DR. DENNIS L. HJERESEN

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The Uses of Technology for Energy and the Environment

Dr. Dennis L. Hjeresen
Senior Program Manager
Environmental Management Programs
Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 665-7251/FAX 5-8118
e-mail: dennish@lanl.gov

INTRODUCTION

The premise of my talk is that science, and the technology derived from science, is not the answer to energy and environmental problems. Science is a method of answering questions and as modern societies we must be very careful and specific in posing those questions. Many of the environmental issues we are addressing at this meeting are the direct result of not being specific enough in the demands placed on the science community. For example, when science was asked to increase chemical production to produce greater and greater quantities of consumer products, we forgot to ask that they be produced without significant damage to the environment. When our societies developed nuclear deterrents to protect national security interests, we failed to consider the life-cycle costs of these weapons systems. Now society must deal with a legacy of hundreds of billions of dollars in clean-up costs. One impediment has been that energy and environmental problems are intrinsically crosscutting, both across scientific disciplines and the decision-making systems of our societies.

I suggest that one approach to this problem is better integration across scientific disciplines and the integration of science and technology with political, economic and social factors. I use three examples of successes to illustrate this.

COUPLED ENVIRONMENTAL MODELS

First, I talked about the coupled models approach to global climate and water resources issues being developed at Los Alamos. By linking together local, regional and global codes through the newest generation of supercomputers we can increase the resolution and predictive value of global information.

The prediction of environmental crises and the development of mitigation strategies require sophisticated models that can couple global events to the regional and local level. Existing global models do not link together ocean, atmosphere, ecology, and human infrastructure impacts. Such coupling demands temporal, spectral, and spatial resolutions that outstrip current high-performance computing capacity. The level of computing and simulation required to create predictive models is currently being developed within the DOE under the Accelerated Strategic Computing Initiative (ASCI).

As we increase our awareness of the impacts of human-influence on the global environment we encounter an ever-increasing scope of direct and unintended consequences of all types of human activities. Air and water quality degradation from energy, industrial and transportation emissions are issues that have been familiar in the U. S., Asia and Europe for many decades with the resulting emergence of sophisticated monitoring and regulatory systems. The high profile issue of the '90s has been global climate change. A clearly increasing trend of greenhouse trace gases in the atmosphere are the likely product of fossil fuel combustion. The expectation of an altered radiative energy budget for the entire earth and a related change in climate has inspired observational scrutiny and a requirement to simulate the system and predict possible changes. There has been a precedent of some success in applying the tools of hydrodynamics, physics and chemistry to local, regional, and global problems.

The practical requirements for modeling and simulation of natural and perturbed environmental systems exhibit many things in common but also highlight some fundamental and significant differences. One of the crucial issues guiding the formulation of models is the **time and space scale** of the natural system and the perturbation. The atmosphere, for example, exhibits a spectrum of motion systems that is the consequence of its energy inputs and sinks and its role in redistributing energy within the earth system. These circulations are fundamental to the system and depend on geography, altitude, season, surface features, among other things. The scientific community has skill to estimate these circulation features at every scale from centimeters up to the dimension of the globe.
However, to do them all in the same calculation is prohibitive in terms of computing resource.

As we take on more difficult practical problems we encounter the next major scientific and computational hurdle, dealing with the interfaces among several geophysical domains. Interface problems are especially complex when the exchange of energy, momentum, mass (or a combination of these) goes both ways. Many climate issues depend fundamentally on the behavior of the coupled ocean-atmosphere system (for example, El Nino). The exchange of water vapor, heat, and momentum between these two global fluid domains depends on processes that range in scale from meters or less up to the dimension of an entire ocean basin (such as the Pacific). Large-scale models rely on an integral representation of "sub-grid" exchanges that are often based on earlier theories that were not developed for the multi-domain problem. A great deal of work remains to (1) understand, and (2) parameterize the interface processes among the relevant geophysical domains.

The NASA Mission to Planet Earth Program has offered a very useful partitioning of the geophysical domains of the earth system into: Atmosphere, Hydrosphere, Cryosphere, Biosphere, and Lithosphere and provides an example of cross agency, transnational cooperation. Each domain interacts with all the others on a broad range of scales in a variety of identified physical or chemical phenomena that may be crucially important for some applications. With the resources coming available through programs like the Accelerated Strategic Computing Initiative (ASCI) and the techniques coming through programs like DOE's Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) the linkages between these domains are challenges that can be met.

It is no surprise that DOE and the defense laboratories such as Los Alamos bring a capability in high performance computing to address problems with the linked complexities of scale and multiple domain coupling. There is a strong interest and capability in the many of the component disciplines (e. g. atmospheric and ocean science, water resources, ecosystems, solid earth geophysics including volcanology). Los Alamos scientists have the background to recognize when the issue is deeper or broader than a computational problem. They have the resources within the laboratory and in cooperation with external collaborators to perform problem definition and acquire complementary data to give a scientific basis improving parameterized processes.

CHINA WATER RESOURCES MANAGEMENT PROGRAM

Second, I talked about the U.S. China Water Resources Management program as an example of bringing together science, management and infrastructure issues in a common framework. This activity is being implemented under the auspices of the Vice Presidential/Vice Premier U.S./China Environment and Development Forum and the U.S./China Joint Commission and Scientific and Technological Exchange. The working committees of the Forum (Energy, Environment, Science and Technology, and Commerce) selected water resources management for immediate follow-up. The objective is to develop a coordinated, sustainable water resources management program between the U.S. and China. The Office of Science and Technology Policy that represents the participating Departments and Agencies has established a cross-agency working group: Agriculture, CIA, Commerce, Defense, Energy, EPA, Interior (NOAA, BuRec, USGS) State, and Treasury. Advisors from industry, finance, academic and the non-governmental sectors have also been engaged.

Four parallel activities are featured in the development of such a bilateral program:

1. Coordinate U.S. and China participants in identification of common problems associated with water resources, both quantity and quality. A compilation of current US/China collaborative programs has been developed, program objectives have been transmitted during bilateral exchanges and Presidential-level agreement to proceed was reached during the June summit.

2. Develop and implement a bilateral water resources management workshop as part of the annual meeting of U.S./China Forum on Environment and Development late in 1998. The purpose of the workshop is to compare approaches to water resources management through side-by-side river basin comparisons and then identify and prioritize key areas where ongoing cooperation could inspire changes in water resource management. A bilateral workshop on River Basin Management is already under development and should take place early in 1999. Workshop issues include Assessment and Prediction, Management and Infrastructure. Water use applications focus on Agriculture/Forestry, Ecology, Domestic and Industrial Use, and Flood and Drought planing and Mitigation.

3. Develop and implement a Framework for cooperative water resources management activities. The plan would include routes to fund joint research and water/energy projects to demonstrate application of selected technical approaches. Chinese government agencies have requested mechanisms to enable long-term collaborative efforts and required technical developments.

4. Involve the private sector in joint efforts to transfer technical approaches to actual application in China and U.S. and develop commercial opportunities The U.S. private sector has been actively involved in program development activities.

The intent is to explore U.S. and China water use applications so that what results is an integrated picture of water management at a river basin scale.

GREEN CHEMISTRY

Finally, I presented Green Chemistry as an example of a cooperative program between academic institutions, government agencies, NGO's, and private companies. Green Chemistry is the predominant name among several common new movements in chemistry that have emerged worldwide --- Green Chemistry, Chemistry for Green Technology, Soft Chemistry (Germany), Benign Chemistry, Sustainable Chemistry (OECD). All of these movements share the underlying principle of moving pollution prevention upstream to change fundamental processes and avoid pollution. All emphasize the use of chemical principles and methodologies for source reduction. Green Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. Examples include alternative feedstocks, replacements for hazardous reagents, enhanced atom utilization in reactions, new solvents and reaction media all leading to new safer materials and chemicals. Collectively, Green Chemistry represents a unifying theme that encompasses all aspects and types of chemical processes---including synthesis, catalysis, analysis, monitoring, separations, and reaction conditions---that reduce impacts on human health, energy consumption, and the environment relative to the current state of the art.

An international program has been promoted by the Green Chemistry Institute (GGI), a not-for-profit virtual organization dedicated to environmentally benign chemical synthesis and processing research and education. GCI's mission is to promote and foster

Green Chemistry through information dissemination, chemical research, and conferences and symposia.

GCI's approach to promoting green chemistry is to engage academic, industrial and government professionals to implement existing, verified, clean production technologies and to collaboratively develop new technologies. GCI, with industrial sponsors interested in particular chemistries or technologies, promotes Green Chemistry by convening focused workshops to develop a needs-based research agenda in identified areas.

There has been a strong international flavor to the GCI program from the inception with GCI chapters being developed in China, Australia, the United Kingdom, Italy, Russia, and for the Baltic Countries (Estonia, Latvia and Lithuania). Information on GCI activities, workshops and educational programs is available in greater detail on the GCI website:

http://www.lanl.gov/Internal/projects/green/index.html

I highlighted the activities underway in China at the University of Science and Technology of China at Heifei under University President Zhu Qingshi. I also made the point that the opportunity to employ new technology is often greater in developing economies compared to the costs incurred by retrofitting existing plants and processes.

SUMMARY

Through linkages between scientific disciplines and with other societal elements significant progress can be made in addressing energy and environmental problems. The failure of our scientific systems to avert the current energy and environmental crisis should caution us against simply asking science to come up with new technological fixes. Our best path forward may require reassessment of our scientific systems and concerted attempts to integrate across traditional intellectual boundaries. This requires education at several levels:

- The development and inclusion of an environmental curriculum within mainstream training in chemistry, engineering and other disciplines.
- Better education of social and political leaders on the strengths and limitations of science.
- The education of the scientific community concerning the impacts of social, political and economic issues on decision making processes.