

IARU COLLABORATION PROJECT

PRELIMINARY DISCUSSION PAPER for
COLLABORATIVE RESEARCH PROGRAM on**ENERGY & ENVIRONMENT****Aim**

The purpose of this essay is to inform and stimulate discussion at the January 2006 meeting of IARU leaders on the possible shape of a collaborative research program on Energy & Environment, and provide a possible basis for further refinement and development of a proposal for such a program if that is what the IARU leaders decide.

Aim of a Research Program within the IARU Collaboration Project

As with the other research programs within the IARU Collaboration Project, ENERGY & ENVIRONMENT aims to bring together the existing research capabilities of the participating institutions in a synergistic way, to work on areas of research which could make a clear and substantial contribution to making progress on addressing pressing global issues, and demonstrate the value of the IARU itself. Proposing topics for a Energy & Environment program within the wider IARU collaboration will be guided by the same criteria as for the other programs.

- Substantial ongoing research capabilities and activities: This is clearly fulfilled for several of the IARU partner universities.
- Substantive research questions onto which shared capacities can fruitfully be focused, taking full advantage of the range and diversity of capabilities and perspectives: this is the most difficult aim which needs to be established by the researchers in each individual project. The latter process can be facilitated but not enforced by high-level agreements. Exchange of faculty, research personnel, and students is one avenue to let true collaborations grow.
- Relevance to Global Change and Sustainability: Focusing on the most pressing issues in the Energy & Environment area will clearly meet this requirement.
- Communication and demonstration of valuable results to wider national and international audiences and stakeholders: This has been formulated as a target for several global research initiatives; it will require a dedicated effort and work only if highly relevant results have been achieved.
- Including both sciences and humanities, and covering as wide a range as possible of disciplines within those broad categories: With its ecological, economic, and societal dimensions, the Energy & Environment topic represents a paradigm opportunity to realize inter- and trans-disciplinary research.

Scope of the Topic

In 2000 the United Nations Millennium Development Goals stated that the principles of sustainable development should be integrated by 2015 into country policies and programs. To meet these goals, a new thinking and priority setting needs to be established, based on sound scientific and engineering knowledge. With the topic E&E, IARU could aim at providing the scientific basis for this integration as a global player.

Fifteen years of post-Rio sustainability research resulted in important findings, especially related to a process-based understanding of decisive environmental problems, but crucial knowledge gaps persist, related especially to environmental issues subjected to international political and scientific debate, with little hope for immediate solutions and consistent strategies (global warming, loss of biodiversity, and degradation of land resources and water supplies at an unprecedented pace) and to the general unwillingness and unpreparedness to think on time scales longer than a life span.

The Big Questions which motivate a focus on E&E are relevant, scientifically challenging and with far-reaching consequences for the future of our society and our planet:

- How can we decelerate the depletion of non-renewable energy and material resources, and decrease the quantity of 'waste' discharged into the environment?
- How do the global element cycles tie in with the claim for a sustainable energy production?
- How can we mitigate the emissions of greenhouse gases by higher efficiency of the energy system?
- How can we mitigate natural hazards and ecosystem mal-functioning and disorders, both for the present and future states of the global ecosystem?
- How does global change induce local (regional) changes in natural and managed environments?
- How can we sustain and / or improve ecosystem services in very different environments?
- How can we decrease primary energy consumption, by emphasizing energy services?
- How can we produce food sustainably for the world's growing population, alleviate hunger and extreme poverty?
- How can we make better use of the underground and its resources?
- What may prevent us from being entrained into an even more unsustainable behavior?
- How can we ensure that the "precautionary principle" enhances sustainability without curbing economic growth?

The first group of questions deals with alleviating pressures on the global ecosystem, covering both adaptation and mitigation approaches. The second deals with the concept of producing services in a sustainable manner. Finally, the third group of issues addresses the demand side and societal attitudes.

All IARU universities have been very active in the field of energy, environment and sustainability. This project will integrate research across disciplines and between the institutions within and outside the IARU partnership, and will form a strategic and operational alliance of partners with complementary strengths with a common mission, an alliance that can progress at a faster pace, create synergies, and optimize the use of the resources of the partner institutions.

Thematic Focus

Several themes could be developed under the overall E&E domain, at the forefront of research and engineering development and cutting across disciplinary boundaries, where the societal need for relevant progress is pressing.

NATURAL ENERGY AND MATERIAL RESOURCES

Goal of this action is to foster the debate on long-term prospects for natural resources and energy in the broader sense. Issues of immediate and growing concern include water, the short- and long-term future of nuclear industry, CO₂ capture and sequestration, energy production from the resource point of view (sources and sinks), the end of cheap oil, the adherence to the Kyoto protocol, the diminishing water supplies for energy hydroelectric power, supply challenges in the 21st century and beyond, the prospects for large-scale geothermal energy production, a comprehensive approach to the use of our underground, and more generally all resource prospectives related to the sustainability of our life quality. The establishment of policy strategies, such as a 30- and 50-year energy outlook require sound scientific data and modeling. One of the great challenges in coming decades is to master the global-scale pressure on natural resources: water, air, soil (including underground) and renewable energy. Increasing population and subsequent needs for food and water services as well as the decline of inexpensive oil are crucial elements of coming developments. The overall mission must be to provide the scientific and technological basis for equitable and sustainable use of natural resources and renewable energy in a world whose population is expected to exceed 8 billion.

CLIMATE AND ENVIRONMENTAL CHANGE

We live on a planet shaped by human activity. Rapid human population growth and continuous exploitation of natural resources impact global ecosystems, lead to dramatic declines in biodiversity, affect the global hydrological cycle and climate, and render the society vulnerable to diseases and natural hazards such as extreme weather. Public health, livelihood, social justice and national security are linked by environmental change. The unique combination of experimental and modeling expertise within the IARU institutions will enable us to make significant contributions to master these intellectual, technological and political challenges. Finding innovative solutions to develop sustainable resource use under changing climatic and environmental conditions, to reverse the dramatic loss of biodiversity, and to reduce the atmospheric greenhouse gas (GHG) concentrations, which are effectively higher than at any other time within the past 500'000 years, will need a comprehensive *Earth System Science* program with a time horizon of "10+" years. Questions which we seek to answer include:

- How does climate and environmental change affect biodiversity and processes in the biosphere?
- How large are the feedbacks of the terrestrial biosphere on the production of GHG and aerosols, the Earth's energy budget, and hence on climate?
- How can a hierarchy of models – from the local subsoil to the global scale – be coupled and nested to improve the representation and the scaling of land-atmosphere interactions across spatial dimensions?
- What can we learn from past climate changes for future climates and their effect on the biosphere?
- How can we assess mitigation and adaptation options and technologies to fulfill Kyoto requirements and to slow-down climate change impacts on economies and societies?

NATURAL HAZARDS AND RISK MANAGEMENT

2005 has been a year of natural disasters, affecting all regions of the globe and all sectors of society. Natural risk reduction is high on the political agenda at all national and international scales. With increasing human pressure and intensification of land use the need for accurate predictions of hazards and the assessment of risks is essential in any economic development planning. The scientific motivations are many and include foreseen improvements as diverse as: Predicting extreme events; Quantifying spatial and temporal variability and scaling in the environment; Development of models to describe the complex non-linear interactions between hydrological/geological history and current weather; Accounting of small scale processes in large scale simulations; Development of ecological and sustainable methods for protective measures; Development of early warning technologies; Policy issues; Sustainable development and building practice.

SUSTAINABLE LAND USE

Global, regional and local degradation of land resources as well as segregation of land-use, e.g. intensification on favorable land and marginalization in remote areas bears a world-wide conflict potential. The latter can be significantly reduced with new technologies, sound modeling approaches and knowledge-based decision support tools that reconcile economic growth and technological progress with ecosystem integrity. The current generation of land-use modeling and negotiating tools have been valuable means for exploring the implications of environmental, social and economic change, but they are limited because they focus on system states that are assumed to represent some kind of equilibrium under current and future conditions, respectively. These limitations are increasingly removed due to computational power, new simulation tools and remote sensing data at different spatial scales as well as advances in the research on the human-landscape interface. This proposed theme could exploit this momentum and proposes innovations in the following fields:

- Early detection and modelling of long- and short-term, spatially explicit landscape and ecosystem quality changes based on temporally, non-continuous data sources
- Modelling and forecasting land use change as a function of demographic, economic, technological and climatic driving forces; implementing the models into frameworks of adapted decision support tools that foster a transparent negotiation among various actors
- Developing technologies and land management schemes that enhance ecosystem functions, services and goods. This know-how will be propagated in a restoring and a preventive mode.
- Evaluating the influence of linear landscape elements (e.g. rivers) on the connectivity of ecosystems

EFFICIENT ENERGY USE

On the technical side, efficiency increases are one of the most effective ways of curbing global primary energy demand. Presently, many energy services are rendered in a highly inefficient manner, and roughly 2/3 of the total primary energy expended is lost in energy conversion.

- The energy required for the heating and cooling of (residential, service, and industrial) buildings amounts to one-third to one-half of total energy consumption, depending on the world region. It has been convincingly shown that the heating energy demand per area can be decreased by 80% from present average. Climate-adapted advanced building technology for new construction, and effective energetic upgrading of the existing building stock, are key for achieving this aim. Decentralized trigeneration schemes for the efficient production of heat,

cold, and electricity, with an increasing share of renewables including environmental heat, are key on the path towards reducing the fossil energy demand in this area.

- Electricity generation, distribution and storage is associated with large losses. Novel high temperature materials, highly efficient gas turbine processes, co-firing of biomass and biogas, as well as CO₂ capture and sequestration techniques, can increase the efficiency of generation. Storage of electric energy with high cycle efficiency is key for enhancing the performance of the system. In a broader sense, the management of the energy system as a whole and the security of the associated distribution grids require in-depth analysis and strategy development.
- The transportation sector, in spite of consuming 20-40% of primary energy (depending on world region) and most rapid growth rates, is characterized by the poorest energetic efficiency, which can be as low as 16% on a well-to-wheel basis for a gasoline vehicle. Important elements for improving the efficiency of this sector include the optimum design of a multi-modal transportation system, the development of efficient and accepted public transportation, rail transport of freight, fast ground transportation to replace short distance air travel, and drastic improvements in the efficiency of motorized individual vehicles (lightweight construction, hybrid powertrains, fuel cells).

DEMAND SIDE ISSUES OF SUSTAINABILITY

Acceptance issues need to be addressed in the context of many energy & environmental technologies; municipal waste recycling schemes, nuclear energy, and wind power may be cited as examples. Societal issues are key for ensuring that the technical measures described above do indeed lead to a more sustainable energy system. For example, the access to ubiquitous and affordable energy is a prerequisite for development in emerging economies, and thereby for a stabilization of the world's population. On the other hand, it could lead to an explosive growth of energy consumption unless accompanied by a strategy for reflecting on the necessary energy services. As a second example, the availability of efficient and environmentally friendly transportation devices could rebound in a demand increase for transportation services, as the fraction of energy costs decreases. A deliberate commitment of societies to limit the per capita energy consumption, as expressed e.g. in the vision of the 2000W society, may thus be essential for achieving sustainability goals in the energy & environment area.

Drafted by Domenico Giardini and Alexander Wokaun

Zurich, January 6, 2006