# Energy and Sustainable Societies

## -- A programme proposed jointly to ICSU by the French Académie des Sciences and the Science Council of Japan --

### 1. Introduction

The concept of "Sustainable Development" was defined in the 1987 report from the World Commission on the Environment and Development subtitled "Our Common Future", and known as "the Brundtland Report". This report pointed out the difficulties in pursuing two urgent and conflicting goals: preventing the degradation of the global environment (which had already reached a critical stage) and urgently pursuing the economic development in the developing countries in order to improve people's quality of life. "Sustainable Development" can be seen as a problem with no obvious solution at the moment.

Over decades, intergovernmental discussions and negotiations have been formulated finding ways to achieve "economic growth," "social development" and "conservation of environment" simultaneously. The scientific community has tried to contribute to this process in particular, through an intensified effort of observation and analysis of the global environment, and through research and development of environmentally sound technologies.

"Energy" has been highlighted during such discussions as a key instrument to achieve sustainable development. Following up to UNCED (United Nations Conference on Environment and Development, Rio de Janeiro, 1992), CSD-9 (the 9$^{th}$ Session of Commission on Sustainable Development, New York, 2001) was organised particularly to address the issue of "Energy and Transport." "World Energy Assessment," which was conducted with the UN initiative, provided us with a good synthesis of relevant knowledge and information available to the global community. "Energy and sustainable development" will continue being a priority topic at the World Summit on Sustainable Development scheduled for September 2002. ICSU has actively participated in this process representing the Science and Technology Community together with other partner organisations and become convinced of the roles and responsibilities of the S&T community and importance of the involvement of all stakeholders in addressing the energy problems.

This proposal is based on the conviction of both proposing parties that science should continue providing the society with integrated scientific knowledge as a basis for the development of sustainable energy strategies, and that it is the role of ICSU to facilitate this process by promoting a new interdisciplinary programme around the theme of "energy." It is also expected that the proposed approach would necessitate and encourage closer collaboration among researchers from different disciplines as well as dialogues between various stakeholders in the society.

## 2. ICSU's experience

ICSU, together with other interdisciplinary bodies and joint initiatives, has been playing a significant role in addressing the global environmental problems mainly through the following interdisciplinary programmes:

- WCRP (the World Climate Research Programme), formed in 1980 jointly with WMO and later IOC;
- IGBP (International Geosphere-Biosphere Programme), established in1986;
- IHDP (International Human Dimensions Programme on Global Environmental Change) established in 1995 in collaboration with ISSC;
- DIVERSITAS (An Integrated Programme of Biodiversity Science), established in 2000.

These scientific research programmes have influenced the development of the international policy in the area of global environment change, by providing relevant scientific information for decision-making. In particular, in the case of climate change, ICSU has played a significant role in formulating the voice of the scientific community, and successfully raised the attention of policy makers to the role of CO2 and global warming. This led to the establishment of the IPCC (Intergovernmental Panel on Climate Change), which has provided integrated scientific knowledge concerning the climate change to serve the policy community as a basis for its international negotiation based on the FCCC (Framework Convention on Climate Change).

No specific joint efforts have yet been made within the ICSU Family around the subject of "energy". However, as the energy issues are at the heart of sustainable development, it would be appropriate for ICSU to take an initiative in formulating a new international and interdisciplinary research programme on the subject, building on its experiences in other areas as summarised above.

## 3. Energy and Sustainable Development: Need for a new interdisciplinary approach

Ever since the acquisition of fire, human beings have exploited various sources of energy such as wind and hydraulic energy, coal, petroleum, natural gas, and more recently solar and nuclear energy. The invention of the steam engine, which triggered the Industrial Revolution, has made large-scale use of energy possible, and resulted in rapid economic growth and the improvement of living standard.

An historic analysis shows that the energy consumption increases with the GDP, while the ratio of these two parameters varies widely from one country to another. In particular, rapidly developing countries will increase their energy needs drastically. Most of energy in these countries is presently generated from fossil fuels, which are limited. The only fossil fuel likely to satisfy these needs during this century is coal, the most carbon emitting fossil fuel (both in term of $CO_2$ and soot, the effect of which is adding to global warming). In addition, coal emits other polluting gases such as $SO_2$ or NO. Therefore, reducing $CO_2$ emissions implies a need for a decrease in energy consumption and/or a shift to alternative energy sources. Evidently associated political choices are strongly influenced by the cost and/or rarity of energy, the projected population growth, and the economic development.

What will be the future energy use by developed and developing societies? How much energy will be needed? What problems will occur, and what research is needed to solve these problems? These fundamental questions will have to be quantified, and put into context with other societal needs to develop best scenarios concerning how to best balance needs for economic, social, and environmental development.

Undoubtedly, the energy problem raises many important research issues, which necessitate interdisciplinary approaches. Many factors should be studied with a broad and long-term perspective, including population growth in the developing countries, the economic growth rate and structure of both developed and developing countries, the evolution of societal needs, the contribution of science and technologies, the overall state of the environment, etc. The role of social science is particularly essential in this approach to assess the acceptability of the various solutions that are technically feasible. Such research should not wait for the solutions to be available, as it could influence their implementation. Motivation research should be also undertaken, as the consumer is central in this approach in order to eventually influence his behaviour in daily-life energy consumption.

## 4. Proposed Programme Framework: The value of energy for human beings and societies

The energy problems also necessitate a close alliance between different stakeholders. What makes this alliance difficult is that the structured knowledge basis has not yet been established to formulate a common concept concerning "the value of energy for human beings and societies.[1]" Such a concept would provide us with a framework to integrate all the related knowledge and enable us to describe the energy problems with a bird's-eye view.

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[1] The study on the value of energy in **natural science** has developed in thermodynamics. Important concepts concerning the quality of energy such as entropy and free energy have been defined and thermodynamics under the non-equilibrium conditions has begun to develop recently. Such developments are ranged with the most advanced academic disciplines such as the theory of self-organization, complex systems, and life paradigm theory.

In the field of **engineering**, exergy is one of the results of attempts to represent the value of energy. Since exergy is a concept that has developed in the field of thermal engineering, it has not yet been sufficiently used in other scientific fields. Exergy plays a very important role in evaluating the energy conservation and the renewable energy utilization.

Meanwhile, the **economic** value of energy is fundamentally determined by the market and expressed as individual prices of energy commodities such as electricity and fuel. When the value of energy for human being is considered, economics is indispensable. In contrast to natural sciences, however, there is no universal concept of energy in economics; there are only respective energy commodities in economics. This economic value needs to cover a more long term, wide range human activities with natural and environmental systems taken into account.

Besides, when the urgent necessity of energy as an indispensable public service and the strategic importance of energy for national security are taken into account, this concept will need to deal with the issues of **equity and security** with the assistance from broader academic disciplines. However, the structured knowledge basis has not yet been established to formulate a common concept concerning the value of energy.

To define "the value of energy for human beings and societies," a new methodology needs to be designed to systematise all energy-related knowledge –from humanities, social science, natural science, engineering, and their intersections-. It is suggested that a proposed new research programme include the following perspectives to attain this goal:

- **Energy and culture:**
  Analysis needs to be carried out from the following view points: philosophical study of energy, value and quality of energy, and correlation between energy and culture. The roles of physical knowledge in energy production will be linked with humanity in energy consumption. The conflict exists between the supply side where energy is thought only physically and the demand side where human work is regarded to have the limitless possibilities. Sustainability is examined by exploring how to bring the concept of "public interest" into this conflict.

- **Energy and socio-economic needs:**
  Study is necessary on international comparison of the decision-making processes for energy policies with the governance concept, systematisation of the economic theory of energy, comprehensive study of energy security, and analysis of environmental impacts resulting from energy consumption. Through this approach, the direction of solutions will be suggested to various energy policy-related issues which human beings will most likely be confronted with during the 21st century. The value of energy will be defined as an economic concept from the viewpoint of social science.

- **Technology and society:**
  Analysis is necessary on the partnership between energy technology and society, past and future of energy technology, energy resources and science and technology, and energy technology and educational activities. The role of energy technologies in human activities needs to be investigated to evaluate the future technological energy options from the viewpoint of the science, technology, and society interactions.

Figure 1 illustrates the schematic image of the proposed programme framework.

## 5. ICSU's role and possible research topics for ICSU

ICSU is in a unique position to help the society develop alternate development paths by mobilizing vast intellectual resources in the world research community, not only from different disciplines in natural sciences, but also from engineering, social sciences and humanities. ICSU would also have a role to facilitate communication between researchers and other key stakeholders in the society, namely educators, industry, policy-makers, and the public, as communication is essential for the research community to ensure its contribution to the decision-making in the society.

To fulfill this role, an adequate mechanism should be developed and built in a research programme. Careful consideration is required in selecting topics and defining the scope of the programme adopting the framework proposed in the previous section.

It is proposed that discussions among the ICSU Family be continued involving potential partners to ensure added-values of ICSU's involvement. Following are some examples of

possible research topics, where both S&T Community's potential contribution and other stakeholders' interest seem to be large:

- **Methodology for studying the energy system:**
  Methodologies to best integrate relevant interdisciplinary knowledge should be studied to provide appropriate advice to policy-makers. For example, currently scenario development that is based on various formal models is being used as a major tool to link scientific and technological knowledge/information with policy options. But could there be any measures to reinforce or complement the scenario approach? How could contribution of the S&T Community in the scenario development be strengthened?

- **Efficiency of energy use:**
  Saving energy without reducing human welfare is a challenge to engineering and natural sciences, which requires contribution from economics, social sciences and humanities. The cost of energy could be more accurately evaluated through a systematization of the economic theory of energy, a comprehensive study of energy security, and an analysis of environmental impacts resulting from energy consumption. Numerical models could be developed to analyze global energy systems, for different technologies and different energy policies, including the life cycle assessment (LCA) of the environmental impact of energy use.

  In the industry sector, energy consumption decreased by 0,8 % in the OECD countries from 1990 to 1995. Especially the energy intensive industries have enough economical incentive for energy saving. ICSU could concentrate its efforts on other domains such as transport which is and is expected to remain the sector with the most rapidly increasing emissions (yearly rate of increase 2.5 %). Reducing car energy consumption is already undertaken. Human sciences could help developing public transportation systems, which many users would prefer to their personal car. How could the needs for transportation be reduced further by the spatial organization of the country, the urban planning, the optimization of the size of cities, the development of information and communication technologies?

- **Storage of carbon dioxide:**
  $CO_2$ capture and storage can contribute to the reduction of the greenhouse gases emissions. ICSU could play a key role in studying the feasibility and the possible impacts of several storage options, such as geological, marine storage options. The capture solutions could be explored in collaboration with engineers outside the ICSU family.

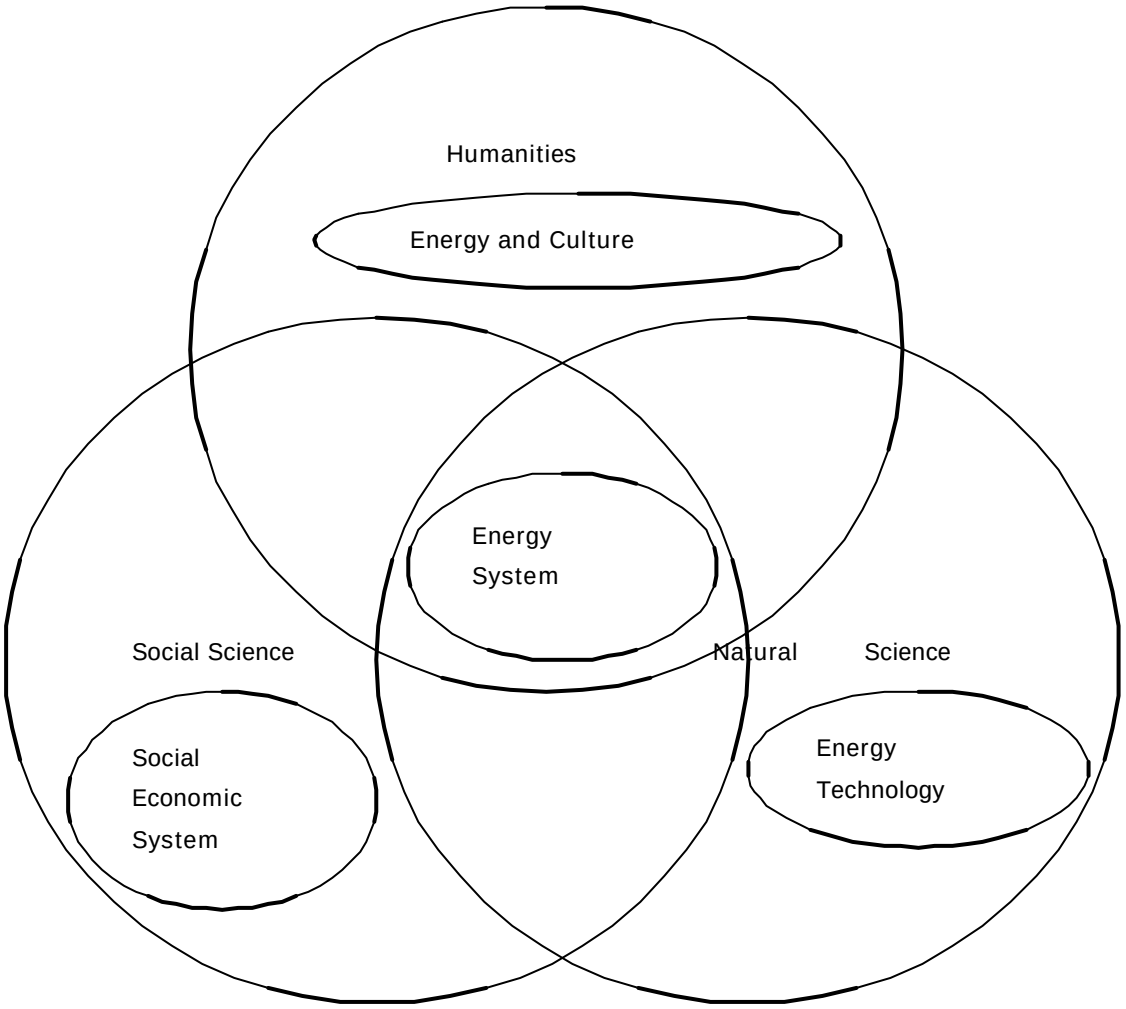
- **Technology for Energy production and storage:**
  Scientifically the problem of energy production should be considered without any a priori, as the challenge is so large that one should not exclude any options. Fossil fuels remain the major energy source in the world. Their resources are limited and the present rate of their consumption lead to a global climate change hardly sustainable. One should consider the ICSU's role in further developing potentialities of energy production means.

  Efforts in developing alternative energy sources, such as renewable energy sources needs to be continued and strengthened. Improving the solar cells efficiency and

reducing their production cost is likely achievable during the next two decades. Potentials of hydroelectricity, wind energy conversion and geothermal, biomass and solar power generation are also need to be explored. The use of nuclear energy is the only centralized one without any impact on the carbon dioxide emission. However the treatment of nuclear wastes needs further research, independently of the development of this energy in the future. Numerous fields of science should be involved to solve the development of new generation of safe power plants, including fusion in the long run, as well as to solve the issue of social acceptance. Fuel cells have the potential to provide highly efficient combined sources of electricity and heat as power densities increase and costs drop, but the production of hydrogen to feed them remains to be solved.

Energy storing remains a major challenge both for absorbing demand peaks and for offering an alternative to liquid fossil fuels for mobile energy sources. Producing electricity in remote sites (e.g. solar cells fields in deserts) would be an interesting alternative, if this energy could be easily transported. However, it is still uncertain if a hydrogen economy a realistic and safe option.

Figure 1: Schematic image of the proposed programme framework



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