IUPAP STATEMENTS AND RECOMMENDATIONS ON THE ENERGY PROBLEMS

I-INTRODUCTION

Energy problems will be among the most important and difficult challenges of this century. In addition, today we are aware that climate changes are linked to the production of energy.

The present world population of about 6.5 billion humans is expected to reach about nine billion around the middle of this century, mainly attributable to developing countries with fast rising populations and fast economic development e.g. China, India and Brazil. In the same period the global Gross Domestic Product (GDP) is expected to rise by at least a factor of two to three, an appreciable fraction from fast developing countries such as those previously mentioned. One can only hope increased energy efficiency in the industrialized countries, like that achieved during the oil shocks of the 1970s and 1980s, will limit the increase of the global demand on energy to about a factor 1.5 to 2 even with the increased demand from developing countries.

Recently, the International Council for Science (ICSU) produced a strategic Plan for the period 2006-2011 and has decided to set up a working group dealing solely with renewable energy. At IUPAP, we decided to have a more complete approach.

Meeting the energy demands of the world with affordable and environmentally acceptable technology will require an enormous amount of work. The science community has a role to play both in developing new energy technologies and in advising the leaders of governments on the realities of alternative technologies and what must be done to make them effective.

This is why the General Assembly of IUPAP, in Berlin, in October 2002, formed a Working Group on Energy, charged with providing an expert

survey of Research and Development (R & D) needs of all Energy Technologies. The report (~400 pages) is available on the web site of IUPAP (http://www.iupap.org/wg/energy/report-a.pdf); a short version (30 pages) can also be found on the same site.

This survey of R & D of Energy Technologies should help to sharpen the interest of:

- scientists, especially physicists, in universities, in research institutions, in industry to devote their further work to this challenging field of science;
- the media to inform the public with sufficiently comprehensive information on this subject of vital importance;
- policy-makers on the attractive potential for future ample business opportunities in the field of energy technologies as well as in many other fields.
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In order to produce the IUPAP report, we invited scientific experts from different countries to provide short surveys of many different energy technologies describing the present status as well as the future R & D required to further develop the corresponding technology for proper ample use in the future. We have further collected reports on the special energy situation in different countries around the globe. The IUPAP experts represent an objective unbiased point of view.

Presently the main sources of primary commercial energy (90% commercial +10% non commercial energy) are the fossil fuels, coal, crude oil and natural gas (about85% of the commercial energy): 40% in power plants to produce electricity, 24% for fuels in the transportation sector, 22% for manufacturing, industry and construction , 14% for house heating.

Within the last 100 years the global annual demand on primary energy rose from about 1 billion tons of coal equivalent (1BtCE) to about 14 billion at present, of which 78% is from fossil fuels, 6% is from nuclear energy, 6% is from commercial renewable energy and 10% from non-commercial renewable energy.

Supply constraints are already evident for oil where prices have increased dramatically in the last few years. Transport constraints for gas have also increased its price. Only the coal supply is not presently limited, but it has severe environmental impacts.

Furthermore, it is of utmost importance to address the climate change caused by climate warming induced by the excess burning of fossil fuels [Intergovernmental Panel on Climate Change, IPCC, 3-rd assessment report, Cambridge 2001]: the direct release of heat by burning fossil fuels - globally only less than 0.01 percent of global warming by sunlight

- is negligible. Not negligible, but highly dangerous is the increase of greenhouse warming due to the increase in the carbon dioxide content of the atmosphere: when burning fossil fuels about half of the carbon dioxide released remains in the atmosphere for at least some hundred years.

Since burning fossil fuels is the main source of energy required by mankind, the carbon dioxide content of the atmosphere has been increased by about 1/3, from 0.28 per mille of volume about 200 years ago to 0.37 per mille at present. Mainly this rise has led to an additional greenhouse warming on global average by close to 1 degree Celsius.

With still further rising consumption of fossil fuels, and with unrestricted release of carbon dioxide, over the next decades we must expect a further rise of the temperature by some more degrees. This rise of temperature poses the risk of climate changes most dangerous to mankind and to nature in many regions around the globe:

In the present status of energy technologies, the future provision of energy from non-fossil energy sources is more or less rather limited:

- either because of limited availability (e.g. hydro power)
- and/or because of relatively high investment costs (e.g. nuclear fission power)
- or because of very high investment costs and lack of availability of energy storage (e.g. wind power and photovoltaics).

Therefore fossil fuels are expected to continue to be the dominant source of primary energy at least within the next decades despite the danger of climate change.

To reconcile both necessities (providing sufficient energy and further reducing the emission of carbon dioxide from burning of fossil fuels) requires strong efforts on both:

- R & D on non-fossil energy technologies such as renewable energy, nuclear fission and nuclear fusion to gradually substitute the further use of fossil fuels within some to many decades
- R & D on clean fossil energy technologies focusing on increasing the efficiency of power plants and advances in both CO_2 sequestration and deposition to allow fossil fuels to continue as the major source of primary energy within the next decades.

There are exciting opportunities to develop new paths based on computational physics, nano-science, and nano-technology to develop the energy conversion and storage methods needed to meet society's energy needs.

A large variety of energy technologies can be tackled by challenging R & D covering essentially all branches of modern physics, not restricted to one branch alone, basic physics and applied physics are inseparably linked. This should include strong collaborations with other disciplines such as chemistry, biology, computer and material science.

II-Statements and Recommendations

A. General

1 Due to the enormous problems to be solved over the next few decades, we believe that the research budgets in the field of energy are not sufficient to tackle the challenges: we urge governments, agencies and also scientists to consider this.

2 The ideal source of energy does not exist today. Each source has advantages and drawbacks: they should be discussed on a scientific basis and not emotionally.

3 Each country has a different situation; but to all it is important to diversify the sources of energy.

4 The problems of energy and climate changes are so important that they should be approached already at the school level, to increase the awareness of the population.

B. Specific Energy and Fuel

1 Fossil fuels (oil, gas and coal): in view of the limited reserves known today, and the environmental problems they cause, it is fundamental to increase the efficiency of power plants and to diminish the amount of CO_2 produced. Further development of the technologies of fossil fuel fired steam and gas turbine power plants, in particular working at higher steam and gas inlet temperatures, is expected to significantly increase the efficiency of converting high temperature heat to electric power.

R&D is needed to show that the CO_2 sequestered at power plants can be deposited in depleted gas fields or in deep saline aquifers. This will imply an additional cost but it will be very small compared to the cost of global damage by the onset of climate change. On a time scale of one or two decades high temperature fuel cells, solid oxide or molten carbonate fuel cells are expected to become economically attractive with an efficiency of about 50 to 60 %.

Coal presents an urgent problem: countries like China, India and the USA have enormous needs for energy. They also have very large reserves of coal. It would be naïve to believe that they will not use

them; this is why it is urgent to have a strong R&D program to learn how to burn coal in a"clean" way.

In the transportation sector, solutions to considerably reduce consumption already exist. What is missing is a political resolve to create incentives for their rapid deployment.

2 Nuclear Fission Energy: in view of the increase in the world population over the next decades and limited fossil fuels reserves, the use of the nuclear fission energy is inevitable.

Strong R&D should be pursued on nearly closed fuel cycle via breeding and reprocessing of fuels and aiming to largely reduce the amount of high level radioactive waste either by burning all the actinides in proper Nuclear Power Plants or by transmutation of minor actinides to shorten the lifetime of radioactive waste.

3 Renewable Energy: solar, wind, hydro, geothermal, ocean wave and biomass will not, in the foreseeable future, replace fossil energy but it should play an increasing role, especially in some countries or at local levels.

Before industrialization, renewable energy had been the only source of energy available. The onset of industrialization caused an extraordinarily fast rise of the demand for energy and caused a severe shortage of firewood in many countries. Fossil fuels soon became the dominant source of primary energy.

At present, renewable energy provides only a rather limited amount of secondary energy; if one removes hydro power energy, the others represent only few percent of the total global demand.
A more extended use is mainly penalized by:
- restricted availability (hydro power, biomass)
- strongly fluctuating and intermittent availability of hydro river, wind power or sunlight
- rather high cost of geothermal energy.

This is a challenge for R&D; we must make the best use of interdisciplinary science and technology, nano sciences and nano technologies, for design and production of new materials to achieve economically attractive solutions

4 Nuclear Fusion Energy: the construction of the International Thermonuclear Experimental Reactor, ITER, has been recently approved: it is a "global" collaboration between the

European Union, Japan, Russia, China, South Korea, India and the USA. Support for this very positive step should be continued but one should not forget that it is a research project on very long term: if it is successful, a production reactor could be built. This may take 50 years.

5 Hydrogen: in principle, hydrogen is a very promising "clean" fuel but it is not an available energy source, i.e., it must be generated by some process requiring an energy source. The production of hydrogen by electrolysis, its liquefaction, storage and distribution requires the expenditure of a least 2 kWh electric energy for 1 kWh caloric energy of hydrogen provided. Therefore a provision of large amounts via electrolysis would require a corresponding large rise of the demand on electric energy. For future provision of hydrogen by large amounts, rather challenging R&D along new directions should be pursued.

III-Conclusion

We appear to have in our hands the means to begin to address the energy problems linked to climate change, and, with performance of the appropriate R&D, more options will become available. As scientists, it would seem to be irresponsible if we fail to convey realistically the demands of the situation.

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