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Multi-stakeholder dialogue on sustainable energy and transport

Note by the Secretary-General

Addendum

Discussion paper contributed by the scientific and technological communities*

Contents

* Prepared jointly by the International Council for Science and the World Conservation Union; the views and opinions expressed do not necessarily represent those of the United Nations.

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The role of the scientific community

1. This paper[1] examines four key topics related to a global transition to sustainable energy and transport systems. Emphasis is put on the aspects related to science and technology. These aspects are important. For example, much of the variation in energy scenarios developed for the future is accounted for by differences in the assumed rate and nature of technological advance.

2. However, a successful transition to sustainability requires more than scientific and technological knowledge. It requires economic tools and sound public policies. Progress towards sustainability has so far been limited more by inadequate policies, and the political choices that underlie them, than by constraints related to science and technology. Sustainability may require even more fundamental societal adjustments.[2] Value systems need to minimize the present emphasis on materials and energy and encourage their more efficient use to introduce more sustainable consumption patterns. Science and technology can help promote such a transition, but that will not be sufficient. There is no "technological fix". The social sciences have a major role to play in this respect.

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[1] The International Council for Science (ICSU), composed of 98 multidisciplinary National Scientific Members (academies of science or scientific research councils) and 26 international, single-discipline Scientific Unions, is a major international forum for the scientific community. The World Conservation Union (IUCN) is the world's largest conservation-related organization, bringing together 76 states, 111 government agencies, 732 NGOs, 36 affiliates, and some 10,000 scientists and experts from 181 countries in a worldwide partnership. Major contributions to this paper from the World Federation of Engineering Organizations (WFEO) and the Interacademy Panel on International Issues (IAP) are also gratefully acknowledged. These organizations have consulted their membership in an effort to reflect a wide range of views from the natural, social, engineering and medical sciences. However this paper does not represent an official position or statement of these organizations.

[2] *Transition to Sustainability in the 21st Century: The Contribution of Science and Technology*, Statement of the World's Scientific Academies, May 2000, http://interacademies.net/intracad/tokyo2000.nsf/all/sustainability_statement. See also statement of Science Council of Japan, *Towards a Comprehensive Solution to Problems in Education and the Environment based on a Recognition of Human Dignity and Self-Worth*, July 2000.

3. Agenda 21 recognised the importance of the scientific and technological (S&T) community in achieving environment and development objectives, especially through providing information to help decision-makers formulate and select appropriate policies. It emphasised the need for better communication and co-operation between the S&T community, decision-makers and the general public. Steps in that direction were taken at the ICSU/UNESCO World Conference on Science (Budapest, June 1999) and the Conference of the World's Scientific Academies organized by the Interacademy Panel on International Issues (Tokyo, May 2000). The participation of the S&T community for the first time in the CSD process is a further response to that mandate.

4. Before addressing the specific agenda items on energy and transport, the international S&T community wishes to call attention to several general issues that warrant careful consideration and action by CSD-9 and others.

5. The first concern is the downward trend in expenditure on energy research and development (ERD). From 1980-1999, government ERD spending in the member countries of the International Energy Agency, which account for the bulk of such expenditure worldwide, fell by over 50 %. (Government spending for all types of R&D has also been stagnant in many countries, but has not fallen so sharply.) The drop in spending for R&D for renewables and nuclear exceeded that average figure.[3] Private ERD spending also appears to have fallen, and most private ERD focuses on a small number of (mainly developed) countries. Moreover there seems to have been a shift of emphasis in both government and private ERD from basic, long-term research to lower-risk, nearer-term ERD projects. This is particularly worrying, since meeting the reduction commitments for CO_2 emissions envisaged in the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) will in the longer term require substantial breakthroughs in energy technologies if the growth of developing countries is to be accommodated. Basic research is not costly, compared to interventions further downstream, such as the buy-down of technologies to reduce their unit cost. Hence it represents cheap insurance for the future. It is important not to take a narrow view of the types of research that

[3] International Energy Agency, Energy Research and Dev. Database, http://data.iea.org/iea/link_wds.asp

may prove important for sustainable energy and transport. The results of basic research are unpredictable, and useful findings may come from unexpected sources. For example, fields such as atmospheric sciences, information technology, materials science and biotechnology may produce discoveries that promote sustainability in energy and transport. Sole reliance on the market is unlikely to produce the right level and type of ERD since it is very difficult for individual firms to appropriate the benefits of long-term, high-risk R&D, which therefore would tend to be undersupplied.[4]

6. Second, a massive effort is needed to strengthen scientific and technological capacity in developing and transition countries. A critical mass of scientific and technical skills and infrastructure (e.g. laboratories, equipment, and supporting institutions) is required for these countries to develop, adapt and produce the technologies specific to their needs; to introduce those technologies effectively into the market; and to provide the needed maintenance on an on-going basis.

7. Third, the full and open exchange of scientific and technological data and information is critical for research and education. Access to such material is a basic requirement for meeting the challenges of sustainable development—including those related to energy and transport. Attempts to restrict access to such data and information or to impose additional costs for access are multiplying. As attitudes and policies regarding intellectual property rights evolve, the importance of full and open access to data and information is being under-estimated, if not ignored. This represents a serious risk to the scientific enterprise in general, and will likely have particularly negative consequences for developing and transition countries.

8. A fourth issue concerns the ethics and responsibility of science and the scientific community. Effective responses to science/policy issues, including those related to energy and transport, require integrity and objectivity in the practice of science. This principle was addressed at the

4 *Funding and priority policy for energy and environment research*, Keynote speech by H.J. Koch at ENEA Seminar on Scientific and Technological Research and Development, Frascati, Italy, October 1998, http://www.iea.org/new/speeches/koch/1998/italy.htm

World Conference on Science and elsewhere but needs to be reiterated and reinforced within the CSD process.

9. Finally, public understanding of energy and environment issues remains weak. There is a need for public education in these matters, directed both at the public at large and at the politicians and civil servants who make and implement policy.

10. <u>General proposals:</u>

(a) Governments, scientific and international organisations, in cooperation with the private sector and other bodies as appropriate, should make an international assessment of the adequacy and efficacy of current public and private research and development expenditure on energy and transport. This assessment should recommend: what level of funding is needed; how any additional funding judged necessary can be mobilized, from both public and private sources; and what research priorities should be. Consideration should be given among other possibilities to the U.K. Royal Society proposal for the establishment of an international energy bank with its own resources, which would allocate funds based on the recommendations of an international committee of scientists, engineers and economists.[5]

(b) Governments, international organisations, major groups and others should conduct a review of present capacity-building activities for science in developing and transition countries (encompassing natural, social, engineering and medical sciences) and take the actions recommended by the review to strengthen and expand them. Consideration should be given to the establishment of regional centres to promote the dissemination of information and the transfer of technology related to energy and transport.

(c) Governments and other organizations, as appropriate, take measures to provide full and open access to data and information for scientific research and education, for environment and development in general and for energy and transportation in particular.

(d) The scientific community, with the support and cooperation of other relevant bodies, should analyze and monitor the ethical implications and means of regulation of scientific work; foster public understanding and debates on the ethical implications of scientific

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5 Royal Society, *Nuclear energy: The future climate*, London, 1999.

knowledge and its application; and develop, adopt, and observe codes of ethics and conduct related to science.

(e) The scientific community, together with governments and others as appropriate, should carry out active information and education programmes on energy and environment issues within their respective spheres of responsibility, aimed at the general public and at those who make and carry out policy.

Topic 1. Achieving equitable access to cleaner energy

11. **Problem** – Some two billion people, mainly in the rural areas of developing countries, have no access to modern forms of energy. This figure is roughly the same as in 1970, as population growth in these areas has offset the achievement of bringing electricity and other modern energies to over a billion people during this period. The lack of availability of clean and convenient energy has serious consequences for health, the quality of life and the economy. Reliance on traditional (unprocessed) fuels and cooking methods results in widespread respiratory illnesses. The need to carry fuel wood manually over ever-greater distances is time-consuming, leads to musculoskeletal problems, and diverts labor from more productive uses. It accentuates the related problems of deforestation and soil erosion. It also helps perpetuate gender inequality as the burden falls mainly on women and girls. The unavailability of energy in rural areas in the quantity and forms needed for processing raw materials and other industrial applications limits these regions' potential for economic growth. The resulting shortage of productive employment opportunities drives the surplus population to cities, thus aggravating problems of urbanization.

12. Most future population growth in developing countries will in any event be in urban areas. Thus the challenge for the future is not only to draw the rural poor into the modern energy economy; it is also to meet the energy needs of those living in cities in developing countries, both those who do not yet have access to modern forms of energy and the billions who will be joining them in coming decades. Together this has been called the 2+2 billion problem: meeting the energy needs of those presently outside the modern system, and providing for the added population to be expected–virtually all of which will be in the South, and in cities.

13. If the unmet energy needs of the South are met in the same way as those of the North have been, there will result major global and local environmental problems. It is therefore desirable that the cleanest available energy sources be used that are consistent with the urgent development needs of these countries.

14. **Solutions** -- While the scale of this problem is vast in terms of the number of people and the land area affected, it is modest in terms of the energy resources required. For example the cooking needs of the 2 billion people not served by modern fuels correspond to about 1.3 percent of global commercial energy consumption or 3.0 percent of global oil consumption.[6] The market can be expected to fill only part of these needs – a smaller part in rural than in urban areas – because of the low incomes of those concerned and the high cost of building the needed infrastructures. Hence properly designed government interventions are also needed.

15. Existing technologies, if effectively and more widely introduced, could go far to solve the problem. For example, the improved biomass stoves - primarily for cooking but also for heating - developed and massively introduced in the last 20 or so years have resulted in significant improvements in terms of reduced household and local air pollution, and of convenience. Familiar fossil fuels such as charcoal, kerosene and liquefied petroleum gas (LPG) can play a larger role to the extent that they are affordable and that the necessary infrastructure exists. Biomass-derived gases - biogas resulting from bacterial action on animal waste in the absence of oxygen, and producer gas resulting from the chemical processing of crop residues - offer advantages over unprocessed biomass, and are increasingly being used for cooking in many parts

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6 World Energy Assessment, United Nations Development Programme, United Nations Department of Economic and Social Affairs, and World Energy Council, New York, 2000, p. 369. The current paper draws heavily on this background report (hereafter referred to as WEA) to which the scientific community made substantial contributions and which is a sound and comprehensive review of the present state of knowledge on “Energy and the challenge of sustainability”.

of the South. Their potential for wider use, especially that of producer gas, is considerable. Rural electrification continues to be essential for modern agriculture and for rural industry, as well as improvements in living standards for rural populations. The traditional centralized approach to electrification gave 800 million people in rural areas access to electricity between 1970 and 1990, a high proportion of which were in China. (China also has promoted decentralized energy, including a large micro-hydro program.) Although inadequate for the more sparsely populated regions and for the poorest segments of the population, who cannot afford it, national grids will continue to be extended. Efficiency in production, distribution and end use is especially important for centralized electricity.

16. The trend towards decentralized ("distributed") electricity generation and distribution systems – some new, some traditional – holds new possibilities for rural communities. This trend is not limited to rural areas or to developing countries. The principal technologies in question are photovoltaics; small-scale wind turbines; small scale hydropower; biopower from producer gas; small (or "micro") gas turbines; geothermal; fuel cells; reciprocating engines; and hybrid combinations of the preceding to match the resources available. Distributed generation systems with mini grids based on these energies avoid the high costs and inevitable losses of conventional transmission and distribution networks, and are better suited to remote and sparsely populated areas. They are relatively clean, and they avoid the heavy maintenance and fuel transport demand and pollution of diesel. Another advantage is that they permit local ownership and management and the deployment of private capital. Their promise stems both from technical progress, and from institutional developments (deregulation) that facilitate supplying locally generated electricity into the grids.[7]

17. The main obstacle to the more widespread use of these technologies has been cost. Access to electricity does not necessarily lead to consumption of electricity; the cost must be bearable for local incomes. Costs have been coming down. For rural areas sustainable technologies can be more economic than more conventional ones if the avoided costs and losses of transmission and distribution are accounted for and if the external environmental and social costs (the

7 The electric revolution, The Economist, 3 August 2000.

"externalities" currently not factored into project costs) are properly included. In view of the steep learning curves it is reasonable to expect that as the scale on which these technologies are deployed increases, further significant cost reductions may be expected, as for example mobile telephones and personal computers.[8] The capital cost of fuel cells, presently between US$5,000 and US$10,000/kW, could drop to US$250/kW, to become competitive with current gas turbines.[9] In the right circumstances producer gas is already more economical than generation from imported diesel fuel. Accelerated RD&D and "buy down" could accelerate this process of cost reduction. The WEA contains (p. 376) a very useful table presenting some near-, medium-, and long-term technological options for rural energy.

18. **Proposals:**

(a) Governments of developing countries, with the support of bilateral and multilateral donors and of the scientific and technological community, should promote the development of competitive and appropriately regulated energy markets, especially for population segments currently without access to commercial energy. Energy policies should recognize the important roles to be played by both markets and private capital and, where market forces do not respond to needs, by government interventions, such as targeted subsidies or price incentives.

(b) Governments in collaboration with appropriate partners should make systematic assessments of renewable energy resources available to be tapped, on a region-by-region basis. Reliable solar, rainfall, wind and biomass resource data should be collected and made publicly available so as to assist investors in making decisions on renewable energy projects.

(c) Governments of industrial countries, in cooperation with other appropriate organizations, should create new and strengthen existing cooperative programmes with developing- and transition-country partners aimed at developing and putting into effect integrated systems based on renewable energy technologies (including energy efficiency) and their hybrids with fossil energy, to provide complete energy services for both urban and rural areas.

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8 N. Nakicenovic et al, eds., Global Energy Perspectives, Cambridge, UK, 1998, p. 50.

9 Communication from the Committee on Science and Technology in Developing Countries (COSTED), based on information from the Electric Power Research Institute.

(d) Governments together with scientific bodies and the private sector should promote international collaboration on energy R&D on industrial-scale biomass energy conversion technologies, emphasizing those that provide both electricity and one or more co-products (heat, fluid fuels, chemicals, food/feed/fiber).

(e) Governments and international organisations, with input and advice from all relevant sources, should make integrated assessments of the energy needs of developing countries and identify options for meeting those needs, taking into account not only narrow economic criteria but broader social considerations such as employment generation, gender aspects and health effects. Such assessments should recommend financing and regulatory arrangements; identify institutional constraints and opportunities for reform and innovation; and propose strategies to generate adequate local capacity to design, adapt, manufacture, disseminate, operate and maintain relevant energy technologies. Priority should be given to providing energy in rural areas to meet the population's basic needs and to create jobs and income-earning opportunities, so as to alleviate poverty and enhance the quality of life.

Topic 2. Choices for producing, distributing and consuming energy

19. **Problem** -- Present energy systems fail to meet the needs of a significant share of the world's population, and tolerance is diminishing for the inequitable patterns of energy use. Per capita energy use in rich countries is now eight times that of the poor. Present patterns of energy use are not sustainable: they lead to serious problems of air pollution at household, local, regional and global level. The most serious and intractable of these problems appears to be the higher concentrations of greenhouse gases, mainly CO_2, in the atmosphere, and the detectable climate change that is likely the result of those higher concentrations. The Intergovernmental Panel on Climate Change (IPCC) concluded as early as 1995 that "the balance of the evidence suggests a discernible human influence on global climate." The IPCC has been a useful mechanism for bringing science to bear on international public policy related to this issue.

20. The trends are not favorable. A continuation of "business as usual" would result in significantly higher levels of atmospheric CO_2 (estimated at 60% more by 2020), as the world economy grows and as the South increases its level of per capita and (given population growth)

total energy consumption. The political and economic resolve to change the present course is not apparent. If it can be found, considerable time will be needed to introduce new energy systems on the scale required, given the slow turnover of existing capital stock. Considerable additional time would be required before reduced carbon emissions from new systems would have any impact on climate stability.

21. **Solutions** – Environmental effects are the product of population size, consumption levels and patterns, and technology. Technologies and energy resources exist which in various combinations could in time put world energy production and consumption on a more sustainable path. However they are unlikely to suffice in the absence of steps both to limit and stabilize world population and to shift consumption patterns towards those that have lower energy- and materials- intensity.[10]

22. Quantified scenarios have been developed which estimate world energy production and use under various demographic, economic, technological and policy assumptions.[11] Scenarios for the transition to sustainable energy foresee energy systems that permit continued economic growth but that are cleaner and more efficient. Compared to the present, these energy systems would use proportionately less oil and coal, more natural gas, renewables, and, under some scenarios, nuclear. Technological developments in these energies are reviewed below.

23. The use of fuel cells based on H_2 or hydrogen-rich fuels such as methane or methanol is likely to grow and should be promoted. Like electricity, during its use H_2 generates zero or near-zero emissions of pollutants and CO_2. In addition to this intrinsic advantage, fuel cells can be used both for stationary energy and for transport. In the long term it is desirable that the H_2 be produced through electrolysis of water using renewables. Pending the time when that is economic, it can be produced from natural gas or other fossil fuels, and that can be done cleanly

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10 Royal Society, Towards sustainable consumption: A European perspective, London, 2000

11 N. Nakicenovic, op. cit.; Brown, M., M. Levine, Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond, Interlaboratory Working Group on Energy-Efficient and Low Carbon Technologies, Lawrence Berkeley National Laboratory, LBNL 40533 (Berkeley, California 1997); John Holdren, "The Energy-Environment-Development Challenge," presentation made at Conference of the World's Scientific Academies: Transition to Sustainability in the 21st Century, Tokyo, May 2000, op. cit.

if the associated CO_2 is removed and sequestered. It could also be produced from electrolysis powered by nuclear-generated electricity.

24. Appropriate policies to discourage use of unsustainable energies, and to encourage that of sustainable ones, are essential. These include the elimination of subsidies for fossil fuel use; full-cost pricing (taking into account "externalities") of all energy options; the targeted and prudent use of fiscal measures and subsidies to encourage more sustainable patterns of energy use; and stronger financial support for RD&D on clean energy options.

25. One "best plausible" scenario sees the possibility of a future in which between 1990 and 2100 world energy use is doubled; fossil carbon emissions are reduced by more than half; and both GDP/person and energy use/person are equalized as between industrial and developing countries. In industrial countries the projected GDP/person level is more than tripled over this period, while the energy use/person is cut by more than half. In developing countries, GDP/person increases 25-fold, and energy use/person about threefold.[12]

Options for stationary energy sources

26. **Fossil fuels** – About 80 percent of world primary energy is still supplied from fossil fuels. They will continue to account for the bulk of energy production for some decades, even if renewables start to be vigorously promoted. It is thus crucial to seize all opportunities for making fossil fuel consumption cleaner and less carbon-intensive. Three trends are predominant in the use of fossil fuels: (i) electricity generation is becoming more efficient (55% for combined-cycle gas turbines and more than 60% for cogeneration, compared to 35-40% for classical steam power plants); (ii) energy generation is becoming cleaner, especially as a result of implementing environmental controls such as flue gas treatment and desulfurization technology; (iii) there is a trend towards decarbonization, due largely to a shift from coal to natural gas for power generation.[13] There is hope in the S&T community that some fossil energy systems can be made

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12 Holdren, ibid.

13 Royal Society, op. cit., p.112

compatible with a world of severely constrained greenhouse gas emissions.[14] Possibilities for doing this include:

(a) Further gains in energy transmission and end-use efficiency;

(b) Continuing the shift from coal and oil to natural gas, which generates some 50 percent less carbon per kWh of produced energy and which is abundantly available, especially in unconventional form (e.g. clathrate hydrates in the deep ocean);

(c) A reduction in flaring of natural gas;

(d) Improving the efficiency of conversion technologies, through for example recourse to integrated gasification combined cycle technologies and to combined heat and power (cogeneration) technologies;

(e) Sequestration of CO_2 derived from carbonaceous fuels in the deep ocean and in geological formations such as hydrocarbon reservoirs, though this technology still requires substantial research including on its environmental effect on ocean ecology; and,

(f) Capturing methane from coalmines, which for example in countries such as China and India could increase supplies of clean energy while reducing emissions of greenhouse gases. In these two countries, human-induced subsurface coal fires generate very large quantities of CO_2 emissions; more could be done to control and extinguish them.

27. Several of these items relate to natural gas, whose relative importance as a primary energy source is likely to grow for several decades. Many things can be done through RD&D to extend this resource and to use it more efficiently and cleanly.[15]

28. <u>**Nuclear**</u> – Although attractive from the viewpoint of reducing greenhouse gases, nuclear has not increased its share of primary energy as once expected. Moreover the present share will decline over the next decade or two, as existing reactors will be decommissioned faster than new ones are coming into service. The issues are high costs, and concerns about safety, waste disposal, plant decommissioning, weapon proliferation, and lack of expertise required for plant

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[14] R.H. Socolow, ed. "Fuels Decarbonization and Carbon Sequestration: Report of a Workshop by the Members of the Report Committee". Center for Energy and Environmental Studies Report No. 32, Princeton University, 1997. http://www.princeton.edu/~ceesdoe.

[15] Communication from the International Union of Geological Sciences. See also N. Nakicenovic et.al., *Global Natural Gas Perspectives*, International Institute for Applied Systems Analysis and International Gas Union, 2000.

maintenance and safety. The safety record of light water reactors (LWRs), some 80 percent of the world's power reactors, is good, as is that of CANDU-type reactors. Moreover there have been significant advances in the basic engineering of new nuclear plants, in retrofitting improvements into older plants, and in operational practice, procedures and training. While basic reactor designs have changed little, there are now under investigation or development several new reactor designs or concepts that are radically different from those used to date and could be made significantly safer through incorporation of passive safety features. These include high temperature helium reactors; advanced LWRs; and the accelerator-driven fast reactor, or "energy amplifier". France and Japan presently are reprocessing spent nuclear fuel for re-use in reactors. Reprocessing is expensive, however, and produces plutonium, which poses the highest proliferation risks. Research is needed to produce safer, more economic and proliferation-resistant reprocessing of nuclear fuels. Waste disposal is among the most problematic issues for nuclear power. Improvements in safety and waste disposal to date have not led to greater public acceptability for the nuclear option, and scientific opinion is itself divided on the issue. Finally, there is fusion, research on which is being conducted at a level of about US$1billion per year, and which if proven feasible could provide abundant electrical energy with a smaller active waste problem to manage. While it now seems nearly certain that a machine could be built which would produce more energy than it consumes, many problems remain to be overcome before one could be realized. It seems unlikely that fusion could make a significant contribution to the energy needs of the world before, at the earliest, the second half of the 21st century.[16]

29. **Renewables** – All scenarios for reaching sustainability in energy use envisage a significant increase in the share of primary energy from renewable sources - geothermal, wind, solar, biomass, hydro and marine. Energy efficiency can also be regarded as a renewable technology. Biomass was discussed above as regards rural energy. Agricultural and forestry residues, and new crops grown primarily for energy production, can also provide industrial-scale energy for electricity, transport and other uses. Marine energy is abundant and can be tapped in various ways: tidal barrages, waves, tidal/marine currents, ocean thermal energy conversion. If it could be exploited economically, it could provide huge amounts of clean electricity. It poses major

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16 The Royal Society and the Royal Academy of Engineering, *Nuclear Energy: The Future Climate*, 1999.

engineering challenges, so in the near term prospects seem limited. However, the various technologies are an early stage of development and further RD&D could change that assessment.

30. Some renewables provide intermittent electricity, e.g. solar when the sun shines, wind power when the wind blows. These pose the issue of energy storage. Storage possibilities include batteries and compressed air. Another, attractive method would be to use the intermittent power to produce hydrogen through electrolysis. The costs are high today, but the advantages are so great as to merit priority research.

31. While renewables are not without environmental consequences, they are generally significantly cleaner and more sustainable than fossil fuels. They may also bring other benefits such as saving foreign exchange and generating local jobs and income. In 1998 only 14 percent of world energy consumption came from these sources, some two-thirds of which was traditional biomass (mainly firewood for cooking and heating) (WEA). Modern renewables thus account for only about 5% -- almost half of which is conventional hydro – although their use is now increasing rapidly. The potential for expanding their use is very large, and scenarios envisage that the share of renewables in the second half of this century could be in the range of 20-50 percent of primary energy. (Germany's climate change legislation calls for 50 percent by 2020.) Much of the science of renewables is generally well understood. Considerable progress has been made in recent years in developing production techniques and establishing markets. Costs are not yet competitive in other than niche markets, but when these technologies are more widely deployed, economies of scale and progress along the learning curve will lead to further cost reductions as with all new technologies.

32. **Hydro** – This well-established energy source could be used on a wider scale. According to the WEA only about one-third of the economically feasible potential is currently being used. Most of the remainder is in developing countries. Most current production comes from large hydroelectric plants. Only 3.5 percent of capacity and production comes from small hydro; however its share may increase due to the trend towards decentralized electricity systems. Development of hydro in recent years has been limited partly because of environmental and social concerns associated with certain types of projects, especially large dams. In many cases

large dams have not produced the expected benefits, and have had significant, and often negative, social and environmental impacts. (The environmental impacts are mainly local, although in tropical countries large hydro with shallow reservoirs produces substantial CO_2 emissions from vegetation decay.) The recent report of the World Commission on Dams has thoroughly and objectively reviewed this debate. It recommends that opportunities be used to optimize benefits from existing dams and that in considering new dam projects, available alternatives be thoroughly assessed.[17]

33. **Wind** – Grid-connected wind turbine capacity worldwide has increased dramatically in recent years, and growth is expected to continue. Wind turbines have become much larger, and rotor diameters have increased with advanced materials. The ultimate technical potential of wind energy is very large–between 2 and 6TW, or between one-fifth and one-half current world energy consumption. Cost is highly sensitive to wind speed, so relatively few areas are economically suitable. Further RD&D is needed on storage technologies to match loads to fluctuations in wind intensity.

34. **Geothermal** – Geothermal energy can be used for heat and power. Currently some 8,000 MW of geothermal electricity is produced globally, most of it in the Americas and in Asia. Some 15,000 MW thermal is produced for heating, almost 40 percent in Europe. With current recovery and utilization technology electricity output from geothermal could increase seven-fold, and with advanced drilling and permeability enhancement technologies twelve-fold. Geothermal already makes a significant contribution to the energy balance of a number of developing countries, including Philippines, El Salvador, Nicaragua, Costa Rica, Kenya and Indonesia. Expanding its use could result in a major reduction in CO_2 emissions compared to fossil-fuel-fired electricity generation. However, the noxious gases contained in geothermal fluids pose an environmental issue; it is sometimes possible and economic to remove or reinject them into drill holes. A significant recent development is the development of ground source heat pumps. These use the earth as a thermal source for heating and a sink for cooling, depending on the season. They can be used anywhere, as they do not depend on the presence of underground thermal water or steam.

17 *Dams and Development: A New Framework for Decision Making*", http://www.damsreport.org

They have been extensively used in Switzerland, Germany, the U.S. and more recently in Australia. This is an energy-efficient form of space heating and cooling, the use of which is expanding rapidly.

35. **Solar** – All technologies for solar energy recovery – photovoltaics (PV), solar thermal-electric (STE), and low-temperature solar – hold considerable potential. PV, currently the highest cost of the three, was noted above in regard to its use in isolated rural areas. Its potential for wider application depends on cost, but there is growing evidence that it could become competitive for distributed and grid-connected power within a decade. Capital costs could fall over the next few years from $6,000 to $3,000/kW, at which level, without the need for grid enhancement, there may be substantial markets in both industrial and developing countries where grid-connected PV systems could become competitive.[18] STE use could also expand. Thermal technologies have the advantage that they can be integrated with existing fossil fuel plants and thus can be phased in with considerable flexibility. This is an attractive option to meet the expanding energy needs of the urban populations in developing countries. Proven low-temperature solar energy collector technologies can be more widely used, especially for hot water, space heating and cooling. They have limited potential for cooking.

36. **Energy efficiency** – Efficiency measures are generally recognized as the best means of reducing the costs and pollution of existing electricity generation systems. Efficiency gains are possible in electricity **production**, particularly through use of combined heat and power (cogeneration), which can increase efficiency from the 30% which is currently typical to about 60%; in **transmission and distribution** systems by upgrading them and pursuing rigorous maintenance regimes; and in **end uses** by utilization of efficient appliances, lighting, motors, etc. There are proven technologies for all these measures. Efficiency improvements are often profitable. The required initial investment outlay often have very short payback periods, sometimes less than one year. End-use efficiency measures can be promoted through legislated standards, incentives and information/labeling programs. Mechanisms need to be found to

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18 Renewable Energy Consulting Services, *The Present and Future Prospects of PV-Based Network Generation: Can an Assured Large Market Bring PV System Costs Down to $3,000 per Installed Kilowatt?* Evaluation carried out for Environmental Projects Unit, International Finance Corporation (1 March 1999).

promote investments in energy efficiency - with special attention to developing nations. Of course, this cannot be done without first investing in training and institution building. This would require a radical change from the current business as usual approach to energy investments.

37. **Proposals:**[19]

(a) Governments should promote market introduction of environmentally sound energy technologies by removing price distortions and regulatory impediments, encouraging competition and removing barriers to energy efficiency, thus encouraging the flow of capital into efficient and clean energy production and usage.

(b) Public policies for energy pricing should provide for internalizing the external environmental and social costs of energy options within agreed and workable mechanisms. Subsidies for the use of fossil fuels should be generally eliminated. These measures are essential if sustainability is to be advanced, as it must be, by market forces.

(c) Governments and other appropriate actors should promote the use of hydrogen as a fuel, inter alia through RD&D on technologies designed to reduce the cost of making hydrogen from carbonaceous feedstocks while facilitating the recovery of byproduct CO_2 for ultimate disposal. The S&T community and governments should cooperate internationally to identify, develop and demonstrate promising integrated systems for hydrogen production and use, from fossil sources, with sequestration of the separated CO_2, and from renewables.

(d) Research should be given to CO_2 sequestration, including standards for the permanency of CO_2 storage taking into account rapid climate change, environmental and social impact studies, and region-by-region assessments of sequestration potential

(e) Support should be strengthened for RD&D dealing with all phases of the natural gas cycle: exploration and production, transport and distribution, gas conversion, and power generation. This should include work on exploration technology for unconventional gas such as hydrates; development of LNG technology; development of H_2 production facilities for fuel cell applications; and CO_2 capture in power reduction.

19 Proposals in this paper are based on inputs from the national academies of science or national research councils of Brazil, France, Hungary, South Africa, the U.K. and the U.S., among other sources.

(f) International research should be promoted which focuses on advanced technologies for improving the cost, safety, waste management, and proliferation resistance of nuclear fission energy systems, and on geologic disposal of spent nuclear fuel and high-level wastes and its long term environmental effects including studies of international interim-storage facilities.

(g) Governments and research funding agencies should collaborate with appropriate partners in measures to accelerate the deployment of grid-connected intermittent renewable electric technologies (wind, photovoltaic, solar thermal-electric) and their hybrids with biomass and fossil energy.

(h) Governments and other research funding agencies should support research in more efficient electricity production, transmission and end-use. Emphasis should be placed on research on more efficient appliances, lighting, motors and cogeneration technologies, especially with regard to their use in developing countries. Incentive systems to promote the adoption of these technologies should also be studied.

Topic 3. Public-private partnerships to achieve sustainable energy for transport

38. **Problem** -- Motor vehicles contribute substantially to worldwide CO_2 emissions. They are also the chief contributors to NOx, which are the precursors of smog and which, together with small particulate and lead emissions, contribute heavily to adverse health effects. Diesel-fueled vehicles, especially trucks and buses, are major contributors, especially for small particulate pollution. In developing countries, 2- and 3-wheeled vehicles using outmoded technologies are major pollution sources. Patterns of vehicle use previously limited to OECD countries are becoming more general: in 1995 more new cars were sold in Asia than in Western Europe and North America combined; in Russia, China and elsewhere car ownership is increasing rapidly. Large passenger vehicles present special problems because of their fuel inefficiency; in the U.S. sports utility vehicles have been classified as trucks, which exempts them from the stricter automobile fuel efficiency standards. Aviation is also a significant contributor to greenhouse gas emissions[20]; and emissions from this source are forecast to increase rapidly. In the absence of

[20] Intergovernmental Panel on Climate Change, *Aviation and the Global Atmosphere*, http://www.grida.no/climate/ipcc/aviation/index.htm

concerted efforts by governments, industrialists and scientists – i.e. following a business-as-usual approach – the problem is likely to worsen.

39. **Solutions** – For transport as for other sectors, the long-term goal should be near-zero air pollutant and greenhouse gas emissions (WEA, p.274). In the industrialized countries much progress has been made in the last two decades in reducing vehicles' emissions of pollutants (e.g. NOx, SOx, lead, particulates) but little or no progress on greenhouse gas emissions. Achieving this latter goal will necessitate the development and wide-scale introduction (a slow process) of more efficient and cleaner vehicle power sources. Electric-powered vehicles have so far had only modest success; further research on storage batteries is needed. Approaches based on oxygenated fuels or alcohols in internal combustion engines have had some environmental benefits and have brought other advantages such as job creation and savings on foreign exchange. Fuels derived from synthetic gas can also be clean energy sources for internal combustion engines, e.g. synthetic middle distillates and dimethyl ether. Strategies based on these fuels have the advantage that for decades the cheapest way of making H2 is likely to be from syngas, so these strategies would pave the way for a hydrogen-based energy economy.

40. More adequate solutions will feature cleaner on-board power sources, derived from cleaner primary energy. Buses and commercial vehicles are being converted to compressed natural gas and fuel cells in a number of countries. In the near term the most promising candidates for cars are hybrid electric/internal combustion engine-powered vehicles. Fuel cell-powered vehicles are being developed commercially and may soon become an attractive option. In both cases attention also needs to be paid to the clean production (e.g. using renewable sources, or fossil fuels with carbon sequestration) of the electricity or of the on-board hydrogen source (H2, gasoline, methanol or hydride) that is used. The short- and long-term options for the choice of fuel cell vehicle are linked. Using gasoline as the hydrogen source, at least during an interim period, would facilitate the needed shift in infrastructure that would be required. A syngas-based strategy might indicate methanol as the source, and processing methanol on-board cars is easier than for gasoline. For both gasoline and methanol, fuel cell-powered vehicles would have major advantages over internal combustion engines in terms of efficiency and emissions.

41. The development of more efficient engines and the use of new lightweight materials and aerodynamic designs offer further possibilities to reduce emissions from vehicles. Materials are being developed which work at high temperatures and allow power systems to convert more of the available energy into motion. Developments include self-monitoring and self-repairing materials, intelligent materials, biodegradable materials, high-strength metal alloys and plastics, and new semiconductors.

42. There is considerable scope for public-private partnerships to develop and promote cleaner vehicles and fuels.[21] Useful examples of partnerships can be seen in the U.S., Europe and Japan. In the U.S. Partnership for a New Generation of Vehicles (PNGV), the three large car manufacturers are cooperating with the government to develop technologies for a new generation of vehicles with fuel efficiencies up to three times those of comparable 1994 family sedans, without sacrificing in terms of performance, cost, safety or emissions. The three industrial partners have all produced "concept vehicles" based on hybrid-electric drive trains using compression-ignition, direct-injection (CIDI) engines. An interesting feature of the program is the provision for independent, science-based review of progress toward that goal[22]. There has also been collaboration between the US Department of Energy and battery manufacturers to develop advanced battery systems for electricity storage through the Advanced Battery Consortium (ABC). In Europe, the European Commission has cooperated with car manufacturers and oil refiners to determine what the most cost-effective ways are for those two industries to divide the costs and responsibilities for meeting emission targets. This "Auto-Oil" programme is another interesting approach to evidence-based policy-making, and has led to significant reductions in road transport emissions. However, the program has not directly addressed the problem of greenhouse gases. In Japan, Honda and Toyota, with the help of the government, have each introduced commercial electric/gasoline hybrid vehicles with greatly improved fuel efficiency. In some of these programmes, joint R&D is also being conducted on hydrogen/fuel cell-driven vehicles. In France a government-sponsored research network, currently comprising

[21] The President's Committee of Advisors on Science and Technology (PCAST), *Powerful Partnerships: A report from the panel on international cooperation in energy research, development, demonstration and deployment*, Washington, 1999

[22] National Research Council, *Review of the Research Program of the Partnership for a New Generation of Vehicles: Sixth Report*, Washington D.C., 2000

56 research activities, has been created to promote cooperation between public and private research bodies on work related to fuel cells. In Brazil, an extensive programme was jointly developed by the government, fuel and vehicle producers for production of ethanol from sugar cane, using bagasse as the refinery fuel; and vehicles have been converted to and produced for ethanol use. The programme halved gasoline use and imports and markedly improved some vehicle emissions. In Taiwan, China (where about three-quarters of motor-vehicles are two-wheelers, which account for 35 percent of CO and 18 percent of total hydrocarbon emissions) the government has cooperated with motorcycle manufacturers and component suppliers to develop and launch electric scooters into the market.

43. Proposals:

(a) Governments should collaborate with the vehicle manufacturing and energy industries and with the scientific/engineering community in partnerships for RD&D of low-cost, efficient, clean power sources for transport. RD&D is needed for all the above alternative vehicle and fuel developments (other than lead elimination). Work should be done not only on cars but also on fuel-cell systems for 2- and 3-wheel vehicles and for trucks and buses, as these are important sources of pollution and greenhouse gases in developing countries. Lead in gasoline should be eliminated and catalytic converters should be required on all appropriate vehicles.

(b) R&D priority should be given to refining and lowering the cost of hybrid electric/gasoline vehicles with regenerative braking systems and use of strong light-weight plastic construction materials with aerodynamic designs – and to production of hydrogen fuels, preferably from renewable resources, and automotive fuel cells which would be virtually pollution-free. Improved production methods for ethanol fuel from cellulosic biomass also should be pursued.

(c) Intergovernmental organizations, with the support and participation of all relevant partners, should commission a study to make an integrated assessment of the use of biofuels for transport, taking into account economic, social and environmental aspects of the issue.

(d) Strategies to reduce greenhouse gas emissions from transport should be based on full fuel-cycle analysis, and scientific and engineering communities should give priority to the development and application of methodologies for life-cycle analysis incorporating externality costs and benefits[23].

(e) A priority area of R&D should be the development of convenient, economic and safe ways of storing hydrogen on-board motor vehicles, e.g. carbon nanofibers.

Topic 4. Sustainable transport planning: Choices and models for human settlements designs and vehicle alternatives

44. **Problem** – Most people, certainly those in the developed world, regard mobility as a fundamental freedom. Yet increasingly this freedom collides with sustainability. Transport is a massive consumer of energy and it has profound environmental impacts, yet modern lifestyles depend on modern transport systems. The perceived conflict between economic development and environmental protection pervades the transport debate, although appropriate policy and technological responses can alleviate the conflict.

45. Not only is transport a major contributor to greenhouse gas and other pollution problems because of the use of vehicles with environmentally unfriendly power sources, as described above. It also raises other questions of sustainability because the demand for transport is expanding everywhere, while traditional models of transport supply, relying heavily on private motorized vehicles, cannot be indefinitely extended. In addition to problems of air quality, the resulting congestion involves increasing time losses with associated costs, while counterproductively reducing the sought-after mobility. Public transport in developing countries is often overcrowded, poorly maintained, unsafe, and slow. It is also often inadequate in industrialized countries. Communities in all countries are often developed without adequate transportation or land use planning. Resulting urban or suburban "sprawl" generates higher requirements for mobility and for private vehicle use in particular than would otherwise be necessary. Inter-modal connections are often lacking or inadequate.

46. The problem has been aggravated by the tendency of most governments to promote road transport and the individual vehicle versus rail and other forms of mass transport. This has often

23 The Institution of Engineers, Australia, *Sustainable Transport: Responding to the Challenges* (1999), p. 13.

been done by limiting the cost to the user (at least the apparent cost) while shifting the real cost to the public at large through tax and subsidies regimes. Not only are most of the infrastructure costs paid by the community, but the user typically bears only a portion of the use and maintenance costs, and this share differs widely from one transport mode to the other. Externalities are rarely taken properly into account.

47. **Solutions** --Two complementary ways of meeting these challenges are needed. One is to adopt lifestyles and land use patterns, which reduce the need for motorized transport. Relevant approaches include integrated land-use and transport planning, with consideration given to encouraging denser urban development; travel-demand management and demand-reduction strategies such as elimination of free parking, subsidization of mass transit use, and car/van pooling; and programs of communication, education and incentives aimed at influencing the transport behavior of the public in the direction of sustainability.[24]

48. The second way is to make use of appropriate policies and modern technology in an effort to reconcile the demand for accessible transport with the objective of sustainability. Here the emphasis is on influencing the distribution of transport demand between modes and between individual and mass systems. Priority should be given to systems of mass transport over individual car use, e.g. through the use of economic tools like fuel and vehicle tax regimes. Technological developments like intelligent transport systems can be used to introduce and guide road pricing; the development of national transport information systems for the various modes can help improve the planning of intermodal transport. Successful examples of public transport systems – such as those of Hong Kong, China; Curitiba, Brazil; and Portland, Oregon, USA – may offer lessons for other cities. Innovative car-sharing schemes, such as Stattauto Berlin and European CarSharing, may also warrant further study.[25] The need for bulk freight transport by vehicles can be reduced through the use of subsurface pipelines and other logistic systems.

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[24] The Institution of Engineers, Australia, op. cit.

49. **Proposals:**

(a) Public policy-makers at all levels, and scientists and engineers should pursue a three-pronged approach that encourages sustainable lifestyles and land use patterns, while using the development of appropriate technologies to create sustainable transport systems. This would be directed towards: making walking safe and secure at any time of day or night; encouraging cycling as a safe alternative to public transport; making bus travel competitive with travel by car; maximising the use of rail for both freight and passenger transport; developing the full potential of safe and environmentally friendly pipelines; reducing the environmental cost of air travel; encouraging the use of marine transport; assisting the mobility of the young, the old and the physically impaired.

(b) Transport planning should be integrated into broader, interdisciplinary planning of human settlements. This process should make full use of the interdisciplinary participation of natural and social scientists and engineers from all relevant specialties.

(c) Public and private funding agencies should promote behavioral research on the motivation of transport users, e.g. what has led to the profligate use of polluting vehicles and what is needed to induce the use of mass transit or shared car transport. Research on the institutional dimensions of sustainable transport should also be supported.

A wide range of individual scientists and scientific institutions has contributed to this brief review of sustainable development issues concerning energy and transport. The rather homogeneous nature of the paper does not do justice to the independent and disparate nature of the scientific community, whose rich diversity is one of its most important assets.

It is important to recognise that the trends highlighted in this paper regarding energy and transport are actually moving in the opposite direction from our recommendations. Official development investment in energy is drastically declining. Government investment in R&D on new energy technologies has decreased. Collaborative R&D with developing countries is almost non-existent. There is inadequate support for institution building and other essential capacity building efforts to support energy and transport, particularly in developing and transition

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[25] http://www.stattauto.de/ECS.html

countries. These trends need to be reversed—and we believe that the science community can contribute significantly to that process.

Science is essential for good governance, at all levels and in all regions. The participation of the international scientific community in the CSD process is a sign of its readiness to play an active role in the identification and implementation of appropriate solutions for sustainable development, in partnership with governments, international organisations, other major groups and society at large.