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Addendum

Contribution by the scientific and technological community**

Overview of recent scientific and technological developments in the fields of energy for sustainable development, air pollution/atmosphere and climate change

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** The views and opinions expressed do not necessarily represent those of the United Nations.

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I. Introduction

1. The present paper, prepared by the scientific and technological community, provides an overview of recent scientific and technological developments in the fields of energy for sustainable development, air pollution/atmosphere and climate change, three of the four themes of the cluster for the fourteenth and fifteenth sessions of the Commission on Sustainable Development. Following from Agenda 21 and the Johannesburg Plan of Implementation, the sections dealing with energy, climate change and air pollution call for numerous actions focused on science and technology. This paper presents a discussion of the progress that has been made and the obstacles that still exist in implementing such actions.

2. While not discussed in depth in this paper, the Commission's theme of industrial development is recognized as a central component of essentially all sustainable development efforts, and is closely linked to the themes of energy, climate change and atmosphere. Increased efforts must be made to ensure that future industrial development is based on environmentally sustainable and economically appropriate production systems. Scientific research and technological innovation will continue to be an essential foundation for such developments.

3. As with all major sustainable development challenges, the issues of energy for sustainable development, industrial development air pollution/atmosphere and climate change must be addressed in a way that integrates the three pillars of social development, environmental protection, and economic development. In order to help decision makers define and implement these integrated approaches, the science and technology community must continue striving to become more policy-relevant, participatory and capable of addressing issues at geographical scales ranging from local to global. There is also a strong need for more integrative, interdisciplinary approaches, which will require continuing efforts to overcome persistent barriers that exist among the natural, social, engineering and health science domains.

4. The ever-increasing global demand for energy and industrial goods and services represents a daunting challenge. Basic energy services and industrial goods are urgently needed by billions of impoverished people around the world, as a necessary foundation for achieving socio-economic development. However, meeting the basic needs and the social and economic aspirations of society has traditionally required a heavy dependence upon highly polluting energy and industrial technologies, primarily through the burning of fossil fuels. This has led to dramatic changes in the composition of the Earth's atmosphere, affecting the very air we breathe and the climate that shapes the life of every human being on the planet. Whether the impacts of these changes are immediate (urban air pollution) or more slowly evolving (climate change), they affect the well-being of people in all nations and all sectors of society. The different themes for the fourteenth and fifteenth sessions of the Commission — energy, industrial development, air pollution/atmosphere and climate change — are thus part of a complex, evolving system that must be understood and addressed in an integrated fashion.

II. Energy for sustainable development

5. There is an urgent need to transform global energy systems towards sustainable pathways as current approaches are causing serious harm to human

health and to the Earth's climate and ecological systems on which all life depends, and because access to clean, reliable energy services is a vital prerequisite for alleviating poverty. At the 2002 World Summit on Sustainable Development, States Members of the United Nations agreed to improve access to "reliable, affordable, economically viable, socially acceptable and environmentally sound energy services and resources". While in some parts of the world there has been notable progress towards this goal, a great deal more effort is needed, both to enhance the implementation of existing clean energy technologies and to spur further scientific understanding and technological development. Meeting the world's rapidly growing energy demands in a sustainable manner will require drastically increasing the efficiency with which energy is produced, delivered and used, and will require utilizing a diverse mix of energy sources and technologies.

A. Energy conservation and efficiency

6. Enhancing energy conservation and efficiency are key for decoupling economic growth from increased energy use, and thus for driving sustainable development worldwide. The World Energy Council estimates that nearly two thirds of all primary energy is lost before it is converted to useful energy. There is a clear need to continue making advances in areas such as: the efficiency of various energy conversion systems (burners, turbines and motors, for example); low-energy designs for electrical appliances and for heating, cooling and lighting of buildings; the dematerialization and recycling of energy-intensive material; and designing land-use and transportation systems that minimize demand for personal vehicle travel.

B. Fossil fuels

7. About 80 per cent of world primary energy is supplied from fossil fuels, a finite resource. The exact time frame over which this resource base will be depleted varies among different forms of reserves (that is, oil, coal and natural gas) and is a function of highly uncertain estimates of actual geological reserves, costs and feasibility of new extraction techniques, and future geopolitical dynamics and energy demand. Regardless, fossil fuels will remain an important part of the global energy mix for the foreseeable future, and it is thus critical that fossil energy technologies continue to evolve towards cleaner, more efficient and less carbon-intensive systems. A number of current technological developments offer promising steps in the right direction (for example, cogeneration of heat and power based on gas turbines and combined cycles; emerging microturbine and fuel cell technologies; and coal gasification to make "syngas"). In the longer term, it is hoped that carbon capture and sequestration will lead to zero-emissions fossil fuel energy systems.

C. Nuclear energy

8. Projections of the future contributions of nuclear energy are highly uncertain, due to the concerns that exist about safety, radioactive waste management, potential proliferation of nuclear weapons and vulnerability to terrorists. It is important, however, to continue developing waste disposal strategies and reactor designs that address these concerns, because nuclear technologies offer a means to provide

energy without greenhouse gas emissions, and because a growing number of countries appear strongly committed to pursuing nuclear energy options. In the longer term, some scientists view nuclear fusion as a potentially inexhaustible and emission-free means to meet the world's energy needs. The "ITER" international experimental reactor is considered to be the next major step in fusion research. The time frame for carrying out the ITER experiments, developing a prototype fusion power plant and commercial power plants is at least 50 years or longer.

D. Renewables

9. A particularly urgent priority must be placed on increasing the share of modern renewable technologies in the world's energy mix. Some encouraging progress is being made in this respect. The International Action Programme from the 2004 International Conference for Renewable Energies (Bonn, Germany) contains ambitious national targets for the expansion of renewable energy in more than 20 countries, including many initiatives for increased cooperation with developing countries. However, while the absolute amount of worldwide renewable energy use has been rising significantly, the overall share of renewables in the world's total primary energy supply has increased only marginally over the past three decades. Scenarios produced by entities such as the International Energy Agency, the World Energy Council and the Intergovernmental Panel on Climate Change (IPCC) all suggest that renewable energy sources could provide a much greater share of global primary energy demand in the coming decades if the appropriate investment and incentive structures are put into place.

10. Renewable energy systems encompass a broad, diverse array of technologies, including, solar photovoltaics, solar thermal power plants and heating/cooling systems and wind, hydro, geothermal, biomass and marine/tidal power systems. The current status of these different technologies varies considerably. Some technologies are already mature and economically competitive, while others need only minor additional development steps to become ready for the market. Certain technologies are still too expensive and may require a few decades of continued research and development before they can make large contributions on a global scale. In some cases, the "technical potential" of particular energy technologies may be much greater than the actual "sustainable potential". For instance, the large-scale use of biomass energy requires consideration of the competing land-use needs (i.e., for fuel crops versus agricultural crops) and the further expansion of large hydro projects may be limited by unacceptable ecological and social impacts. On the other hand, some renewable energy technologies, such as solar photovoltaics, appear to have virtually unlimited sustainable potential, and should be vigorously pursued.

E. Transportation

11. The transportation sector plays a crucial role in all of the focal themes of the fourteenth and fifteenth sessions of the Commission, as it accounts for a large proportion of worldwide energy demand, is a major source of air pollution and greenhouse gas emissions and is an important element of effective industrial development. The challenge is to enable freedom of mobility while reducing the consumption of fossil fuels. This requires making transport technologies more clean and efficient, and reducing the demand for personal motorized vehicle transport.

12. Transportation technologies are progressing on many fronts towards lower emissions of air pollutants and greenhouse gases, including, for instance: cars powered by electricity, hybrid electric engines and fuel cells; buses and commercial vehicles powered by compressed natural gas; the use of alternative fuels derived from various biomass sources; and continued improvements in the fuel efficiency and emissions of standard gasoline and diesel-powered vehicles. These various technological innovations are all gaining commercial success at differing rates. Their continued market penetration needs to be encouraged through appropriate economic incentive programmes and ongoing research, development, and deployment efforts.

13. Even with the aggressive implementation of cleaner vehicle technologies, there remains a strong motivation to reduce demand for personal vehicle transport, because crippling traffic congestion is a serious impediment to economic growth, quality of life and personal safety in countless places around the world. A growing number of communities are implementing effective public transportation systems although at present discouraging trends still dominate. Public transport options remain inadequate, and demand for private vehicles continues to grow dramatically, in industrialized and developing countries alike. This challenge must be addressed on several fronts, such as subsidizing mass transit development and use, encouraging “smart growth” urban development patterns and enacting public communication and incentive programmes to influence personal transport choices.

F. The role of science and technology

14. Although energy technologies are rapidly developing, it is widely acknowledged that existing solutions are not yet sufficient to meet the world’s growing energy needs in a sustainable manner. Much more work will be needed for a new generation of clean technologies for heat, fuels and electricity to reach the mainstream market. These advancements must be supported with great urgency because it will take decades to realize the necessary technological innovations, to develop related markets for new technologies and to expand related production capabilities.

15. Advancing cost effectiveness and market penetration of sustainable energy systems will require technical research aimed at improved energy conversion techniques, supply structures and end-user technologies, as well as non-technical research into a wide array of related social, political and economic issues. Strategies for enabling widespread diffusion of advanced energy technologies need to encompass the whole “innovation chain”, from basic research to early deployment and development of niche markets. There is a need to expand and deepen the community of scientists and engineers who work on energy issues, for instance within the disciplines of physics, chemistry, biotechnology and the social and economic sciences.

16. Given the highly complex nature and rapid evolution of energy research and development, it is important that decision makers at all levels have access to the most recent and accurate scientific and technological information. Hence there is an ongoing need for review and assessment reports, such as those produced by the World Energy Council, the International Energy Agency and IPCC. In addition, a report on research and development into energy technologies was recently produced

by the International Union of Pure and Applied Physics, and a major new assessment effort on "Transitions to sustainable energy" is currently being carried out by the InterAcademy Council.

Examples of important energy research and development topics

Photovoltaics. Achieving cost reductions for crystalline silicon and thin-film solar cells.

Wind. Developing multimegawatt turbines and robust systems for offshore applications.

Biomass. Increasing the efficiency and versatility of combustion and gasification systems. Developing commercially feasible methods for production of ethanol from cellulosic materials.

Hydrogen. Advancing technologies for hydrogen storage, and hydrogen production from renewable energy sources.

Carbon sequestration. Continuing pilot studies of the technical feasibility and ecological impacts of carbon sequestration. Advancing techniques for carbon dioxide separation and capture from waste streams.

Cross-cutting. Integrating decentralized, intermittent energy sources into electricity grid structures. Advancing systems for cogeneration of heat and power. Understanding the factors that motivate energy conservation efforts at the individual and community levels. Identifying novel financing mechanisms to overcome the economic barriers to market penetration of new energy technologies.

G. Obstacles to accelerated progress

17. Some key barriers to the achievement of sustainable energy goals include:

- *Need for appropriate economic incentives*. Economic incentive systems need to be directed towards encouraging the implementation of clean energy technologies. This requires, inter alia, including the costs of externalities such as environmental degradation in energy pricing and using subsidies to bring down the initial costs of new technologies in order to make them more competitive. As market shares increase, steady progress in lowering costs can be expected to continue through economies of scale. The historical learning curves for many renewable technologies teach us that costs per unit power fall approximately 20 per cent every time that accumulated production doubles.
- *Need for enhanced research and development funding*. Government investment in research and development in the energy sector, particularly for renewable energy sources, has been declining since the mid-1980s, and currently only a minor share of such support is directed towards renewables. At the same time, deregulation and competitive forces in the energy industry have led to private-sector research and development investment being redirected from longer-term, basic research towards low-risk, market-oriented research. There is a clear need for stronger, more consistent public support for research and

development efforts in this field, together with a policy environment that encourages private-sector investment in the desired direction.

- *Need for capacity-building.* Although a few developing countries do have notable research and development programmes in the energy sector, the vast majority of research and development is carried out by a small number of industrialized nations. Many efforts to disseminate clean energy technologies within developing countries have limited or no success because the technologies introduced are poorly adapted for local needs and/or because there is insufficient local capacity to maintain the systems over the long term. This points to a need for moving beyond a traditional "technology transfer" mentality towards a greater focus on building the endogenous scientific and technical capacity of all nations and integrating these science and technology capacity-building efforts into long-term economic development programmes.

- *Need for stronger sectoral interactions.* In general, the different energy supply sectors (fossil, nuclear and various renewable sources) have little interaction and sometimes act as competing "lobbies". Energy efficiency is, likewise, rarely addressed as a cross-cutting, strategic issue. When development prospects for different energy options are viewed in isolation from each other, opportunities for effective synergies in research and development strategies are missed. For instance, related developments in hydrogen transport and storage, fuel cells, turbines, batteries, and the like are needed for numerous renewable and fossil fuel-based energy systems.

- *Need for greater international cooperation.* Lack of coordination among national research and development programmes can lead to unnecessary redundancies, missed opportunities for productive collaboration and the problem of critical research and development topics "falling through the cracks". The transformation of the global energy system is an issue of critical concern for the entire world community and the development of technological capabilities and scientific knowledge must be encouraged in an equitable, open manner among all countries. Regional initiatives and networking between centres of excellence can be particularly effective strategies for exchange of information and expertise.

18. To overcome these barriers, there is a need for stronger mechanisms of interaction among national and sectoral research and development efforts in the energy sector and for objective international bodies that can provide leadership and guidance in the development of coherent global strategies for advancing energy systems. This need is particularly great in the realm of new renewable technologies where the institutions and infrastructures for information sharing are less mature than for more traditional energy technologies. In response to this need, the International Council for Science (ICSU) is currently exploring the idea of establishing an international science panel on renewable energy.

III. Climate change

A. Progress in climate science

19. There is scientific consensus, documented in the assessment reports of IPCC, that the increase in greenhouse gases in the atmosphere due to human activities is

altering the Earth's climate, bringing about a general global warming. Human activities, in addition to natural climate variability, are producing these changes.

20. Global scientific simulation models, which have become more robust during the last decade, have significantly increased our capacity to anticipate future risks related to the impact of climate change although they still remain insufficient as regards projections for specific regional and subregional patterns of climate change and their impact.

21. Even though a long-term (50-100 years) prediction of exactly what will happen at a specific location on the planet is not yet possible, scientists do have the ability to paint a picture of how our environment is likely to evolve in response to anthropogenic climate change. Sufficiently confident projections of future climate change do exist, including:

- Depending on the emission scenarios and climate models used, the globally averaged surface temperature is projected to increase by 1.4 °C to 5.8 °C above 1990 levels by 2100. It is very likely that nearly all land areas will warm more rapidly than the global average, particularly those at northern high latitudes in the cold season. In winter, the warming for all high-latitude northern regions exceeds the global mean warming in each model by more than 40 per cent.

- For high greenhouse gas emission scenarios, global climate change is projected to raise sea level by up to 0.88 metres over the current century. This would put vast, often densely populated, coastal areas in all parts of the world in danger of permanent flooding. Archipelagoes and coral atolls would be at risk of disappearing, and the populations living there would face permanent displacement.

- Projections indicate that extreme weather events will become more common in the future. For instance, temperature extremes, such as the 2003 heat wave in Europe, are projected to become more common in the next 50 years. There is evidence that the frequency and intensity of extreme precipitation events will increase over many areas worldwide, notably over many northern hemisphere mid- to high-latitude land areas. Hurricane intensity is expected to increase as greenhouse gas concentrations in the atmosphere rise.

- In addition, projections show that the range of environmental effects goes far beyond the kinds of weather-related events described above. Examples of other effects include diminishing freshwater supply in many regions, due to extended droughts and as a result of the melting of high-altitude glaciers and the decrease in snow cover in mountain areas.

- There is evidence of increasing acidification of the oceans due to increased carbon dioxide absorption, with far-reaching consequences for the survival of coral reefs and the dynamics of organisms in the oceans that are the basis of the marine food chain. This implies serious risks for a primary source of protein needed for a growing world population.

22. Even if greenhouse gas emissions were to be stabilized at present levels, the global warming trend and sea-level rise would continue for hundreds of years, due to the atmospheric lifetime of some greenhouse gases and the long timescales on which the deep ocean adjusts to climate change. The continuing increase in

emissions will augment the intensity and duration of their impact on the environment.

23. The most recent scientific information on climate change was recently summarized in a joint statement on the global response to climate change issued by the science academies of the States members of the Group of Eight as well as of Brazil, China and India, on the occasion of the meeting of Heads of State and Government of the Group of Eight in Gleneagles, United Kingdom of Great Britain and Northern Ireland, in July 2005.

B. Relevant ongoing international scientific cooperation programmes

24. Most of the recent advances in climate science have been generated within international scientific cooperation programmes established in the 1980s and 1990s. These programmes are the World Climate Research Programme, jointly undertaken by the International Council for Science (ICSU), the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC), of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Geosphere-Biosphere Programme of ICSU and the International Human Dimensions Programme on Global Environmental Change, jointly undertaken by the International Social Science Council and ICSU. In the years to come DIVERSITAS, another international global change research programme, dealing with biodiversity, will provide data and enhanced knowledge on the links between climate change and biological diversity.

25. In addition, WMO, the United Nations Environment Programme (UNEP), IOC and ICSU established the Global Climate Observing System in 1992 to ensure that the high-quality observations and information needed to address climate-related issues are obtained and made available to all potential users. The Global Terrestrial Observing System, co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), UNESCO, UNEP, WMO and ICSU, and the Global Ocean Observing System, co-sponsored by IOC, WMO, UNEP and ICSU, have important climate-related components.

26. The World Climate Research Programme and the International Geosphere-Biosphere Programme must be seen as the main mechanisms by which the scientific community worldwide is mobilized to provide improved understanding of the climate system. Moreover, it must be much more strongly recognized that the major foundation of the natural science assessment of IPCC is the collaborative work of many scientists and countries through both of these programmes, as well as through the global environmental observing systems.

27. Some of the research undertaken through the World Climate Research Programme and the International Geosphere-Biosphere Programme has been of major immediate socio-economic benefits. For example, with the advances in forecasting the advent of the El Niño/Southern Oscillation (ENSO) weather pattern, fishermen and farmers in the Andean coastal zones and also communities in Asia and Africa usually affected by ENSO have the benefit of early warning and thus are better able to mitigate the impacts of these events.

C. Obstacles to accelerated progress

28. In its third assessment report in 2001, IPCC reported that observational networks were declining in many parts of the world and that additional and sustained climate observations would be required to improve the ability to detect, attribute and understand climate change. While some improvements to networks have been made since the third assessment report, the overall trend has not changed significantly. Following the second adequacy report on climate observations commissioned by the Conference of the Parties to the United Nations Framework Convention on Climate Change, the Implementation Plan for the Global Observing System for Climate in Support of the Convention was prepared and approved by the Conference in 2004. This Plan, available at the WMO website, identifies 131 actions needed over the next 5 to 10 years to address the critical issues related to global observing systems for climate.

29. While the Plan outlines the actions needed to make the Global Climate Observing System fully operational and efficient, it also highlights the importance of climate-related data to be provided by the Global Terrestrial Observing System and the Global Ocean Observing System. The need for strengthening observing systems for climate data was one reason for the recent establishment of the Global Earth Observation System of Systems the advent of which represents an important step forward. Sizeable resources will have to be made available by Governments and considerable work will have to be carried out in order to realize the goals set for the System and its climate components.

30. The significant remaining gaps in our knowledge on climate change, its impacts and adaptation strategies pose obstacles to improving and accelerating implementation of climate policies. The scientific communities must continue to increase our understanding of the climate and the Earth system, to refine our predictive tools and to reduce remaining uncertainties in efforts to project future climate and the impact of change, in particular at the regional level.

31. In its fourth assessment report, due for completion in 2007, IPCC will address the state of knowledge since 2001 on some of the most important unresolved issues, such as:

- Will changes in cloud cover and characteristics and in atmospheric aerosols amplify or moderate the rate of climate change?

- Will as much as about half of the anthropogenic emissions of carbon dioxide continue to be taken up by the oceans and biosphere? If ocean circulation slows (as warming might induce) or carbon dioxide fertilization of the biosphere saturates (as may happen), much more of the emitted carbon dioxide would remain in the atmosphere. The rate of warming would further accelerate and the emission cutbacks required would need to be increased if dangerous anthropogenic interference is to be avoided.

- How fast is the ocean taking up the heat trapped by the increased concentration of greenhouse gases? Lack of knowledge on ocean heat uptake limits our ability to pin down more precisely the amount of future global temperature rise in the twenty-first century due to projected emissions.

- How will global climate change alter climates at the regional level? For example, given that monsoons provide water to more than half of the global population, any change could have a dramatic impact. How will monsoon patterns be affected?

- Will countries, in particular those in the developing world, be able to adapt their agricultural practices rapidly in response to climate changes? How will infectious and vector-borne diseases be affected in different parts of the world?

D. Action needed now by society and in science

32. There is broad consensus among scientists that the scientific understanding of the ongoing climate change is sufficient to warrant taking urgent action in order to mitigate the impact of future climate change, including both the environmental impacts and the socio-economic consequences. Not taking action now will aggravate environmental impacts and will make the socio-economic costs even higher.

33. Action is needed in order to reduce greenhouse gas emissions. It is projected that world energy demand will continue to grow rapidly in the coming decades. Meeting this demand in a sustainable manner will require drastically increasing the efficiency with which energy is produced, delivered and used. At least for the next few decades, it will also require accepting a diverse mix of energy sources and technologies, with increased attention to be given to renewable sources of energy (see sect. II above).

34. Action is needed by countries and regions to design and start implementing strategies to adapt to the consequences of climate change, particularly for the most vulnerable regions, nations and socio-economic groups. International collaboration will promote the development of best practices and the effectiveness of strategic approaches to climate change adaptation. At all levels, participation of a broad range of stakeholder groups will be essential in this undertaking.

35. The scientific community needs to continue to increase its understanding of the climate and the Earth system and to refine its predictive tools and reduce remaining uncertainties in projections of future climate and its impacts, particularly at the regional level. In this respect, important priorities during the coming years are:

(a) To enhance long-term observations of the Earth system by making the global environmental observing systems fully operational through implementation of the Global Earth Observing System of Systems;

(b) To vigorously pursue the implementation of the World Climate Research Programme and the related global environmental change research programmes, including the International Geosphere-Biosphere Programme, DIVERSITAS and the International Human Dimensions of Global Change Programme.

36. It is equally important that a new line of interdisciplinary research be initiated, involving natural, social and economic sciences, aimed at a better identification and understanding of coupled environmental and socio-economic impacts and vulnerabilities, and at increasing the knowledge-base for drawing up possible adaptation strategies to climate change. Since climate change is an ongoing process, we must become better prepared for adapting to it and for limiting its socio-economic costs in societies worldwide.

37. The Conference of Parties to the United Nations Framework Convention on Climate Change has agreed, in principle, on the development of a five-year programme of work on impacts, vulnerability and adaptation. A workshop convened by the secretariat in October 2005 in Bonn, Germany, was dedicated to defining the content of the five-year programme of work of its Subsidiary Body of Scientific and Technological Advice. Needs identified at this workshop include:

(a) Promoting development and dissemination of impact and vulnerability assessment tools and methods;

(b) Improving access to high-quality data and information on current and future climate variability and extreme events;

(c) Improving availability of socio-economic information on vulnerable populations and economic sectors and on the economic impacts of climate change;

(d) Stimulating adaptation research and technology;

(e) Promoting international cooperation to assist vulnerable countries in enhancing their resilience and managing climate risks, giving priority to the most vulnerable countries.

38. As a result of global warming, the polar regions are a unique barometer of environmental change. In the Arctic and in regions of Antarctica, average surface temperatures have risen much more quickly than in the rest of the world in the past decades. This fact has also been confirmed by the results of the independent Arctic Climate Impact Assessment, published in 2004. Consequently, among the topics to be investigated by the upcoming International Polar Year 2007-2008, sponsored by ICSU and WMO, climate change research must be supported strongly, in addition to the development of polar components of the global environmental observing systems.

39. The scientific and technological community also calls for continued support to the highly important work of IPCC as a forum for carrying out independent scientific assessments and enabling interaction between natural and social scientists, policymakers and other stakeholders, thus strengthening participatory approaches.

40. The links between research, long-term monitoring, integrated assessments and policymaking at the global level have been considerably improved during the last 10 to 15 years, although such links are still lacking in most regions, in particular at the country level.

IV. Air pollution/atmosphere

41. One of the most profound ways in which human activity affects the natural environment is through changes in the composition and chemistry of the atmosphere. Of greatest concern are three closely intertwined issues: the occurrence of health-damaging air pollution; the build-up of heat-trapping greenhouse gases; and the depletion of the Earth’s protective stratospheric ozone layer.

A. Air pollution

42. Clean air is a basic requirement for human health and welfare and an important prerequisite for sustainable economic development. Air pollution[1] results primarily from the combustion of fossil fuels in transportation and power generation, from various industrial emissions and from large-scale biomass burning in some parts of the world. Air pollution is known to be a major factor in respiratory and heart disease and a number of air pollutants are known or probable carcinogens. Though very difficult to quantify, it is estimated that millions of people die prematurely due to air pollution each year worldwide. Air pollution also adversely affects natural ecosystems, for instance, through damage to plant growth, acidification of waterways, accumulation of mercury in the food chain and eutrophication of coastal ecosystems, all leading to impacts on agriculture, fisheries, forests and a host of "ecosystems services" upon which all life depends. Much still needs to be learned about the specific details and mechanisms of air pollution exposure and impacts on both human and ecosystem health; however, current scientific understanding provides ample evidence to warrant urgent action.

43. In most developing countries air pollution is a serious problem, the result of rapid urbanization and population growth and the consequent growth in the demand for energy and automobile transportation, combined with poor environmental regulation and highly polluting vehicles and industrial production systems. In many rural areas a major health threat (particularly among women and children) is chronic exposure to indoor air pollution, resulting from the combustion of biomass and coal in rudimentary, inefficient systems for cooking and heating. In this context, relatively small investments in implementing existing pollution control technologies could have huge environmental and public-health benefits.

44. In most industrialized countries effective regulatory programmes implemented over the past few decades have led to the introduction of cleaner technology, especially in the power generation and transport sectors, which has led to a significant improvement in overall air quality. In many places, however, the gains made by tighter regulations and improved energy efficiency and pollution control technologies have been offset by the increase in traffic (vehicle-miles-travelled) and the demand for energy. The emission of fine particulates from diesel engines and power plants is seen as a significant health risk that remains inadequately addressed.

45. A matter of growing attention and concern is the long-range transport of air pollutants across national boundaries and between continents, which can raise background pollution levels over large regions of the globe and make it impossible for any one country to fully address its air quality concerns in isolation. In the 1980s and 1990s, widespread concern about acid rain pollution in North America and Europe led to extensive research and assessment efforts that greatly enhanced understanding of long-distance transport of sulphur and nitrogen oxide pollution. More recently the scientific community has been striving to develop robust techniques for documenting long-distance transport of ozone, particulates and persistent organic pollutants. The Convention on Long-range Transboundary Air Pollution and its associated protocols have been important instruments for enhancing international collaboration, and there has been significant progress in the development of integrated regional policies for air pollution assessment and control throughout Europe and North America. There is still a great need, however, for comparable types of efforts in other parts of the world, for instance across Asia and

Latin America, where there is clear evidence that regional-level atmospheric pollution is a significant and growing problem.[2]

B. Greenhouse gases

46. The build-up of long-lived greenhouse gases[3] in the atmosphere is well documented and is well understood to result from human activities. Further details about the consequences of this profound change in global atmospheric composition and about scientific progress and obstacles in addressing such issues are covered in the section on climate change (see sect. III above).

47. The issues of air quality and climate change are closely coupled on several levels. Most notable is the fact that carbon dioxide, the major anthropogenic greenhouse gas, and many conventional air pollutants come from the same sources (burning of fossil fuels) and can thus be simultaneously addressed through mitigation of those sources. There are also some contexts, however, that can require trade-offs between efforts to reduce emissions of greenhouse gases and emissions of conventional air pollutants. Climate change and air pollution are also linked through chemical and physical processes in the atmosphere. For instance, tropospheric ozone is a powerful greenhouse gas and particulate pollutants can have strong effects on local and regional climate. In turn, climate patterns directly affect the sources, transport and deposition of air pollutants; and a major concern is that global warming will exacerbate the problem of urban air pollution in many parts of the world.

C. Stratospheric ozone

48. The actions taken to preserve the stratospheric ozone layer provide an example of remarkable success of scientific and political cooperation in addressing a major environmental threat. As a result of the successful implementation of the Montreal Protocol and its amendments, the atmospheric concentration of chlorofluorocarbons (the man-made chemicals that destroy stratospheric ozone) has generally begun to decline. However, stratospheric ozone destruction in the polar regions and the consequent rise in dangerous ultraviolet radiation is still occurring at near record levels. It is anticipated that near complete recovery of the Antarctic ozone layer will occur by approximately 2050. The future evolution of ozone in the Arctic is more difficult to estimate, due to the more complex feedback processes involved. Some key remaining needs/challenges include:

(a) Reducing international trafficking of existing chlorofluorocarbons and ensuring a timely phase-out of methyl bromide and hydrofluorocarbons;

(b) Further advancing scientific understanding of how climate change can affect the dynamics of stratospheric ozone loss and recovery;

(c) Ensuring that the effective atmospheric monitoring systems put into place over the past few decades are maintained.

49. The stratospheric ozone example is often cited as a model for the effective use of scientific information in guiding policy responses to global change concerns. It must be acknowledged, however, that other global change issues pose far more complex challenges in this respect. For instance, effectively responding to climate

change requires understanding highly complex cause-and-effect relationships and feedbacks and controlling emissions from a wide array of sources and sectors that are of central importance to social and economic development.

D. The role of science and technology

50. Effective air quality management systems are developed in the context of diverse social, economic and political considerations. However, a strong scientific and technical base is indispensable as a foundation for such systems, playing a critical role in setting appropriate emission standards and ambient air quality objectives, designing and implementing effective air pollution control strategies and technologies and assessing emissions, ambient air quality, exposure patterns and impacts on human and ecosystem health.

51. *Observing systems.* Understanding atmospheric change requires an integrated system for collecting data on a wide array of parameters, including: greenhouse gases, ozone, solar radiation, precipitation chemistry, aerosols, reactive gases and meteorology. Such data is collected through: surface-based monitoring networks; aircraft- and balloon-based measurements in the lower atmosphere; and, increasingly, space-based satellite observations. The atmospheric science community has made great progress in advancing and coordinating these complex observational networks and in applying them to study air pollution transport, map and assess pollutant emissions, develop air quality forecasting systems and support international policy formulation. The WMO Global Atmosphere Watch programme recently developed a proposal for an Integrated Global Atmospheric Chemistry Observation System to ensure more accurate and comprehensive global observations of key atmospheric gases and aerosols and to make such observations accessible to users. This new initiative could become part of the Global Earth Observation System of Systems. Likewise, ecological and human health research communities continue to advance systems for monitoring air pollution impacts. Such systems are critically important for determining priorities and evaluating the effectiveness of air quality control measures. However, linking observed trends in human and ecological health with ambient air quality trends presents a major scientific challenge, given the multiple stressors to which these systems are exposed and the wide variety of systems and responses involved.

52. *Modelling tools.* There also continues to be a great deal of progress in developing advanced atmospheric modelling tools, ranging from the local to the global scale. Notable examples include the United States Environmental Protection Agency’s Community Multiscale Air Quality modelling system; the Regional Air Pollution and Simulation (RAINS) and Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) models from the International Institute for Applied Systems Analysis, which allow the user to examine the costs and effectiveness of different emission control strategies, and to design emission control strategies that simultaneously meet air quality targets and limit the emissions of greenhouse gases. A wide array of ecological and biological/epidemiological models are likewise continuing to be developed for studies of air pollution impacts.

53. *International cooperation and capacity-building.* Almost all nations share similar challenges in dealing with air pollution, but the capacity to address these challenges varies tremendously. In many developing countries the current impacts of

air pollution and the future risks that may result from different development pathways must be made clear so that decision makers can determine effective policy responses. There is a need to encourage the education and training of more scientists and engineers in order to carry out basic research and observations, to implement and maintain emission control technologies and to give competent advice to policymakers and the public. The most advanced observational and modelling tools, pollution prevention and control technologies and knowledge about best practices in air quality management must be shared effectively among industrialized and developing nations. The efforts of the International Union of Pollution Prevention Associations, the International Global Atmospheric Chemistry Project, the Global Atmosphere Watch Programme and other organizations all play an important role in advancing this international cooperation.

V. Education, training and science and technology institutional capacity-building

54. Addressing the challenges of developing sustainable energy systems, mitigating and adapting to climate change, reducing atmospheric pollution and promoting a sustainable path to industrial development requires strong and focused national, regional and global science and technology systems. However, it is now clearer than ever that these challenges have thus far outstripped the capacities both of the science and technology community and of society to forge effective and comprehensive responses. Nothing less than a massive effort will be needed in order to strengthen scientific and technological capacity in all regions of the world and, in particular, in developing countries.

A. Bridging the North-South divide in scientific and technological capacity

55. The countries of the Organization for Economic Cooperation and Development (OECD) spend annually more on research and development than the economic output of the world’s 61 least developed countries. Developed countries employ 12 times the per capita number of scientists and engineers in research and development than developing countries, where there is often a woefully weak institutional capacity. This gap in science and technology capacity between the developed countries and a majority of developing countries is generally still widening.

56. Developing countries must address this problem and significantly enhance investment in higher education and scientific and technological capacity. Bilateral donors and other funding mechanisms should include science and technology capacity-building among their priority areas of development cooperation and substantially increase the funds they allocate to this sector for sustainable development. Special attention should be given to the areas of energy, climate change, air pollution and industrial development. A critical mass of scientific and technical skills and infrastructure (for example laboratories, equipment and supporting institutions) is required for all countries to: develop, adapt and produce the technologies specific to their needs; introduce these technologies effectively into the market; and provide the needed maintenance on an ongoing basis. Capacity-building at the international, regional and subregional levels must also be given

increased attention as it is often the most cost-efficient way to build a critical mass of capacity.

B. Recent initiatives and ongoing programmes

57. At the end of August 2005, the world's leading international scientific, engineering and medical organizations issued a joint statement on science, technology and innovation for achieving United Nations Millennium Development Goals (www.icsu.org/9_latestnews/latest_5.html). The statement was addressed to the Heads of State and Government gathered at the 2005 World Summit at United Nations Headquarters in September 2005. The Summit participants recognized that science and technology, including information and communication technologies, are vital for the achievement of the development goals and adopted a number of commitments in this regard. Two of the commitments refer specifically to:

(a) Assisting developing countries in their efforts to promote and develop national strategies for human resources and science and technology, which are primary drivers of national capacity-building for development;

(b) Promoting and supporting greater efforts to develop renewable sources of energy, such as solar, wind and geothermal.

58. The importance of addressing science and technology capacity-building issues worldwide has been highlighted in a 2004 report from the InterAcademy Council entitled *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology*. The report provides a blueprint of action needed to enhance the science and technology capacity of those developing countries that still lack this capacity.

59. At the January 2004 meeting of the OECD Committee for Scientific and Technological Policy at ministerial level, Ministers adopted the Declaration on International Science and Technology Cooperation for Sustainable Development, which stated that moving towards sustainable development objectives requires better ways of cooperating internationally to build capacities in science and technology, enhancing knowledge and technology transfer and creating effective networks in the developing countries. Governments, academia and businesses in both OECD member countries and developing countries have important roles to play. In order to follow up on the Declaration, an international workshop, coorganized by the Government of South Africa and OECD, took place in South Africa in November 2005. The workshop included a particular focus on identifying good practices in international science and technology cooperation in the areas of energy and climate change. It is expected that results of this workshop will be taken into consideration at the fourteenth and fifteenth meetings of the Commission on Sustainable Development.

60. In the field of science related to climate change, the SysTem for Analysis, Research and Training (START) acts as a platform to enhance the scientific capacity of developing countries to participate in global environmental change research programmes and to address issues of impacts and vulnerability and mitigation and adaptation at the national, subregional and regional levels. START is co-sponsored by the World Climate Research Programme, the International Geosphere-Biosphere Programme and the International Human Dimensions of Global Change Programme.

It seeks to establish and foster regional networks of collaborating scientists and institutions in developing countries and undertakes a wide variety of training and career development programmes. Increased financial support for START is necessary in order to enable the programme to better fulfil its tasks.

61. Detailed needs in science and technology capacity-building in the broad area of climate change and reduction of greenhouse gas emissions have also been drawn up by the Subsidiary Body for Scientific and Technical Advice of the United Nations Framework Convention on Climate Change.

62. A major instrument for enhancing education focused on energy, climate change, air pollution and atmosphere issues will be the United Nations Decade of Education for Sustainable Development 2005-2014. Within different domains of education for sustainable development (basic education, higher education, reorienting existing education programmes, developing public awareness and understanding of sustainability and specialized training) the specific themes of sustainable energy, mitigation of and adaptation to climate change, air pollution/atmosphere and industrial development should receive particularly high attention. The science and technology community, for its part, is committed to making an active and important contribution to the Decade in this respect.

VI. Conclusions

63. The present report demonstrates that science and technology are essential means for accelerating the implementation of actions agreed in the Johannesburg Plan of Implementation, aimed at addressing the problems of climate change and air pollution and at meeting the world’s growing energy demands in a sustainable manner. Progress in meeting sustainable development goals in these fields will require substantive further advances in science and technology and a massive effort in order to strengthen scientific and technological capacity in all regions of the world, in particular in developing countries.

64. The science and technology community remains committed to helping identify and implement sustainable solutions to the pressing problems highlighted here. To that end, our community seeks to enhance further cooperation with Governments, business and industry and civil society, in implementing research. We are also striving to develop new platforms for ongoing dialogue with policymakers, development specialists and the wide array of other stakeholder groups that are directly involved in meeting sustainable development challenges. These dialogue efforts are aimed at providing more open, participatory mechanisms to define key needs for new scientific knowledge and technological innovation.

Notes

[1] The World Health Organization recognizes six main types of air pollutants: carbon monoxide, nitrogen dioxide, particulate matter, sulphur dioxide, tropospheric ozone and suspended particulate matter. In addition, some countries specify as air pollutants: heavy metals (such as lead and mercury), volatile organic compounds (such as benzene and formaldehyde) and a broad array of other chemical compounds classified as air toxics.

[2] For instance, the INDOEX field experiment (http://www.indoex.ucsd.edu/) led to the discovery of a massive pollution cloud extending over the Indian Ocean, South and South-East Asia and China, with serious potential impacts on marine life, agricultural productivity, and climate and monsoon hydrological cycles. This phenomenon is currently being studied further under the UNEP Asian Brown Cloud Project.

[3] The anthropogenically produced greenhouse gases include: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); and sulphur hexafluoride (SF_6).