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Addendum

Contribution by the scientific and technological community**

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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. As co-organizing partners of the scientific and technological community major group, the World Federation of Engineering Organizations and the International Council for Science are submitting the present paper on sustainable consumption and production, transport, chemicals, waste management and mining for consideration at the eighteenth session of the Commission on Sustainable Development. While the paper discusses particular sustainability issues as they relate to those topics separately, none of those areas functions within an isolated silo. For example, mining clearly relies on transport and waste management; by the same token, mining impacts transport and waste management. Sustainable consumption and production is discussed as a cross-cutting and overarching issue of sustainable development.

2. Agenda 21 and the Plan of Implementation of the World Summit on Sustainable Development ("Johannesburg Plan of Implementation") call for numerous science- and technology-based actions relating to the themes under review. The present paper provides information on some progress that has been made and discusses the obstacles that still exist in implementing such actions. The paper also outlines major new challenges and opportunities in harnessing science and technology for a more sustainable path to development in the five areas mentioned in paragraph 1 above.

3. In preparing the present paper, the World Federation of Engineering Organizations and the International Council for Science consulted their members worldwide, which provide expertise in the relevant scientific, engineering and technological disciplines (e.g., their respective international scientific unions). The International Social Science Council also provided very valuable input. In fact, the two co-organizing partners of the scientific and technological community major group each has a large network of national and international scientific and professional partners. Cooperation and information exchange with these partners contributed significantly to the development of the ideas contained in the present paper. Examples of these partners include the Academy of Sciences for the Developing World, the Stockholm Environment Institute and global environmental change research programmes co-sponsored by several organizations of the United Nations system and the International Council for Science.

4. Science and technology are major driving forces that have an impact on change and development generally, including in the topical areas of the eighteenth session of the Commission on Sustainable Development. Through the application of science, engineering and technology, the scientific and technological community has a direct and vital impact on the quality of life for all people. Generally, science and technology strive to serve the public interest by promoting the health, safety and welfare of all in a sustainable manner. The pressing challenge now is to expand science, engineering, technology, innovation and application in pursuit of the goals of sustainable development.

5. In July 2009, in Lausanne, Switzerland, several prominent engineering societies, representing over 350,000 members worldwide, hosted a workshop on the topic of "Engineering solutions for sustainability: materials and resources", which focused on the engineering answers for cost-effective sustainable pathways, the

strategies for effective use of engineering solutions, and the role of the global engineering community.

6. The operational definition of "sustainability" developed on that occasion is multidimensional and encompasses the following issues and objectives:

(a) Economic: The engineered system needs to be affordable;

(b) Environmental: The external environment should not be degraded by the system;

(c) Functional: The system has to meet the needs of users during its life cycle, including the needs of users for functionality, health and safety;

(d) Physical: The system should endure the forces associated with its use, as well as accidental, wilful and natural hazards, over the course of its intended service life;

(e) Political: The creation and existence of the system needs to be consistent with public policies;

(f) Social: The system has to be, and should continue to be, acceptable to those affected by its existence.

7. Engineering organizations at both the international and national levels have examined the roles and responsibilities that the engineering profession has and will have in achieving sustainable development. For example, the recently published *Future Climate Engineering Solutions: Joint Report*[1] focuses on climate change and contains many observations on engineering and sustainability, which were made with the input of 13 engineering associations from 12 countries.

8. Climate, lifestyle, macroeconomic, political and social changes will alter demands and resources for infrastructure systems. Engineered systems must therefore meet today's needs and be adaptable to changes in future needs. The concept of "resilience" has been developed for engineering to resist natural, accidental and wilful hazards; it means the system must possess the power of recovery. Similarly, a resilience definition of sustainability is now being developed. It recognizes the need to enable current and future generations of society to be resistant to anticipated and unanticipated changes in economic, environmental, political and social systems. This means that engineered systems and practices should be adaptable to unforeseen demands and technical capabilities. For a multidimensional, resilience-oriented understanding of sustainability to become operational, life-cycle-assessment methods that cover all dimensions of sustainability and that provide for transparent weighing of the commensurate effects are needed.

9. The concept of resilience is also central to a systems science approach of understanding sustainability and a holistic approach to sustainable development. The goal of sustainable development is to create and maintain prosperous social, economic and ecological systems. These systems are intimately linked. Humanity depends on the services of ecosystems (such as clean water and air, food production and fuel) for its wealth and security. Moreover, humans can transform ecosystems

[1] *Future Climate Engineering Solutions*, joint report published by the Danish Society of Engineers, September 2009.

into either more desirable or less desirable conditions. Negative shifts in ecosystem conditions, with consequences for human livelihoods, vulnerability and security, represent a loss of resilience of both ecosystems and socio-economic systems.

10. Research undertaken during the past decade has revealed the tight connection between resilience, diversity and sustainability of interconnected social-ecological systems. Resilience, for social-ecological systems, is related to (a) the magnitude of shock that the system can absorb and still remain within a given state, (b) the degree to which the system is capable of self-organization and (c) the degree to which the system can build capacity for learning and adaptation. “Management” of the system can destroy or build resilience, depending on how the social-ecological system organizes itself in response to management actions.

11. Global imbalances in societal and economic development mean that there is uneven access to the material and human resources required to develop and implement sustainable solutions. Achieving a balance among economic prosperity, environmental health and social equity will require significant changes in business strategies, operating technologies, personal behaviours and public policies. The engineering and scientific communities can engage with communities of interest in the process of improving quality of life by helping to balance the need for resources, including minerals, metals and fuels, against the need to protect the environment and society from unnecessary adverse impacts. Communication and understanding between the policy domain and the engineering and scientific communities must be improved.

12. One major challenge lies in the lack of research and development funds, as the development of science and engineering will be essential for adaptation to a changing world. Sustainability requires building solid awareness, among both political leaders and the general public, of the need to support forward-looking policies that encourage well-coordinated investment to develop and apply scientific and technological innovations. At times, the responses of engineers to the challenges of sustainability might be to propose cutting-edge technology. In other cases, the solutions may have existed for a long time, but implementation may require the will, the means and the diffusion of knowledge to make it happen. In other words, answers may lie in combining new and old tools.

II. Sustainable consumption and production

13. There are huge differences between the per-capita consumption levels of wealthy and poor societies around the world. Within many countries, in particular in the developing regions, there are similarly great differences in consumption between different social groups. In developed countries, consumption of energy, household goods and other materials has reached very high aggregate levels, which is placing tremendous stresses upon the environment and natural resource bases and is ultimately having a negative effect on our life support systems. By contrast, in many developing countries, large segments of the population struggle with poverty, including the lack of food and other basic requirements, posing serious health concerns and limiting prospects for productive livelihoods. Neither of these two extreme consumption patterns can be regarded as sustainable.

14. During the past 20 years, scientists have accumulated clear evidence that human actions have become the main driver of global environmental change and

that the current aggregate trends and patterns of consumption and production are unsustainable. The list of global environmental change problems is becoming longer, and the consequences of these changes are becoming more and more severe:

(a) There is scientific consensus, documented in the assessment reports of the Intergovernmental Panel on Climate Change, that the increase in greenhouse gases in the atmosphere as a result of human activities (largely because of the still growing reliance on fossil fuels) is altering the Earth's climate, bringing about a general global warming. Indiscriminate and inefficient energy consumption is an important part of this problem;

(b) Similarly, the Millennium Ecosystem Assessment, the first state-of-the-art scientific appraisal of the conditions and trends in the world's ecosystems and the services they provide, such as food, forest products, clean water and natural resources, found that 60 per cent of the ecosystem services are being degraded or used unsustainably. The major changes that have been made to ecosystems, mainly over the past 50 years, have contributed to net gains in human well-being and economic development; however, these gains have been achieved at an ever increasing cost: the degradation of many ecosystem services. These problems, unless addressed rapidly, will substantially diminish the benefits that future generations obtain from ecosystems;

(c) There is also scientific consensus that, as a result of human impacts, other subsystems of the Earth system are about to leave their "safe operating space". These human impacts are the following: human interference with the nitrogen cycle, humans increasing the rate of biodiversity loss and people now using almost 50 per cent of all available freshwater running off of land (water withdrawals have doubled over the past 40 years), all of which have led scientists to agree that humanity is faced with a looming global water crisis;

(d) Chemical pollution on a global scale has become another area of great concern expressed by scientists. No comprehensive quantification and scientific assessment of the planetary impact of chemical pollution has thus far been undertaken. Consequently, research efforts must be increased to quantify the amount of persistent organic pollutants, plastics, endocrine disrupters and heavy metals emitted into, or their concentration in, the global environment, and to better understand the effects of this pollution on the world's ecosystems and the functioning of the Earth system.

15. As the scientific and technological community major group, it is our responsibility to bring to the deliberations of the eighteenth session of the Commission on Sustainable Development this clear message: that the current consumption and production patterns in many countries are unsustainable and that a major shift in the direction of human development is urgently required. We welcome that the document entitled "Proposed input on a 10-year framework of programmes on sustainable consumption and production", to be presented at both the eighteenth and nineteenth sessions of the Commission, defines as an ambitious objective of the framework of programmes a decoupling of economic growth and social development from environmental degradation. It has not been made clear, however, whether the programmes that are to become part of the framework will be commensurate with the huge tasks. A true strategic approach will be needed in order to engage humanity with a sense of urgency in a transition to sustainable models of consumption and production.

16. A framework of this kind is at heart an effort to organize major social change. This change is considered a consequence of policies primarily in three fields: information and awareness-raising; regulation; and international agreement. It has to be stressed that the framework should also include programmes that address the economic, financial (consumer and producer), behavioural and cultural obstacles to change. For instance, not placing a value on ecosystem services has become an economic obstacle to a transition towards sustainability.

17. Governance institutions need to be part of the change, as well as drivers of fostering change towards sustainability. Effective governance institutions must be able to: (a) lengthen the time horizons for which societal and individual decisions are made; (b) broaden the orientation of Governments to the needs of the many over the long term; (c) enable the private sector, Governments, individuals and entire societies to consider short-term sacrifices that offer long-term improvements; and (d) include the capacity for rapid, constructive response to evidence of the unsustainability of a certain course of action. Furthermore, a strategic framework of action would include addressing the role of international business and industry in shaping demand, issues of conflict of priorities and directions, social movements of different kinds and questions about what drives personal behaviour.

18. Issues surrounding the concept of consumer choice are of great importance in this context. Hence, a 10-year framework of programmes on sustainable consumption and production should clearly spell out the underlying understanding of consumer choice and what the role of Government in "editing" that choice is. For instance, strict product norms are a good tool for protecting human health and the environment.

19. It must be acknowledged, however, that, even when effective institutional arrangements and incentives are in place, a successful transition to sustainability requires citizens that place a high priority on meeting such goals. This is why issues of understanding sustainability, consumer and producer behaviour, culture and values must be considered as of high importance. Social science research has already provided numerous insights into many of these issues.

20. Moreover, engineering and technology will be critically important for achieving transitions to sustainability. The challenges that current consumption and production patterns pose to sustainable development point to the questions of what materials and resources will be required and how these materials and resources will be produced and used in a sustainable manner. The use of specifically recyclable materials (e.g., alloys) is one of the current means to address such questions. This will require:

(a) Engineering solutions for enhancing recycling rates and recovery, such as integrated sorting systems;

(b) Designing for recyclability prior to manufacturing, for example, standardized alloys;

(c) Developing new recycling processes for products that are made currently;

(d) Optimizing existing technologies and new technologies to recover small amounts of rare metals present in many products.

21. For these measures to be successful, it is important to disseminate among all production and consumption sectors two main concepts:

(a) Knowledge of product life cycle;

(b) True cost of a product, including the recycling costs.

22. Another area in which engineering and technology will be key in transitions to sustainable consumption and production patterns relates to energy. There is progress within the global community in agreeing to transform our energy systems, redirecting them towards sustainable pathways, and to move to a low-carbon economy. Meeting the world's rapidly growing energy demands in a sustainable manner will, during the coming decades, require utilizing a diverse mix of energy resources and technologies while increasing efforts to enhance the implementation of existing clean energy technologies and to spur further scientific understanding and engineering design aimed at the development of new clean energy technologies.

23. Enhancing energy conservation and efficiency is 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 the heating, cooling and lighting of buildings; the dematerialization and recycling of energy-intensive material; and the design of land-use and transportation systems that minimize demand for travel in personal vehicles. Moreover, there is the equally important and vast field of necessary behavioural changes in terms of energy consumption.

24. In an increasingly globalized economy, the places where product manufacturing takes place are sometimes far from where the end users of those goods are located. Increasingly, products that once may have been produced locally, or at least domestically, are made abroad and shipped to consumers halfway around the world. Goods not only travel farther to market; in some cases, once used, they make the return journey as recycled material. While diversified trade and such recycling can be seen in a positive light, in the absence of more efficient transportation such trade expends more energy. This can be mitigated through engineered actions to improve the handling and shipment of goods.

25. One specific example relates to trade in agricultural commodities. Combined with available infrastructure to process, store and move food products, global agricultural trade has allowed many parts of the world to enjoy a more varied diet and higher levels of nutrition. In addition to the high energy intensity of global food trade, however, many other shortcomings remain in domestic and international food distribution networks. The result is that enormous amounts of food, with the potential to sustain large human and livestock populations, are wasted or spoil before reaching end users. Engineering technology applied to harvesting crops, preserving and refrigeration, and in warehousing and transporting food products, can reduce such wastage. In many cases, the technology to safeguard food exists, but the knowledge and resources to apply that know-how are not readily accessible.

26. Promoting greater technological efficiency is one way forward, but it is insufficient, and sometimes problematic. For instance, efforts to promote efficiency often suppose and reproduce unsustainable forms of consumption. Freezers can be

made efficient, but expanding the current system of global transport networks for frozen food to cover the consumption aspirations of billions more people should not be the goal, as this particular pattern of consumption does not seem sustainable.

27. Infrastructure is a critical area in an engineering- and technology-oriented approach to reducing environmental degradation and increasing efficiencies of material and energy use.

28. Infrastructure includes the manufactured products, constructed facilities and natural features that shelter and support most human activities: buildings of all types, communications, energy generation and distribution, natural features, transportation of all modes, water resources and waste treatment and management. Manufactured products can be part of infrastructure, just as automobiles are an element of transportation infrastructure. Infrastructure need not be confined to the "built or engineered environment". Natural features, such as a wetland that contributes to waste treatment or a lake that contributes to a water supply, are also part of infrastructure.

29. Not only does the design of infrastructure change over time, but so does the inventory of what is included in infrastructure. A century ago, few would have envisioned the airline infrastructure that now exists around the globe. Mere decades ago, only visionaries could have foreseen the information and communications technology infrastructure that today extends to so many facets of life in developed and developing countries. Even now, engineers and scientists are shaping new visions into new realities. In perhaps just a few years, these realities may be taken for granted and contribute significantly to sustainability.

30. For the very reason of its importance to safety, health, quality of life and the economies of developed and developing countries, sustainability of infrastructure must be a major focus of national and international activities. Infrastructure improvements can take many forms. The following are just some of the areas in which such improvements are needed:

(a) Quantitative performance objectives for infrastructure systems, including the dimensions of sustainability and the integration of infrastructure systems;

(b) Infrastructure products such as intelligent vehicle-highway systems and smart grids for the generation, transmission and distribution of electrical power;

(c) Engineering tools and practices such as integrated data systems, modelling-simulation-visualization tools, integrated project delivery systems and performance-based standards with streamlined systems for acceptance by multiple regulatory authorities.

31. The wider debate on climate change involving the public, Government and specialists has focused attention on the vulnerability of certain public and private infrastructure to long-term climactic changes. Responses have included making buildings, transportation and sanitation systems "smarter". Recommendations that engineers and others have advanced to make infrastructure more sustainable in the face of a changing climate may also prompt other improvements to infrastructure. These could make infrastructure more durable and adaptable in terms of function, economics or other factors. For example, installing heat pumps, solar power, higher-efficiency appliances, enhanced building envelopes, district heating and energy

management systems, besides reducing carbon footprints, may also yield life-cycle savings.

32. From the viewpoint of the scientific community (natural, social and economic sciences), the 10-year framework of programmes on sustainable consumption and production should reflect both sustainable consumption and sustainable production, be more science- and engineering-based and include support to internationally coordinated research efforts aimed at a more holistic understanding of production and consumption systems. For instance, questions about consumer decisions (including the role of both individuals and institutions) require far greater attention. Research on this issue has thus far been highly fragmented and hampered by disciplinary barriers.

33. The current cycle of the Commission on Sustainable Development should be used to further promote the interesting approaches to interdisciplinary research that have been developed over the past 10 to 20 years, such as: (a) analysing what sustainable lifestyles mean in different parts of the world and for different social groups; (b) studying the impact of specific consumption and production patterns on poverty reduction in different parts of the developing world; (c) measuring the resources consumed to support people's lifestyles in terms of "ecological footprints"; (d) evaluating the values and attitudes that drive consumption-related behaviour and lifestyle; (e) focusing studies on households and settlements as the primary units of analysis, since this is the level at which most consumption decisions are made; (f) conducting systems analyses that are place-based but that at the same time consider the globalization of production and consumption cycles (for instance, that examine how the consumption patterns of developed countries are linked to the export of natural resources from developing countries); and (g) studying production and consumption systems through a life-cycle approach, from the extraction of raw materials through processing, distribution, use and disposal. Such a greatly enhanced body of knowledge in these areas would benefit policymakers, Governments, the private sector, civil society and practitioners in general.

34. Most countries distinguish between research and development policies, which focus on the generation of new knowledge, and industrial policies, which focus on building manufacturing capabilities. Convergence of these two approaches could foster the expanded use of existing sustainable technologies, while also building a foundation for long-term research and development efforts. Creating links between knowledge generation and enterprise development is one of the most important challenges facing developing countries. Targeted taxation regimes and market-based instruments, along with a wide variety of strategies for unlocking financial capital, are needed to create and develop enterprises that contribute to sustainable production and consumption.

III. Transport

35. Transportation technologies are progressing on many fronts towards lower emissions of air pollutants and greenhouse gases, including in the following areas: cars powered by hybrid engines, electricity 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. Even with the aggressive implementation of cleaner vehicle technologies, there remains a strong need to reduce demand for transport by personal vehicle and the long-distance road transport of goods.

36. Not only does transport require its own infrastructure, but a transportation system also shapes the infrastructure that it surrounds and passes through. Seeking energy sustainability through shorter travel distances may lead to an urban landscape of closer-knit residential, commercial and industrial buildings.

37. Actions for promoting cleaner fuels and vehicles must be complemented by policies to reduce the overall demand for the use of personal vehicles by furthering public transport, although modifying unsustainable patterns of transportation energy consumption will require cultural and behavioural adjustments. The current global economic crisis has created a framework favourable to implementing such adjustments in many key countries.

38. Currently, many Governments are developing policies that foresee:

(a) Diversification of mobility means;

(b) Emphasis on public transport in urban zones;

(c) Low-fuel-consumption vehicles, for example, hybrid and electrical cars;

(d) Management of public space in cities with new modes for car usage.

39. One success story in numerous developed countries is the new type of mobility services, like the free use or low-cost rental of bicycles, multi-user taxi-sharing and car-sharing, now employed in several cities. Another partial success story is the downsizing of car dimensions, weight, speed performance and engine-cylinder volume in order to achieve low fuel consumption.

40. There is opportunity for using the Internet for the precise transfer of transportation information, such as location, safety and scheduling. Within a city or between cities, information and communications technologies allow for "intelligent transport systems" with high efficiency and safety. This can lead to faster travel with less stopping and starting. Governments should encourage all stakeholders to build and maintain national information infrastructure and create information resources to make information and communications technology tools available to all people, urban and rural, for learning and working.

41. Some success has been demonstrated in the abatement of carbon dioxide (CO_2) emissions in cars. A priority area of research and development should be the development of hybrid electric-gasoline cars with regenerative braking systems, as well as electrical vehicles. Similarly, investment in research and development aimed at the development of convenient, economic and safe ways of storing hydrogen onboard motor vehicles (e.g., carbon nanofibres) must be stepped up significantly. Making automobiles lighter by using new materials, such as aramid fibre, can reduce vehicle weight and, with it, fuel consumption.

42. Investment in engineering opens up numerous ways of making transport more sustainable. A report from Japan notes the presence of more than 500 million cars on

the road worldwide. Losses resulting from friction and heat account for two thirds of their fuel consumption. If the annual fuel consumption of these cars could be cut by 10 per cent by reducing friction, it is estimated that the conserved energy would provide electric power for all households in Japan for a year or more.

43. Programmes for producing ethanol and biodiesel are already in place, based on different crops (e.g., cassava, castor beans, cotton seeds, jatropha, palm oil, soybeans, sunflowers and sweet potatoes). Biomass production for fuels requires land resources and, in many parts of the world, may have to compete with food production. Moreover, the water footprint of biofuels is a challenge that should not be ignored. Some tropical countries have large tracts of degraded lands that could benefit from the establishment of bioenergy plantations. Planting arid, semi-arid, degraded and marginal lands that are unsuitable for food production with non-edible biofuel crops would not compete directly with current food production and could help rehabilitate the soil. For large agricultural areas, scientific, engineering, social, economic and sustainability analyses should be conducted, on a case-by-case basis, on the comparative advantage of planting food or biofuel crops, especially in the face of the ongoing global food crisis.

44. A shift towards cellulose-based second-generation biofuels using wood and grassy crops would offer greater reductions in carbon dioxide emissions and less land used per unit of energy, although technical breakthroughs would be required to achieve this.

45. Increasingly, high-speed rail is emerging as an alternative to short-haul air transport, and urban areas are turning to new modes of light-rail transit. Sustainability would be enhanced by shifting the movement of goods to rail as an alternative to road transport.

46. The door is swinging open for innovation and improvement not only in land transportation but also in aviation and maritime transport through changes to aircraft and vessels that enhance engine performance and reduce friction. Further benefits may accrue from powering vessels with methane fuel, improving the use of waste heat from propulsion machinery, utilizing new sail technology or applying new types of paint to hulls. Adjustment to route patterns may also bring about fuel savings.

IV. Chemicals

47. The management of chemicals in a sustainable manner, often called sustainable or sound chemicals management, which must be science- and engineering-based, requires strong regulatory frameworks at the national, regional and global levels. While human society generally benefits greatly from chemicals, it is essential to address systematically the possible risks for human health and the environment. The scientific and technological community strongly supports the implementation of the globally harmonized system of classification and labelling of chemicals, as well as the adoption of a global system of recognizing and communicating risks and hazards. The concept of “no data, no market”, which requires that a comprehensive set of data and information about a chemical be made available to regulators and to users before it can be sold, should be followed. Sustainability principles will also require that chemical industries adapt their technologies so as to reduce the carbon footprint for all material and processes.

48. In a number of developed countries, the chemical industry remains the largest manufacturing sector. The industry employs millions of people worldwide, including several hundred thousand scientists, engineers and technicians engaged in research and development. International trade in chemicals has exceeded one billion tons since 2000.

49. Several international instruments and mechanisms to address the issue of sustainable management of chemicals at the policy level have been established during the nearly two decades since the United Nations Conference on Environment and Development, held in 1992 in Rio de Janeiro. Negotiations for a global legally binding instrument on mercury will commence in 2010, to be completed by 2013. Mercury is traded globally, used in products and chlor-alkali plants and emitted from coal-fired plants, incinerators, cement kilns and contaminated sites.

50. In order to overcome existing shortcomings, policies and measures should focus in particular on the following areas: risk assessment, data collection and information transparency; stepping up implementation of international instruments; strengthening national regulatory infrastructure; supporting developing countries in building up human and institutional capacity in sustainable chemicals management; and involving multiple stakeholders at the national and international levels.

51. To enhance the coherence of national and international activities in chemicals management and to incorporate chemical safety issues into the international and national development agendas, the Strategic Approach to International Chemicals Management, led by the United Nations Environment Programme (UNEP), has started to contribute significantly to a more rapid dissemination of relevant information and to ongoing discussions of priorities and emerging issues. The International Conference on Chemicals Management, at its second session, reviewed the global plan of action of the Strategic Approach and added five emerging issues: nanotechnology and manufactured nanomaterials, chemicals in products, lead in paint, electronic waste and perfluorinated chemicals. More scientific and engineering research is required in order to ensure that these five areas will become fully part of sound chemicals management and regulatory systems.

52. Management of chemicals throughout their life cycles must be made an integral part of sound chemicals management. Life-cycle producer responsibility has not yet been widely respected and sufficiently implemented. For example, much of the electronic waste created in developed countries is sent to developing countries, often illegally. This influx of toxic waste has resulted in the contamination of land, water and humans.

53. Another challenge is how best to ensure that for new hazardous chemicals, such as pesticides and persistent organic pollutants, the necessary toxicity, health and safety assessments are undertaken without delay. Scientists and engineers call for developing a mechanism for identifying emerging problems associated with new hazardous chemicals. The work on nanotechnology and nanomaterials led by the Organization for Economic Cooperation and Development (OECD) reflects this approach.

54. In many countries, the attention paid to the safe and efficient use of pesticides, as well as to environmental impact assessments of the application of pesticides, remains insufficient. Special programmes to dispose of obsolete stocks of pesticides

(and other chemicals) and to prevent further accumulation of such stocks should be encouraged.

55. The best form of sustainable chemicals management is, whenever possible, the development and use of safe, environmentally benign substances (in replacement of more hazardous ones), often based on renewable raw materials. Governments and industry should encourage this "green chemistry" through enhanced research, education, incentives and favourable market conditions. There is a great need to increase international cooperation in the development and transfer of technology for safe chemical substitutes and in the development of capacity for their production.

56. Among the challenges faced by developing countries in implementing and strengthening sustainable chemicals management is the lack of adequate human resources and institutional capacities in the following areas: risk assessment and interpretation; the implementation and enforcement of regulatory frameworks; the rehabilitation of contaminated sites; emergency response; and effective education, training and awareness-raising programmes. Increased North-South and South-South cooperation is needed to ensure that all countries and regions have the capacity to manage chemicals in a sustainable way, in particular in the light of the increasing trade, use and production of chemicals in developing countries. Countries should be encouraged to take an integrated approach to chemicals management when seeking assistance and cooperation from bilateral and multilateral donors.

57. Both developing and developed countries should give greater emphasis to the involvement of the private sector, scientific research and engineering organizations, educational institutions, farmers and community groups in the development and implementation of sustainable chemicals management policies and strategies and in the building of respective capacities.

V. Waste management

58. One of the biggest returns on investment in health comes from developing sustainable systems for clean water and waste management. In fact, improvements to water supply and sanitation brought on by engineering, both in developed and developing countries, represent the single largest contributor to improved public health and, by extension, human sustainability.

59. On a closely related front, scientists and engineers continue to improve and develop new means to safely release water used in agriculture and industrial processing into the environment.

60. Policies for the progressive limitation of release of waste involve a need for implementing waste-management measures and for recycling materials and equipment. Waste is one major cause of unsustainability. In Europe, about 50 per cent of all solid and liquid waste products are produced by human activities inside buildings. In previous years, as much as one half of the entire gross domestic product of the United States of America might have been attributable to some form of waste.

61. Cogeneration, which allows use of otherwise "waste" heat from the residential, commercial and industrial sectors for electrical generation, makes good sense both environmentally and economically. Energy efficiency measures in the industrial sector (such as climate-ready utilities) also have some co-benefits, owing to

reduction in fuel and material use, leading to reduced emissions of air pollutants, solid wastes and wastewater.

62. The Johannesburg Plan of Implementation calls for the "3R" approach to waste management: reduction and prevention of waste and the maximization of reuse and recycling. The Plan of Implementation also calls for the replacement of products with harmful waste with environmentally friendly alternative materials. Without sustainable waste management, several of the Millennium Development Goals, in particular the target of halving by the year 2015 the proportion of people without access to safe drinking water and basic sanitation, will not be met.

63. Management of solid waste should be considered an important public service. In many developing countries, however, this service is wholly inadequate, owing to a lack of resources. In fact, waste management is often not seen as a priority by local authorities and national Governments, which disregards the potential public health and environmental consequences. Landfills that are poorly designed and maintained represent an ongoing challenge, often even in developed countries. Seepage of effluent, sometimes into water courses, and the escape of greenhouse gases such as methane are surmountable technical problems that need to be addressed. Overall, a policy of moving away from landfill use to more sustainable waste management is required. Incinerating waste and transferring residues to the soil and fine particles to the air have their own problems with regard to environmental sustainability, however.

64. Sustainable policies for consumption and production and sustainable waste management are closely interrelated. City governments, within their jurisdictions, and also national Governments, as part of national sustainable development strategies, should conceptualize and make operational "integrated sustainable waste management systems". Such a system consists of a variety of activities, including reduction, reuse, recycling and composting, operated by a variety of stakeholders at various scales. Not only technical and operational aspects, but also financial, training, legal, institutional and economic aspects and linkages, must be addressed in an integrated manner in order to enable the overall system to function and ensure its sustainability.

65. There is no globally accepted classification of hazardous wastes, which should be corrected. Globally, the generation of hazardous wastes is increasing alongside the accelerated increase in total waste. Special care must be applied to the management of hazardous wastes, and respective national regulatory frameworks must be established, monitored and regularly updated. All countries should become parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. Its three pillars — effective and more rigorous implementation at all levels of scale, waste minimization and capacity-building of waste management — require strengthening in many countries and subregions. In several parts of the world (e.g., Eastern Europe and Central Asia), there is a legacy of accumulated hazardous wastes. There exist large stockpiles of obsolete pesticides containing persistent organic pollutants and large amounts of industrial waste, mainly from resource mining and processing activities. The wastes often contain radioactive nuclides and metal compounds (e.g., cadmium, lead, zinc and sulphates).

66. The developing international trade in electronic waste has become an issue of concern, as large quantities of such waste are being exported to developing countries for the purpose of reuse, repair, recycling and recovery of non-ferrous and

precious metals. Moreover, plastics in the marine environment have become a major problem. Plastics release toxic chemicals into the ocean.

67. Radioactive waste that results from numerous processes of human activity requires special management attention, and its disposal must be done with special care to avoid harming people and the environment. Low-level waste constitutes the bulk of radioactive waste in terms of volume and mass, although it comprises only a small fraction of total radioactivity in waste. The origin of low-level waste is quite diverse: nuclear power, medicine, research and industry. Intermediate-level waste with long-lived isotopes and high-level waste originate almost exclusively from nuclear reactors and their fuel-cycle facilities, as well as from the defence facilities of countries that have developed nuclear weapons. Though quite limited in volume, these forms of waste constitute the bulk of total radioactivity in waste.

68. Nearly all radioactive waste will be placed in a storage facility for some time, with the ability to retrieve it. Thus, storage is an essential step in the management of radioactive waste, although the targeted duration of storage will vary hugely (e.g., radionuclides with short half-lives will decay away rapidly, so after a few months there will be essentially none left; a number of isotopes require storage for about three centuries; plutonium with a half-life of 24,000 years can be removed beforehand by using reprocessing technologies). The available technological solution for the disposal of intermediate-level waste with long-lived isotopes and high-level waste is long-term containment in deep subsurface storage facilities considered geologically stable and "watertight", making sure that the migration time of the radioactive particles from their original site to the biosphere will be long enough for the radioactivity to have decayed to far below acceptable limits or that the particles will stay fully confined in their deposit location.

69. It needs to be recognized that, in some countries, solving the problem of the disposal of intermediate-level waste with long-lived isotopes and high-level waste is as much a social and political process as a technical one. In these countries, there often exists no political or public consensus on strategies for disposing of high-level waste or on actual waste disposal sites. In some European countries, it became clear that the past practice of deciding where deposits should be built without an extensive engagement of civil society and the local communities concerned has generally failed.

70. A lot of waste is generated when existing infrastructure (roads, buildings, etc.) is replaced. This can be averted or minimized by recycling or finding new uses for the material, for example, by reusing crushed concrete during road construction. The Leadership in Energy and Environmental Design (LEED) approach to building design, engineering and construction has gained increasing acceptance in recent years. The LEED approach not only encourages the capture, conservation and recycling of grey water but also promotes a life-cycle approach that considers the end of a building's useful life. Where possible, consideration should be given to requiring all plans for new and rebuilt infrastructure to project long-term costing, including decommissioning.

VI. Mining

71. Attention is drawn here to the important Milos Declaration on the contribution of the community of minerals professionals to sustainable development, which was

adopted at the first International Conference on Sustainable Development Indicators in the Minerals Industry, held in 2003 on the island of Milos, Greece. The Declaration is a statement of contribution to a sustainable future through the use of scientific, technical, educational and research skills and knowledge in minerals extraction and utilization that was endorsed by the leading global professional and scientific organizations and institutes representing the mineral-mining professions.

72. Mining can contribute to sustainable development through the consistent use of leading practices for environmental stewardship and the provision of equitable benefits to local communities, thereby meeting the needs of today and tomorrow. The large physical footprint of surface mines should be carefully planned in order to reduce environmental impacts during mining and return the land to a sustainable post-mining use. Safety guidelines and good practices for tailings management should be developed. Numerous examples of reuse and redevelopment are led by projects such as the Eden Project in the United Kingdom of Great Britain and Northern Ireland. These actions must be taken with the full engagement of communities, Governments and other stakeholders. Similarly, it is fundamental that environmental and social impact assessments be done, in consultation with the local communities, before extractive activities start, for both opencast and underground mining.

73. The 2003 Milos Declaration also elaborates the commitments necessary to fulfil the sustainability vision in the minerals sector through professional responsibility, education, training, development and communication. The commitments include the following objectives that are widely endorsed within the professional engineering community:

(a) Employing science, engineering and technology as resources for people, catalysts for learning, providers of increased quality of life and protectors of the environment, human health and safety;

(b) Encouraging the development, transfer and application of technologies that support sustainable actions throughout the life cycles of products and mines;

(c) Promoting the teaching of sustainability principles in all engineering programmes at all academic levels;

(d) Encouraging a global exchange in academic training, as well as apprenticeship and internship programmes;

(e) Disseminating technical information on sustainable development and the role of minerals, metals and fuels in sustainable development, including information on the role of minerals in maintaining a high quality of life.

74. Development of new mining technologies must be encouraged by Governments, with the recognition that all energy and water needs are unique to individual locations and to the mineral being produced. Some cutting-edge success stories include:

(a) The introduction of modern techniques and particular chemicals for in situ leaching;

(b) More efficient rock-breaking technologies to reduce energy use;

(c) Technologies that reduce water requirements;

(d) Innovative transportation, such as slurry pipelines in place of trucking transport;

(e) The application of enhanced robotics and remote mining technology that can improve human working conditions and save on associated ventilation and cooling systems.

75. One example of chemical production in mining providing multiple benefits is coal-bed methane recovery. Methane needs to be removed to make the mining of coal safer by reducing mine explosions. Methane is a natural gas, a clean-burning fuel. Use of CO_2-enhanced coal-bed methane recovery, combined with sequestration, is recommended when sources of anthropogenic CO_2 are available. Subregional, regional and global cooperation and the sharing of best practices in this area should be increased, with special attention paid to countries in need of technical assistance.

76. The challenge for the mining sector will be to enhance the social and environmental sustainability of this segment that is important to many national economies, as well as globally. For instance, countries should ensure that adequate environmental monitoring systems are put in place. The absence of such systems makes it difficult to assess present and past pollution from mining activities. As a result, waste composition and volume and the extent of soil, surface and groundwater contamination and its effects on human health are often not known. Corporate social and environmental sustainability and accountability is required. There should be a broader international approach to policies related to the mining sector, from the subregional to the global level.

VII. Education, training and institutional capacity-building in science and technology

77. Mainstreaming “sustainability” in the transport, chemicals, waste disposal and mining sectors requires professionals with solid training and knowledge in different fields of science, engineering and technology. Addressing the challenges of sustainable development in these sectors, as well as in the overarching field of sustainable consumption and production, requires strong and focused national, regional and global scientific, engineering and technological systems. Nevertheless, it is now clearer than ever that these challenges have thus far outstripped the capacities of both the scientific and technological community and society at large 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, in particular in developing countries.

78. The still widening North-South divide in scientific and technological capacity must be bridged. OECD countries annually spend more on research and development than the economic output of the world’s 61 least developed countries. On a per-capita basis, developed countries employ 12 times as many scientists and engineers in research and development as developing countries do.

79. 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 sustainable consumption and production, transport, mining, waste and chemicals. 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.

80. Building and maintaining the quality of key national institutions of learning and research, especially universities, is critical to sustainable development. The responsibility for this capacity-building lies squarely on the shoulders of national Governments; however, the global development assistance community and the international scientific and technological community should enhance collaboration and partnerships with developing countries in this field. Experience shows that cooperation by the international scientific and technological community, through efforts such as the creation of scientific and technological networks, scientific exchanges and the establishment of scientific centres of excellence among nations with weak scientific infrastructure, is an excellent strategy for building up development policies. At the same time, coordinated measures must be taken to counter the negative effects of "brain drain" on countries that are working to develop their own scientific and technological community and institutional capabilities.

81. With respect to the goals of sustainable development, it is also necessary to encourage and develop innovative new approaches to education and training. Educational curriculums at all levels, but particularly in higher education, should be re-examined from a sustainability viewpoint. Educational and training efforts should encourage linkages between natural and social science disciplines, development studies and applied engineering and technology, together with a strong grounding in the basic disciplines of science and engineering.

82. The ongoing United Nations Decade of Education for Sustainable Development (2005-2014) is a major instrument for international cooperation in this field, as well as for sharing experiences, best practices and networking. Within different domains of education for sustainable development, the overarching issue of sustainable consumption and production should receive particularly high attention. Education on sustainability aspects of transport, mining, waste and chemicals should also be included. The scientific and technological community is committed to making an active and important contribution to the Decade.

VIII. Conclusion

83. **Progress in meeting sustainable development goals in the areas under review at the eighteenth session of the Commission on Sustainable Development will require substantial innovative advances in science and technology. Science, engineering and technology must be global in their reach, yet local and national in their application. Enhanced North-South and South-South scientific and**

technological cooperation, knowledge networking and dissemination, along with engineering know-how and technology-sharing, will be essential.

84. **The scientific and technological community remains committed to increasing its efforts towards a better harnessing of science and technology for the necessary transition to a sustainable path of human development. To this end, our community also seeks to enhance further its cooperation with all stakeholders, including Governments, local authorities, business and industry, farmers and all other major groups.**