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THE ROLE OF SCIENCE IN SUSTAINABLE DEVELOPMENT

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Global change is creating enormous challenges for humanity. The world's population is expected to grow from nearly 6 billion today to 8.5 billion by the year 2025. Global energy requirements will continue to increase. The newly industrialized countries of Asia and Latin America are experiencing very rapid economic growth that is bringing modern society's environmental problems, including air and water pollution and waste problems, to wider areas of the globe.

The ecological problems caused by human economic activity are worsening and taking on global dimensions. Climate change, ozone-layer depletion, and loss of forest cover are important examples. At the same time, social conditions continue to worsen in many developing countries. It is estimated that more than 1 billion people now live in poverty without sufficient food, adequate educational opportunities, or any possibility of political participation. Although financial and economic markets are becoming more and more interconnected and we like to think in terms of a "global village," our efforts to enshrine environmental protection and development as the common task and responsibility of all countries have just begun to make headway.

The key aim for the 21st century is "sustainable development," which the international community embraced at the 1992 UN Conference on Environment and Development. Sustainable development seeks to reconcile environmental protection and development; it means nothing more than using resources no faster than they can regenerate themselves, and releasing pollutants to no greater extent than natural resources can assimilate them.

If we are to move toward sustainable development, the industrialized countries will have to accept special responsibility—not only because of their past ecological sins, but also because of their present technological know-how and financial resources. Yet, one must keep in mind that sustainable production and consumption involve not merely technical progress, but also cultural patterns of individual behavior and values.

The German government has chosen the socio-ecological market economy (okologische und soziale Markwirtschaft) as the framework for shaping production and consumption in keeping with sustainable development, while at the same time encouraging innovation in industry and society. The key is to sever the traditional link between economic growth and the consumption of resources, which increasingly threatens the natural basis for life and the preservation of natural and landscape diversity.

There are several possible ways to achieve environmental compatibility in lifestyles and economies. Technical and scientific innovations provide excellent prospects for environmental protection. As we approach the end of the 20th century, industrial society is becoming a knowledge-based society. It is vital that we use our growing knowledge and capabilities responsibly, and that we use them in the interest of environmentally appropriate development. Science must play an important role in the pursuit of sustainable development, especially in the following categories:

Energy use. The key technologies of sustainable development include new energy and propulsion technologies that will help reduce emissions of climate-damaging greenhouse gases. Simply to stabilize atmospheric greenhouse-gas concentrations at twice their preindustrial levels, we will have to reduce current global greenhouse emissions by over 50%. Germany has set a goal of reducing CO_2 emissions by 25% by the year 2005, with respect to the 1990 level. Achieving this goal involves focusing on improved thermal insulation in buildings, on the use of heat/power cogeneration, and on efficient support for the use of renewable energies. Currently the most progress is found in the area of wind energy; in the medium term, the use of solar energy, with photovoltaic technology, will continue to grow in significance. An honest consideration of our options indicates that we cannot afford to discontinue peaceful use of nuclear energy.

Closure of substance cycles. Modern microsystems and control technologies are also providing new opportunities to design environmentally friendly production processes. While filter and wastewater-treatment technologies have considerably enhanced air and water quality in recent years, they are never more than the second-best solution, and have been surpassed by integrated environmental technology, that is, technology that optimizes the use of materials and energy. This

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involves material-efficient, energy-efficient production processes as well as the manufacture of environmentally compatible products, especially those that generate little waste. We have created the necessary framework for this with the Closed Substance Cycle and Waste Management Act, which came into force in 1996. Instruments such as eco-audits, which help identify the saving potentials from environmental protection investments, also promote development of such "clean" technologies.

Environmentally compatible mobility. Environmentally compatible traffic concepts are a particularly important category for innovation. In Germany, the automobile industry now accounts for about 20% of all industrial investments in research and development. "Three-liter cars" (that is, cars consuming less than 3 liters of gasoline per 100 km), natural-gas engines, electric cars, hydrogen engines, and fuel-cell engines can all play a role in eliminating motor-vehicle emissions. Telematics can enable traffic to move more efficiently. Information and communication technologies can eliminate the need for physical transports in some areas, and computerized logistics in goods transports can reduce total transport distances.

Biotechnology. Biotechnology is expected to bring important advances in medical diagnosis and therapy, in solving food problems, in energy saving, in environmentally compatible industrial and agricultural production, and in specially targeted environmental protection projects. Genetically altered microorganisms can break down a wide range of pollutants by being used, for example, in bio-filters and wastewater-treatment facilities, and in the clean-up of polluted sites. Genetically modified organisms can also alleviate environmental burdens by reducing the need for pesticides, fertilizers, and medications.

Sustainability, as a strategic aim, involves optimizing the interactions between nature, society, and the economy, in accordance with ecological criteria. Political leaders and scientists alike face the challenge of recognizing interrelationships and interactions between ecological, economic, and social factors and taking account of these factors when seeking solution strategies. To meet this challenge, decision-makers require interdisciplinary approaches and strategies that cut across political lines. Environmental discussions must become more objective, and this includes, especially, debates about the risks of new technologies, which are often ideologically charged. In light of the complex issues involved in sustainable development, we need clearer standards for orienting and assessing our environmental policies. In this context I consider the current work on indicator models as a means to assess and monitor the success of sustainability strategies, to be of great significance.

Sustainable development can succeed only if all areas of the political sector, of society, and of science accept the concept and work together to implement it. A common basic understanding of environmental ethics is needed to ensure that protection of the natural foundation of life becomes a major consideration in all political and individual action. A dialogue among representatives of all sectors of society is needed if appropriate environmental policies are to be devised and implemented.

In the long term, "progress" works against us if it continues to be detrimental to nature. This realization will find increasing acceptance. Environmental protection will play a central role in the 21st century and will be a major challenge for politicians and scientists alike.

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