KEEPING OPTIONS OPEN
ENERGY, TECHNOLOGY & SUSTAINABLE DEVELOPMENT

BY HANS-HOLGER ROGNER, LUCILLE LANGLOIS
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Central to sustainable development is improvement in socio-economic well-being — especially for the world's poor. This is given overriding priority in the original 1987 definition of sustainable development devised for the Brundtland Report to the United Nations. That report set the stage for Agenda 21, the document adopted in 1992 at the United Nations Conference on Environment and Development, or Earth Summit.

The Brundtland Report stated: *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:*

- *the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs"*.

These two concepts still guide the debate on how to achieve sustainable development. Many international governmental and non-governmental organizations such as the Commission on Sustainable Development (CSD) and the World Energy Council (WEC) echo this same emphasis: They acknowledge the important fact that the world's poor two billion people -- one-third of the world's population mostly living in developing countries -- lack access to affordable modern energy and transportation services. And they recognize that, if these two billion people are to be provided with access to such basic services in a way that does not destroy the carrying capacity of the natural environment, unprecedented changes in technology, lifestyles, and social organization will be needed.

In April 2001 the Ninth Session of the Commission on Sustainable Development (CSD-9) – the first CSD session to focus on energy – specifically noted that "energy is central to achieving the goals of sustainable development".

HOW MUCH ENERGY IS NEEDED?

How much might future global energy use have to grow in plausible sustainable development scenarios? The World Energy Assessment (WEA) -- prepared by the United Nations Development Programme, United Nations Department of Economic and Social Affairs, and WEC as an input to CSD-9 - cites scenarios developed by the WEC and International Institute of Applied Systems Analysis (IIASA). These scenarios suggest 60% to 180% growth in energy use by 2050 consistent with sustainability. Even at the low end of these ranges, in scenarios where *per capita* and absolute energy use decline in countries of the Organization for Economic Cooperation and Development (OECD), global energy use climbs substantially. By any measure, economic development – the most crucial prerequisite for sustainable development -- will require a lot more energy than we use today, particularly for the poor.

More Efficient Energy Use. Fortunately, thanks to technology, the expansion of energy supply and use in the future can be much cleaner and more efficient than it has been in the past. While upstream advances in the geosciences, exploration,

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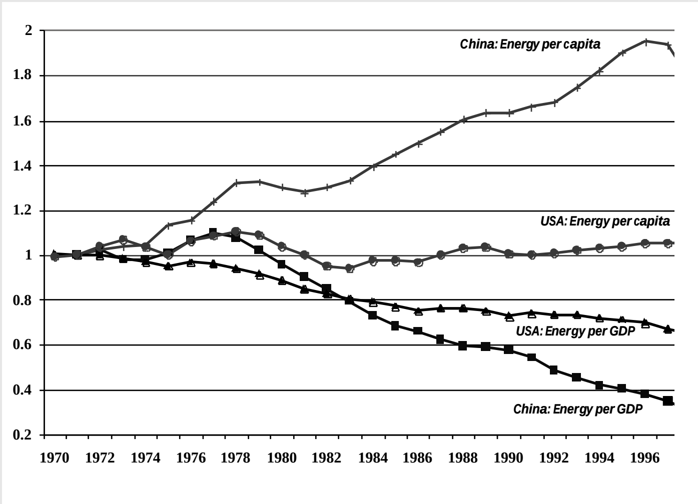
ENERGY INTENSITIES AND PER CAPITA ENERGY USE
IN CHINA AND THE USA, 1971-1998



Sources: Adapted from International Energy Agency, Energy Balances of OECD Countries; and the World Bank's World Development Indicators (2001).

drilling and upgrade technologies (of lower quality energy resources) continuously expand the resource base, innovation and technology change improve the performance of energy conversion and end-use technologies and infrastructures.

Recent improvements have been tracked in the United States and China in energy intensity, i.e., the amount of energy required to produce a unit of gross domestic product (GDP). *(See graph, this page.)* Energy intensity is an aggregate indicator for overall efficiency and effectiveness of energy production and use as well as for structural shifts away from more energy-intensive industrial processes and subsectors to less energy-intensive ones.

Since 1970, US energy intensity has dropped 32%, an improvement of 1.4% per year. The figure indicates improvements were more rapid during the oil shocks of the 1970s and early 1980s than more recently, but even long-term US data indicate an average improvement of about 1% per year.

Current energy intensities in Western Europe and Japan are even lower than in the US, and there is no reason to expect the historical trends toward ever lower energy intensities will come to a sudden stop or reverse. The IIASA-WEC scenarios cited in the WEA study assume long-term global average improvements between 1% and 1.4% per year.

Opportunities in Developing Countries. Opportunities for improvement are even greater in developing countries than in industrialized countries, as data for China indicate. Here the intensities have improved at a staggering rate of 4% annually. There are several reasons for this.

First, the overall energy intensities in developing countries, taking into account both commercial and non-commercial energy use (e.g., agricultural residues or fuel wood), decrease with development just as in industrialized countries. Statistics limited to commercial energy use can confuse the issue, as they generally show an initial increase in energy intensity with development. This is because a switch from cooking on non-commercial wood fires, for example, to commercial electricity or liquified petroleum gas (LPG), shifts some energy consumption from the non-commercial category to the commercial category. Other things being equal, the commercial energy intensity goes up. But in reality, because cooking with electricity or LPG is more efficient than open fires, the overall energy intensity would go down.

Even larger effects may materialize as more efficient industrial production processes replace traditional ones. Because overall energy intensities in developing countries, and in countries with economies in transition, are generally greater than in OECD countries, so too are the opportunities for improvement.

Second, opportunities for improvement are better simply because better technologies are available to developing countries today than were available to present-day industrialized countries when they were at comparable stages of development.

Developing countries do not have to follow, and have not followed, the same path taken by their predecessors. Data on commercial energy intensities show that countries that develop later have lower commercial energy intensity peaks, and reach those peaks at an earlier stage of development. The advance of technology creates opportunities for technological, and institutional, leap-frogging. Data show that countries and investors in these countries take advantage of at least some of those opportunities. More can undoubtedly be done.

As noted earlier, projected global energy needs still go up substantially – even with continuing energy intensity improvements and even in scenarios considered to be consistent with sustainable development. That is due to the substantial development needs of huge numbers of people who are already poor, and who will be born poor in coming years. But the good news is that, thanks to technology, the required increase in energy use will be relatively smaller, cheaper and more efficient than it would have been a century – or half a century – ago.

However, "much of the world's energy…is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially," states Chapter 9.9 of Agenda 21.

HOW MUCH POLLUTION?

Other things being equal, big increases in energy use mean big increases in pollution. Fortunately, in the energy system as elsewhere, other things are never equal. One reason is the well-observed fact that the better off an individual becomes, the cleaner is his or her mix of energy sources.

This is not surprising. With more disposable income and less need to concentrate on subsistence, an individual can begin to pay to satisfy other needs and desires including a cleaner and healthier environment. This is still true both in the industrialized countries and in the developing countries that will account for all the big increases in future energy use. A study of energy use in Brazil, for example, showed that highly polluting firewood accounts for almost all energy consumption by the poor. Better off individuals, on the other hand, shift steadily away from firewood to cleaner fuels – electricity, gas and liquid fuels.

Another reason is that development shifts both the nature and the distribution of environmental pollution, for example from local air pollution to regional acidification to higher atmospheric greenhouse gas concentrations. Development also includes industrialization and urbanization, and these tend to increase pollution at least in and around cities.

Studies indicate that very poor countries tend to have high levels of household pollution, from cooking on open wood fires, for example. Household pollution levels decrease with development, but industrialization and urbanization cause pollution in cities to start to rise (e.g., from electricity generation and transportation). Eventually, at later stages of development, urban air pollution peaks and starts to decline as environmental protection efforts become affordable.

In the century ahead of us, these peaks in urban air pollution and regional acidification will likely come sooner and be lower for today's developing countries than the peaks experienced by today's industrialized countries with yesterday's technologies.

Today's developing countries quite simply have opportunities that were not available even 20 years ago, and at a much lower cost than even 10 years ago. They were certainly not available to one of the most industrialized countries of all during the killer London smog of 1953. Many of today's developing countries are already making good use of sulphur dioxide abatement opportunities. *(See graphs, page 38.)*

Finally, pollution reduction has a positive feedback effect on economic development (by reducing illness and health care costs or damage to infrastructures). Reducing pollution at earlier stages of development means that the associated positive economic feedback can therefore occur sooner, speeding development.

GLOBAL WARMING

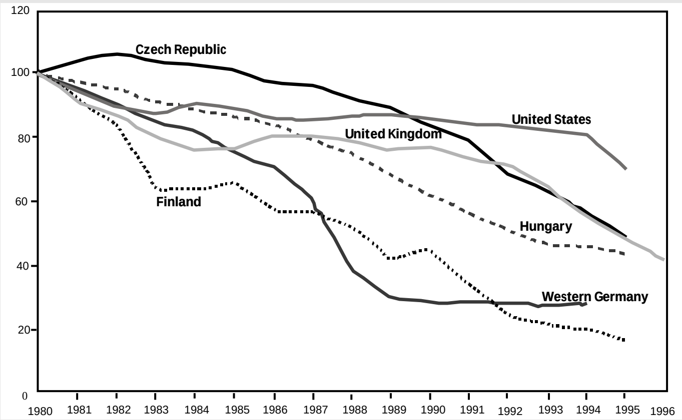
Studies have shown a constant increase in greenhouse gas (GHG) emissions with increasing wealth, even as levels of air pollution decline.

We seem to be simply trading one form of pollution for another, with potentially wide-reaching consequences. Yet the trends indicate the potential impact of innovation

EMISSIONS OF SULPHUR DIOXIDE

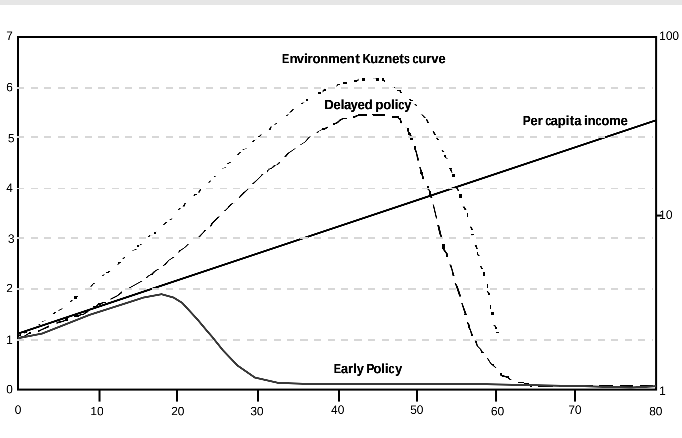
The top graph shows general trends in SO_2 emissions in the United States and selected European countries. The second graph shows projected SO_2 emissions in Asia. In that graph, the dotted line traces emissions growth if Asia begins emission reductions when its *per capita* income reaches the level at which today's industrialized countries (those in the top graph) started to reduce their SO_2 emissions. The solid line labeled "Early Policy" shows much lower emissions if Asia were to take advantage today of state-of-the-art technologies not available when the top graph's industrialized countries started reducing their emissions. Many of today's developing countries are already making good use of such abatement opportunities.

TRENDS IN SO_2 EMISSIONS
IN SELECTED INDUSTRIALIZED COUNTRIES



Source: World Energy Assessment: Energy and the Challenge of Sustainability, UNDP, UNDESA, and WEC, New York (2000).

SIMULATED EFFECTS ON SO_2 EMISSIONS IN ASIA OF EARLY AND LATE ENVIRONMENTAL POLICIES



Source: Summers, R., and A. Heston. 1991. "The Penn World Table (Mark 5): An Expanded Data Set of International Comparisons, 1950–1988". Quarterly Journal of Economics 56: 327–69.

and technological progress on pollution control. As one form of pollution becomes unacceptable, emissions control approaches are devised. This does not prevent new forms of pollution from developing, nor old forms of pollution from becoming unacceptable in their turn, but it does indicate the continued possibility of environmental improvement in the context of increased energy use.

The 21st century will have many more alternatives available for energy service supplies than were available in 20th century. *(See table.)* Recent cost improvements are seen for several electricity generating technologies, and it is reasonable to expect additional costs improvements in the future. The history of technology development to date provides a strong basis for optimism in this respect.

Extrapolating today's pollution trends based on a continuation of today's prices, consumption patterns, and technologies, without taking sufficient account of technology learning, would provide a false impression of environmental conditions in the 21st century. And it would constitute a false basis for making future decisions about energy technology and infrastructure investment.

WHICH RESOURCES AND WHICH TECHNOLOGIES?

Natural resources are essential for sustainable development, while sustainable development itself is about avoiding unduly the loss of environmental and resource assets available to future generations.

COMPARISON OF ELECTRICITY GENERATING COST ESTIMATES FOR NON-FOSSIL AND LOW-CARBON EMITTING TECHNOLOGIES

Technology	Current average cost (US cents per kWh)	Future average cost (US cents per kWh)	Comments
Wind	5 - 13	3 - 8 3 – 8	Costs declined six-fold from 1985 to 2000.Costs are for good to excellent wind sites.
Biomass	5 – 15		25 MW steam cycle plants in Brazil declined by a factor of three since 1980s.
Photovoltaic systems Insolation, 2500 kWh/m^2 Insolation, 1500 kWh/m^2 Insolation, 1000 kWh/m^2	20 - 40 35 - 70 50 - 100		Based on costs of $5-10/peak watt. Costs have declined 50-fold since 1975, 5-fold since 1980, 2-fold since 1990. Off-grid, stand-alone applications add another $8-40/peak watt in storage costs.
Thermal solar	10 - 18		Parabolic troughs in high insolation areas only. Latest vintage of around 1990.
Geothermal	3 – 10		Costs vary greatly with location.
Gas-fired combined cycle plant $2/GJ fuel cost $5/GJ fuel cost	3 ± 20% 5 ± 10%	3 ±15% 4 - 5 5 ± 8% 7 - 8	No carbon abatement. Includes carbon removal and disposal. No carbon abatement. Includes carbon removal and disposal.
Integrated gasif. comb. cycle $1/GJ fuel cost $3/GJ fuel cost	4 - 5 5 - 8	3 - 5 5 - 7 5 – 7 7 - 9	No carbon abatement. Includes carbon removal and disposal. No carbon abatement. Includes carbon removal and disposal.
Nuclear power	4 - 8	2 - 5	Future cost range covers evolutionary design improvements and new innovative designs.
Grid supplies Off-peak Peak Average, urban areas Average, rural areas	2 - 3 15 - 25 8 - 10 15 to > 70		Depends on peak. Rural areas in developing countries.

Note: All figures are rounded and based on 10% discount rates.

Sources: World Energy Assessment: Energy and the Challenge of Sustainability. United Nations Development Programme (UNPD), United Nations Department of Economic and Social Affairs (UNDESA) and World Energy Council (WEC), New York, 2000. IPCC, 2001: Climate Change 2001: Mitigation. Third Assessment Report of the United Nations Intergovernmental Panel on Climate Change, Working Group III, Chapter 3. Cambridge University Press, Cambridge, UK.

However, resources are recognized as valuable assets only when they are in demand. This also implies the availability or development of technologies to exploit them and use them to produce socio-economically valuable goods and services. Resources therefore are dynamically changing as a result of desired lifestyles and available technology.

The concept known as "strong sustainability" recognizes that some environmental losses may be permanent, that fossil energy resources are finite or that the potential impacts of climate change may be irreversible. In its most stringent forms, it can imply a desire to halt both technological change and evolution. It suggests there should be limits on our ability to use or degrade natural and environmental resources, at the peril of undermining socio-economic development. But this ignores the dynamically changing nature of resources and lifestyles, which may well obviate over time the need or desire for some of the limits suggested by strong sustainability. Man-made assets may substitute for depleted natural resources.

Man-made assets, for example, include the world's stocks of technological and human capital, including the inexhaustible capability of human ingenuity to innovate, as well as cultivate, agricultural lands. The depletion of finite fossil resources can thus be offset by an expansion of overall man-made assets by way of developing non-exhaustible energy infrastructures as well as a larger knowledge base.

Similarly, land-use change such as deforestation for agricultural purposes may be offset by improved agricultural techniques and by reforestation. This concept of allowing substitution within and between classes of assets is known as "weak sustainability".

Many environmental pressure groups hold the view that efficiency improvements, harvesting renewable energy sources, and the dematerialization of the production and consumption process are the only viable substitutes for fossil fuel use. Where weak sustainability cannot be accomplished by these measures, they postulate lifestyle changes. Although acknowledged as a virtually zero-emission technology, nuclear power for them is not considered a sustainable technology. But this highly publicized view, which has prevailed in the context of international climate change discussions under the aegis of the United Nations Framework Convention on Climate Change (UNFCC) and Kyoto Protocol debates, is not the only viable view.

The Role of Nuclear Power. The Ninth Session of the Commission for Sustainable Development (CSD-9) in April 2001 provided an excellent opportunity for a full debate on the role of nuclear power in sustainable development, as part of its over-all discussion of energy, transport and the atmospheric change issues.

On nuclear power, there were two important conclusions. First, countries agreed to disagree on the role of nuclear power in sustainable development. CSD-9's final text recognizes that some countries view nuclear power as incompatible with sustainable development while others believe it is an important contributor to sustainable development. For each case, the reasoning is presented in the text. The second conclusion, on which there was consensus agreement, is that "the choice of nuclear energy rests with countries".

The arguments in favor of an important role for nuclear power role in sustainable development are that it broadens the resource base by putting uranium to productive use; it reduces harmful emissions; it expands electricity supplies and it increases the world's stock of technological and human capital. It is ahead of other energy technologies in internalizing all externalities, from safety to waste disposal to decommissioning – the costs of all of these are already included in the price of nuclear electricity in most countries.

The complete nuclear power chain, from resource extraction to waste disposal including reactor and facility construction, emits only two to six grams of carbon per kilowatt-hour -- about the same as wind and solar power and two orders of magnitude below coal, oil, and even natural gas. In addition, nuclear power avoids the emission of many other air pollutants, such as SO_2, NOx and particulates.

POLICY CONSIDERATIONS

There are grounds for optimism that we can make good progress in accomplishing the dual goals of sustainable development – the overriding priority of economic development for the world's poor, and the responsible stewardship of the earth's natural and environmental resources.

But that is not the direction in which we are currently headed. All business-as-usual scenarios in studies such as those referenced here, point to higher pollution in the future, greater resource consumption and limited progress for the world's poor. Absent pro-active policy measures, current trends might leave us closer to today's problems and further from tomorrow's promise of sustainable development.

There can be no perfect formula to guarantee a successful shift to a more sustainable trajectory. But we can spell out two important principles and suggest some related policy considerations.

First we reiterate that priority economic development for the poor will require substantial growth in energy use. Second, technological progress – in energy production, energy consumption and pollution control – will be essential for reducing energy intensities, reducing pollution and expanding the energy resource base in tandem with increasing energy use.

Pro-Technology Policies. Consider first the characteristics of policies to promote technological progress. Such policies should encourage technological innovation and diffusion. In the energy sphere they might emphasize reduced energy intensities, reduced pollution and GHG emissions, and efficient use of both new and existing resources guided by the "weak sustainability" concept.

Liberalized energy markets, including market based energy prices, have many advantages in fostering such innovation and diffusion. Already, liberalization and competition in various markets around the world have led to improved efficiencies, which often also imply lower costs. However, the liberalization process also has its pitfalls, and these require continued and careful policy attention from governments. Some relevant economic policy considerations include the following:

The first pitfall, as demonstrated in California, USA, is the danger of bad liberalization policies. Politically attractive but economically unwise constraints, like capped electricity retail prices and limits on long-term contracts, can bring failure. A public once burned is twice shy, so even if policymakers learn from their mistakes, they are likely to have greater difficulty in persuading voters to allow them a second try at liberalization.

As with much R&D, the private returns of energy R&D may be lower than the social returns. Because energy inventors cannot turn all the social benefits of their inventions into personal profits, private R&D investments are likely to be less than socially optimal. Thus governments have a clear role to play in funding additional R&D beyond what the private sector provides.

There are few incentives to reduce energy emissions that cost the emitter nothing. Carbon dioxide is the obvious example. CO_2 emissions in most countries are unregulated and free. There are thus no economic incentives to develop technologies and management innovations to reduce such emissions. The solution is policies that turn carbon emission reductions into something profitable. Different policies (taxes, subsidies, permits, etc.) may be appropriate in different countries, and at the international level there is always room to improve on the emission trading schemes under the Kyoto Protocol.

But whatever mechanisms different people prefer, what is certain is that without policies to make the avoidance of carbon emission directly profitable, the economic incentives to reduce emissions are nil. Note that policies penalizing energy use are misdirected. Pollution threatening human health and environmental integrity is undesirable and should be penalized. Energy use by itself is good and necessary for improved standards of living. Even in industrialized countries, energy taxes hurt the poor without creating any incentives to reduce the thing that matters – pollution, rather than energy use.

Liberalized markets frown on government subsidies, but subsidies have a legitimate role in overcoming barriers that new technologies face when initially competing with entrenched old technologies. Some will argue that sustainable development requires the elimination of all subsidies. But we believe there is a role for discerning subsidies with clear sunset clauses that help new technologies move from the laboratory into the energy market where they can thrive (or not) based on their own merits.

Pro-Energy for the Poor Policies. Liberalizing energy markets, internalizing negative externalities like pollution damage costs, and generally "getting the prices right" are all important, but in the case of the very poor, they are not enough. For those unable to pay any price, "getting the price right" is not a solution. If they are to enjoy economic development and become active consumers in liberalized energy markets, the poor will need special help throughout the world such as education and health care, innovative small business finance schemes, technology transfer, andthe establishment of stable institutions.

Governments' social and infrastructure policy decisions broadly influence technological developments that might facilitate economic development and help steer it in a sustainable direction. For example, rural extensions of electricity grids or natural gas pipeline networks often cannot be justified economically in liberalized markets. In these cases, new off-grid renewable technologies may offer the best promise of delivering modern energy services to the rural poor. For customers in developing rural energy markets, projects along these lines are an introduction to appropriate technologies to serve their needs. For the new technologies, these markets are niches in which to gain experience and make the adjustments necessary for long-term cost reductions and diffusion. And from the global perspective they promote the sort of technological leap-frogging that will allow future economic and energy growth to be more efficient, more rapid and cleaner than was the Industrial Revolution.

Three illustrative examples are:

- A rural project in India in which seed money from US Agency for International Development facilitated the installation of solar photovoltaic (PV) systems to support income-generating basket weaving by local women.
- 200 PV and wind energy projects, among Mexico's 88,000 villages without electricity, to pump water for drinking, irrigation, and cattle ranching.
- Solar-powered radio communications for remote coffee growing cooperatives in the highlands of Chiapas, Mexico. Radio communications allow cooperative members to better time and coordinate harvesting, transport and other production activities in response to market conditions. Radios have also helped reduce losses and danger during forest fires.

Sustainable development must also be attentive to the needs of the urban poor and growing mega-cities. Urbanization creates large centralized power demands that mean a continuing and increasing need for large centralized power generation. Much of the energy growth projected for the 21st century will occur in cities, so advances in off-grid renewables suited to rural development must be complemented by improvements in centralized generation suited to mega-cities and large metropolitan areas such as nuclear power or clean fossil power generation (high conversion efficiency, pollution abatement and carbon sequestration).

Liberalized markets, appropriate taxation supplemented by policies limiting pollution and GHG emissions, can do much to promote new efficient and clean technologies for centralized generation. But more activist government policies may again be needed for the initial introduction of new technologies into competitive urban markets.

Proactive & Flexible Policy Mix. Policies, and policy outcomes, will differ among countries. Sustainable development will require a mix of energy technologies and their relative attractiveness in different countries will depend on differences in resources, economics, geography, demography and social preferences. Solar power is more attractive where it is sunny than where it is not, and wind power is more attractive where it is windy, just as coal, oil and hydropower are more attractive where they are plentiful. Service economies are less energy intensive than manufacturing economies, the transport sector consumes more where distances are large and resource-poor countries are more concerned about energy security and supply diversity than energy-rich countries.

Thus while all policies should promote development, particularly of the world's poor, and foster opportunities for more efficient and cleaner technologies, there is not a "one-size-fits-all" set of specific policies. Countries must be flexible to cater to their own circumstances.

The main thrust of sustainable development, as laid out in the Brundtland report quoted in the introduction of this article, is about maintaining valuable assets and keeping options open. As regards nuclear power, and in light of the conclusions of CSD-9, those countries able and willing to keep the nuclear option open have a particularly important role to play. Their challenge is to encourage innovation and adaptability in the nuclear sector so that nuclear technologies can contribute where relatively emission free energy will be needed most, including in major cities and in developing countries. Continuing improvements in nuclear power technologies will have much to offer to those who choose to use them. ❐