Energy and electricity supply and demand: Implications for the global environment

An overview from the Helsinki symposium

by T. Mueller

For several decades, electricity production and use have been a growing source of concern among individuals and groups monitoring the quality of the environment. Emissions from coal-fired power plants, impacts of hydroelectric development, and risks associated with nuclear energy use have been particular targets for political action, dating to the early days of the environmental movement in the late 1960s.

Environmental concerns sharpened in the late 1980s, as evidence of depletion of the Earth's protective ozone layer was combined with evidence of increasing concentrations of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere, which could lead to global warming.

Electricity services

Electricity as an energy delivery form is clean and safe. It has no environmental emissions at the point of end use, in contrast to solid, liquid, and gas fuels. From the point of view of end uses alone, substituting electricity for fossil or biomass fuels is almost always advantageous to the physical environment. For instance, electric railways are less polluting than diesel or coal-powered railways, and electric highway vehicles are less polluting than conventional automobiles or trucks. In this sense, electricity can be a key part of a strategy to improve the global environment, provided impacts on the supply side are controlled.

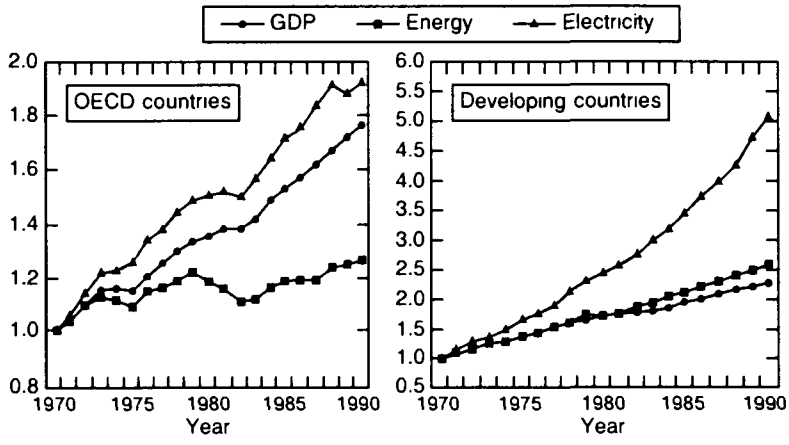
It is important to recognize that the fundamental desire is for services, not for electricity supplies themselves — for a quantity of lighting or space conditioning, not for a quantity of kilowatt-hours. Increasing the efficiency of electricity service supply can provide more services without more electricity production. However, this does not necessarily translate into a decrease in total demand for electricity. Consumers looking for more services may choose to invest the resulting economic savings in further service consumption rather than in maintaining the same level of services at a lower energy cost.

This means that a growing demand for electricity services is a fact of life in our world. In many lower income areas, there is a vast reservoir of unsatisfied demand on the part of people without lighting, refrigeration, sanitary water supplies, television, air conditioning, and other electricity services; and economic development will surely provide a driving force for demand. Furthermore, many organizational and business strategies, along with structural changes in national economies (e.g. towards a greater emphasis on services), are focused on the use of electricity.

Diverse needs and conditions

A fundamental problem is that any global effort to design appropriate energy futures is pervaded by uncertainty and diffused by an incredible diversity of national and sectorial conditions.

Mr Mueller is a staff member in the IAEA Division of Nuclear Power. This article is based upon a key issues paper (number 1) prepared by an international expert group under the chairmanship of K. Leydon of the Commission of the European Communities (CEC) for the Senior Expert Symposium on Electricity and the Environment in Helsinki in May 1991. The full report is being published by the IAEA in the symposium proceedings.



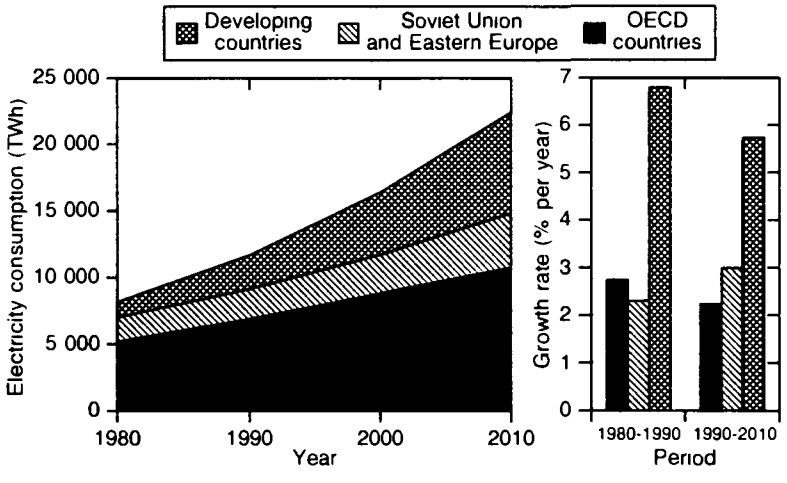
Note: All values normalized to 1.0 in 1970. OECD = Organization for Economic Co-operation and Development.

Growth trends for gross domestic product, energy, and electricity

To highlight the key uncertainties that affect the energy and electricity outlook, there are demographic, economic, social and political, and technological uncertainties about the future. Besides, there are geographical and sectorial diversities that complicate energy and electricity forecasting and, hence, policy making.

When long-term economic, political, and energy conditions cannot be forecast with confidence, when countries and regions differ from each other dramatically in their resources and needs and, furthermore, when the range of electricity system options is apparently so extensive, it is difficult to get decision makers to take firm decisions. The challenge is to incorporate these complexities into strategy development without allowing inaction to result.

Outlook for growth in electricity consumption



OECD = Organization for Economic Co-operation and Development.
Source Commission of the European Communities (CEC)

Illustrating the issues

To illustrate the issues which merit policy reflection, scenarios have been chosen for two time horizons and three groups of countries: the Organization for Economic Co-operation and Development (OECD), a grouping of market economy industrialized countries; Soviet Union and Eastern Europe (SUEE), traditionally quoted as centrally planned economies, although now in the early stages of major structural changes; and developing countries (DC). The first time period covers the period to 2010 and the second extends into the longer term future to 2050. These scenarios display possible evolutions of energy supply and demand, and point to those parameters that can influence the general outcome of energy futures. The outlook until 2010 draws on the work of the Commission of the European Communities (CEC) and the World Energy Council (WEC), while the longer term outlook reflects the work of a member of the expert group.

A base line scenario — "conventional wisdom scenario" — was formulated allowing for smooth changes of key parameters: steady economic growth, improvements in technologies (i.e. efficiency improvements), and improvements in the rational use of energy and electricity (scenario 1). Alternative scenarios were created for the CEC countries, reflecting prospering economies but without policy measures on environmental impacts and only based on market mechanisms (scenario 2); prospering economies and stringent environmental standards (scenario 3); and moderately growing economies and stringent environmental standards (scenario 4).

Efficiency improvement throughout electric power systems, from generation to end use, has a substantial potential and should be pursued vigorously. In general throughout the world, there is a large realistic potential to reduce emissions and other impacts through efficiency improvement measures that can be considered virtually a "no regret" option. However, the full potential for improvements in end use efficiencies would be possible only with significant policy interventions and would materialize only in the medium- and long-term time horizons.

Efficiency improvement alone, however, will not realize the full potential for impact reduction; supply side alternatives to fossil fuels should also be emphasized wherever they can contribute towards economic growth as well as towards environmental management. It is illusory to think that efficiency improvements will obviate the need for investments in electricity supply facilities. To realize the entire potential for impact reduction, every part of the electricity

World electricity consumption at final level: "Conventional wisdom" scenario

	1980	1990	2000	2010	Growth rate per year (%)	
	in terawatt-hours				1980-1990	1990-2010
OECD countries	5 242	6 852	8 720	10 615	2.7	2.2
USA	2 453	3 016	3 888	4 810	2.1	2.4
Canada	346	549	710	894	4.7	2.5
Japan	576	816	1 062	1 321	3.5	2.4
Europe 12	1 292	1 720	2 140	2 507	2.9	1.9
Other*	575	751	920	1 083	2.7	1.8
Soviet Union + Eastern Europe	1 777	2 274	3 029	4 142	2.3	3.0
USSR	1 294	1 681	2 280	3 118	2.7	3.1
Eastern Europe	483	593	749	1 024	2.1	2.8
Developing countries	1 302	2 507	4 634	7 590	6.8	5.7
China	301	602	1 158	1 818	7.2	5.7
Africa	215	324	545	905	4.1	5.3
South America	391	624	1 115	1 852	4.8	5.6
Middle East and Other	395	957	1 816	3 015	9.2	5.9
WORLD	8 321	11 633	16 383	22 347	3.4	3.3

* Australia, Austria, Finland, Iceland, New Zealand, Norway, Sweden, Switzerland, and Turkey.

Note: Electricity consumption at final level excludes energy sector's own consumption of electricity.

Source. Commission of the European Communities (CEC)

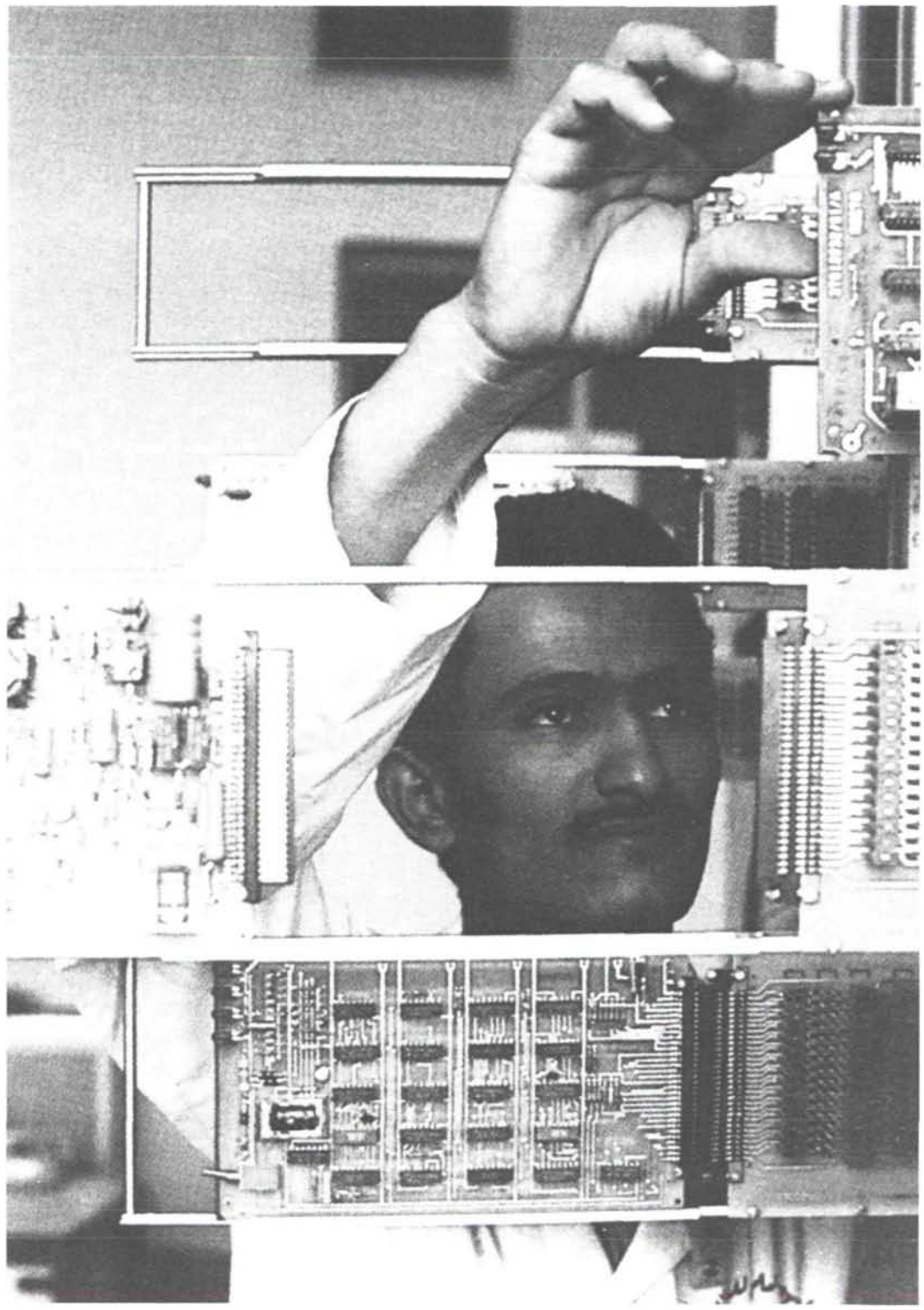
system must play a part. Besides efficiency improvements, other alternatives include supply options that *do not* emit greenhouse gases and those that emit *less* greenhouse gases.

Considering a certain potential in efficiency improvements, the base line or "conventional wisdom" scenario made plain that world electricity consumption would nearly double in the coming decades up to 2010. *(See graph and table.)* The regional distribution shows that countries of the OECD region would demand an additional 55% above their 1990 level of electricity consumption, while the Soviet Union and Eastern Europe would require another 80% more electricity, and the developing countries would even demand another 200% above their 1990 level of electricity consumption. The prospering industrialized economy without environmental regulation (scenario 2) would demand 58% more electricity above the 1990 value to fuel its economy. Moderate growth and stringent environmental conditions (scenario 4) show the lowest additional demand of only 13% above the respective 1990 figure. For all scenarios, an increase in CO_2 emissions by the power sector is expected, relative to the 1990 levels. In summary, the expert group concluded that by 2010 the Toronto targets could not be achieved, even with stringent measures in industrialized countries. *(See table.)*

Carbon dioxide emissions in the European Community

1000 tonnes	1986	1990		2000	2010
TOTAL	2560.5	2764.9	Scenario 1	3025.8	3143.2
			Scenario 2	3405.4	2481.7
			Scenario 3	3120.8	2426.3
			Scenario 4	2701.5	2098.4
Power sector	786.4	857.5	Scenario 1	1046.4	1190.5
			Scenario 2	1218.3	1334.2
			Scenario 3	1099.9	912.3
			Scenario 4	961.8	880.5
Energy sector	93.3	103.3	Scenario 1	110.4	105.7
			Scenario 2	115.7	105.1
			Scenario 3	101.9	77.8
			Scenario 4	110.2	96.1
Final sector	1680.7	1904.2	Scenario 1	1869.0	1847.0
			Scenario 2	2071.4	2042.5
			Scenario 3	1919.1	1436.2
			Scenario 4	1629.5	1121.7

Source Commission of the European Communities (CEC)



Electricity demands will grow in years ahead to meet social and economic needs. Here, a technician in Yemen works on a communications network. (Credit: UNDP)

Looking ahead

Energy developments over the next two decades, based on current policies, will affect energy needs and environmental impacts much further into the future. It is therefore important to look beyond 2010. Electricity consumption per capita by that year will have increased three to five times depending on different assumptions, primarily related to energy efficiency; however, it would still be significantly lower than that of industrialized countries today. The difficulty in

forecasting possible allocations from different energy sources for electricity generation up to the year 2050 is that the richer industrial group of countries could outbid most of the developing countries for convenient or preferred fuels. Because of the large gas resources in the Soviet Union, and the ability of OECD countries to outbid others for gas imports, natural gas would probably be used disproportionately by the industrial group.

It could be expected that the overall energy balance would probably lead to severe energy stresses for developing countries, unless the industrialized countries adopt a substantial programme for the development of nuclear power. Policy decisions taken during the next decade on the development of energy technologies will determine which options can make significant contributions towards electricity supply during the next half century. It is not possible to foresee the full range of needs requiring energy and electricity in the future, nor the full range of options for meeting them. Solutions to meet these needs may be frustrated, or aided, by changed perceptions, new technologies, or a changing climate. It would seem prudent to seek flexibility by retaining the widest possible variety of options in order to be able to match future energy needs and changing perceptions with acceptable supplies. A decision to close off any option means that its potential contribution must be met by other options.

Potentials and limits for change

Any realistic consideration of alternative electricity futures revolves around the potentials for change and the limits to change. One of the beneficial effects of the rising concern about environmental protection may be to stimulate more attention to the potential of options that are currently underutilized. No possibility should be rejected out of hand.

Realizing the complexities in forecasting, each region (and country) has to face different roles and realities. Appropriate and effective strategies for reducing environmental impact will be specific to each region, country, and location. Because countries and regions differ so markedly in their energy and economic conditions, their institutional settings and their priorities and preferences, detailed strategies for impact reduction cannot be introduced very usefully at a global level. They will emerge from local decision making processes responding in part to global concerns and in part to resource allocations.

OECD countries have a special responsibility for pioneering alternative strategies. Their expertise, experience, and financial resources place them in a particularly favourable position to pursue impact-reducing alternatives, thereby minimizing uncertainties in their costs and benefits.

The Soviet Union and Eastern Europe face major uncertainties about paths for economic growth and institutional change, but they have a substantial potential to contribute towards impact reduction through energy efficiency improvement if financial and other resources are available. This region is unique in the near-term uncertainties it faces; these will have a direct effect on the electricity requirements and strategies. Its potential for energy efficiency improvement, however, represents one of the most significant opportunities for impact reduction worldwide, provided capital and other resources can be invested to realize this potential.

Developing countries, in particular those in the lower income group, are fundamentally different from higher income countries in their needs and options. Although they can indeed contribute to global impact reduction, their first priority will be economic and social development. If the gap between higher and lower income countries is to be reduced, developing countries will need not only substantially more electricity services in the years to come, but also more efficient electricity supply facilities than at present. Meanwhile, they face severe constraints on capital supply and institutional capabilities, which affect both electric power sector strategies and the more general development process. Strategies related to electricity supply and demand will have to be developed and pursued as an integral part of this process.

In most developing countries, carbon emissions and other environmental impacts will increase as economic and social development progresses. This means that other countries and regions will have to adopt more stringent targets if global goals are to be met.

Effective international co-operation will be needed to realize the potentials for reducing environmental impacts. Just as many environmental concerns have become globalized over the past several decades, so have many elements of the impact reduction strategies. The pace and ultimate magnitude of impact reduction will depend heavily on the effectiveness of international partnerships — treated not as North to South assistance but as true international collaboration — to facilitate adaptation and transfer of technologies, access to financial resources, and co-operation in institutional development.