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Efficient use of energy and materials: progress and policies

Report of the Secretary-General

SUMMARY

There is growing awareness of the serious problems associated with the provision of sufficient energy to meet human needs and to fuel economic growth worldwide. This has pointed to the need for energy and material efficiency, which would reduce air, water and thermal pollution, and the production of waste. Increasing energy and material efficiency would also provide the benefits of increased employment, improved balance of imports and exports, increased security of energy supplies and the use of an environmentally advantageous energy supply.

Significant potential exists for saving energy through efficient use of improvements in the use of energy and materials. Technologies do not now - nor will they in the foreseeable future - be the limiting factors with regard to continuing energy efficiency improvements.

There are serious barriers to energy efficiency improvements, including unwillingness to invest, lack of available and accessible information, economic disincentives and organizational barriers. A wide range of policy instruments and innovative approaches have been tried in some countries in order to achieve the desired improvements in energy efficiency, and they hold promise for other countries. They include regulation and guidelines, economic instruments and incentives, voluntary agreements and actions, information, education and training, and research, development and demonstration. One area

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that requires particular attention is that of improved international cooperation in the development of policy instruments and technologies to meet the need of developing countries. Material efficiency has not received the attention that it deserves. Consequently, there is a dearth of data on the qualities and quantities of final consumption, thus making it difficult to formulate policies. Available data, however, suggest that there is a large potential for improved use of many materials in industrialized countries.

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INTRODUCTION

1. The Committee on New and Renewable Sources of Energy and on Energy for Development, at its first session (7-18 February 1994), requested the Secretary-General to prepare a report on efficient use of energy and materials. 1/ The present report was prepared in response to the Committee's request. It is a summary of an extensive study commissioned by the Secretariat. 2/

I. BACKGROUND

2. There is growing awareness of the serious problems associated with the provision of sufficient energy to meet human needs and to fuel economic growth worldwide. Current energy production and usage patterns rely heavily on the combustion of fossil fuels, a key factor in the unprecedented increase in carbon dioxide (CO_2) concentrations in the earth's atmosphere which contribute to global warming. Documents like Agenda 21 3/ and the United Nations Framework Convention on Climate Change 4/ underline the international recognition of the problem of climate change, in particular, and other environmental problems associated with the use of energy. Key environmental problems range from the global (possible climate change), regional (acidification of soil and water) and local (smog, urban air quality, solid wastes, effluents and thermal pollution) to the personal (indoor air pollution). In many areas of the world, particularly in the developing country mega-cities, the health and environmental effects of energy use are even more extreme, since technologies and policies for abating pollution and producing cleaner energy are not always available or implemented. Given current patterns of population and economic growth in the developing world, these health and environmental problems will continue to worsen.

3. In 1987, the World Commission on Environment and Development (WCED) concluded that the best route to sustainable development of the energy system is a low energy path, which means that countries should take the opportunities to produce the same levels of energy services with as little as half the primary energy currently consumed. The improvement of energy efficiency, or the more rational use of energy, is generally viewed as the most important option in the near term for reducing greenhouse gas emissions and reducing the negative impacts of the use of energy and/or fossil fuels. Energy efficiency is defined as decreasing the use of energy per unit activity without substantially affecting the level of the activity. The industrial sector consumes over 40 per cent of world energy. The bulk of this is for production of basic materials such as metals, chemicals, paper, and non-metallic minerals. The consumption of energy in this sector is also dependent on how efficiently basic materials are used in the creation of intermediate and final products (material efficiency). The use of less material to produce the same or better products helps to encourage the shift to a less energy-intensive economic or industrial structure. By analogy to energy efficiency improvement, material efficiency improvement is described as reducing the consumption of primary materials without substantially affecting the service or function, or - in a broader definition - without affecting the level of human activities qualitatively.

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4. Increasing energy and material efficiency offers other benefits as well - e.g., increased employment, improved balance of imports and exports, increased security of energy supply, and ease of adopting an environmentally advantageous energy supply (e.g., non-fossil and renewable energy sources). These benefits are especially of interest to energy-importing developing countries which shoulder a heavy burden supporting growing energy demand.

5. This study focuses on the potentials for improving energy and material efficiency and subsequent policy implications, with special attention given to developing countries.

II. IMPROVING ENERGY EFFICIENCY

A. Agriculture

6. Energy consumption in agriculture is divided into direct (on-farm) and indirect (e.g., fertilizers, pesticides) consumption. Direct consumption in agriculture comprised about 3 per cent of total world consumption in 1990; direct commercial energy consumption varies significantly, depending on agricultural practice and crop. In traditional agriculture, direct energy consumption can be solely non-commercial, including important sources such as animal and human labour. In this report the focus is on direct consumption of commercial energy.

7. Increasing degrees of mechanization led to higher energy inputs per unit of product. Direct energy consumption per hectare of arable land in world agriculture increased 3.3 per cent/year on average between 1980 and 1990, and per unit product, only 1.1 per cent/year. The difference can be explained by the increase in productivity per hectare. For developing countries these figures were 4.2 and 1.4 per cent/year, respectively.

8. Energy can be saved in tractor use by improved gears (estimated technical savings of 5-28 per cent), the maintenance and development of diesel engines (12-38 per cent), and reduced tillage (34-70 per cent). High energy savings (27-86 per cent) are possible through the proper design, retrofitting and maintenance of irrigation pumps. Energy savings in drying products, livestock production and horticulture, of up to 60 per cent in industrialized countries, are also feasible.

B. Industry

9. Although significant potential exists in all industries to improve energy efficiency, this analysis focuses on identifying the energy efficiency potential in five energy-intensive industries. These subsectors, which account for roughly 45 per cent of all industrial energy consumption, are iron and steel, chemicals, petroleum refining, pulp and paper, and cement. In 1992, industry accounted for 43 per cent (134 EJ) of global energy use. Between 1971 and 1992, industrial energy use grew at a rate of 1.9 per cent per year, slightly less than the growth of world energy demand of 2.3 per cent per year. This growth rate has slowed in recent years, falling to an annual average growth of

0.3 per cent between 1988 and 1992, primarily because of declines in industrial output in Eastern Europe and the former Soviet Union. Energy use in the industrial sector is dominated by countries that are members of the Organisation for Economic Cooperation and Development (OECD), which account for 45 per cent of world industrial energy use. Developing countries and Eastern Europe and the former Soviet Union use 32 per cent and 23 per cent of world industrial energy, respectively.

10. Much of the potential for improvement in technical energy efficiencies in industrial processes depends on how closely such processes have approached their thermodynamic limit. More efficient technologies exist for all industrial sectors.

11. A large number of energy-efficient technologies are available in the steel industry, including continuous casting, energy recovery and increased recycling. Large technical potentials for saving exist in most countries, ranging from 25 to 50 per cent, even for industrialized countries. A few bulk chemicals, (e.g., ammonia, ethylene) represent the bulk of energy use in this sub-sector. Potentials for energy savings in ammonia-making are estimated at 1-35 per cent in the European Community, 16-34 per cent in Eastern Europe and the former Soviet Union and of 20-30 per cent in South-East Asia. Saving estimates for ethylene production are only available for industrialized countries, where they are up to 12 per cent (including feedstocks).

12. Energy savings in petroleum refining are possible through improved process integration, cogeneration, energy recovery and improved catalysts. With state-of-the-art technology, the savings in industrialized countries are estimated to be 28 per cent, and higher for developing countries.

13. Paper is produced in many countries, after the process of wood pulping, from pulp and waste paper. Large potentials for savings exist in nearly all process stages (e.g., improved dewatering technologies, energy and waste heat recovery, and new pulping technologies). Savings of up to 40 per cent are estimated, with higher long-term potentials.

14. Energy savings in cement production are possible through increased use of additives (replacing the energy-intensive clinker), the use of dry process, and a large number of energy efficiency measures (reducing heat losses and use of waste as fuel). Compared to today's best practice, potential savings are estimated at 4-36 per cent for industrialized countries, 30-57 per cent for Eastern Europe and the former Soviet Union and 13-14 per cent for developing countries.

C. Buildings

15. The building sector includes a wide variety of specific energy applications such as cooking, space heating and cooling, lighting, food refrigeration and freezing, office equipment, and water heating. These applications are so-called end-use services, emphasizing the concept that what is important is not the energy consumed but the service delivered (cooked food, a warm space, or a lit office). The most important factors that drive energy consumption in buildings

are population, economic growth, the type of energy services demanded, and the energy efficiency of devices to provide those services. For example, building technologies such as energy-efficient lighting or air conditioning reduce the energy required to provide the same level of service in a building.

16. Approximately 36 per cent of world primary energy is consumed by commercial and residential buildings. Global buildings energy use was 104 EJ (commercial fuels only) in 1992, with buildings in industrialized countries consuming 58 per cent of total world buildings energy use, followed by those in developing countries (22 per cent) and Eastern Europe and the former Soviet Union (20 per cent). Energy use in residential buildings is about twice that of commercial buildings world wide. However, energy demand in commercial buildings has grown about 50 per cent more rapidly than demand in residential buildings for the past two decades. Between 1971 and 1992, average growth in energy use for buildings was 2.7 per cent per year, faster than the global average energy use. Average annual growth rates in energy consumption between 1971 and 1992 were slowest in the OECD (1.9 per cent) and much more rapid in Eastern Europe and the former Soviet Union (3.0 per cent) and developing countries (6.2 per cent). Average declines of 3.8 per cent per year were experienced between 1988 and 1992 in Eastern Europe and the former Soviet Union.

17. A wide variety of energy efficiency measures exist for all end uses, space conditioning (including changes in the building envelope), efficient appliances (in households and offices), improved lighting, motors in ventilation and energy management systems. Studies estimate technical potential savings to the year 2000 of 27-48 per cent in residential buildings for various industrialized countries. In commercial buildings estimates vary from 23-55 per cent in the industrialized countries, to up to 50-60 per cent in Eastern Europe and the former Soviet Union and developing countries.

D. Transport

18. From 1971 to 1992, global transport energy use grew at a rate faster than total world primary energy use and nearly doubled, jumping from 37 EJ to 63 EJ. The rate of growth in consumption for developing countries was rapid over the time period (4.7 per cent) while growth in industrialized countries and Eastern Europe and the former Soviet Union countries was more moderate (2.1 per cent and 2.0 per cent, respectively). Transport energy is divided between passenger and freight transport, both of which include several modes, such as automobile, truck, rail, ship, and air. Road transport, by passenger car and commercial trucks, accounts for the vast majority of total energy use (73 per cent), followed by air (12 per cent), rail (6 per cent), and other modes (9 per cent).

19. The industrialized countries dominate transport energy use, accounting for nearly two thirds (39 EJ) of total world energy consumption in 1992. Over the past two decades there has been a steady increase in the number of kilometres driven annually to transport both freight and passengers in industrialized countries. Most of the additional activity has occurred on roads. Energy use for transport in developing countries almost tripled between 1971 and 1992, growing from 9 EJ to 14 EJ.

20. Rapid economic growth has been accompanied by increased demand, resulting in a tremendous growth in road energy consumption, averaging 6 per cent annually. The share of energy use from road transport has increased to match industrialized countries levels (80 per cent), while the share of rail has declined to about 8 per cent of total energy use. Fuel intensities in developing countries are often much higher than in industrialized countries owing to poor roads and infrastructure and poor maintenance, partly due to the wide variety and age of cars used. Relative to the industrialized countries, transport energy use in Eastern Europe and the former Soviet Union has been low, growing at about 2.0 per cent annually, from nearly 6 EJ in 1971 to over 8 EJ in 1992. The more recent transformation of the economies in Eastern Europe and the former Soviet Union has resulted in increasing demand for road freight and a dramatic rise in the ownership and use of passenger vehicles.

21. Transport energy use can be reduced by improving the efficiency of transportation technology (e.g., improving automobile fuel economy), shifting to less energy-intensive transport modes (e.g., substitution from passenger cars to mass transit), improving the quality or changing the mix of fuels used in the transportation system, and improving the quality of the transportation infrastructure. For all modes of transport, substantial opportunities exist to improve transportation equipment. Measures that reduce energy use in conventional automobiles include improved engine technologies, improved transmission, and decreasing weight of the vehicle. Aircraft efficiency improvements centre around similar measures. The technical potentials for passenger cars are estimated at 15-55 per cent, with similar figures for trucks. Energy savings in railway traffic are estimated at 10-33 per cent worldwide. Significant reductions in energy use can be achieved by encouraging shifts to less energy-intensive modes of transport.

III. IMPROVING THE EFFICIENCY OF MATERIALS

22. Historically, industry has been an open system, transforming resources to products or services that are eventually discarded after use by society. That system is non-sustainable, since it consumes non-regenerative resources and produces large quantities of waste. The environmental problems associated with each step in the production and consumption processes have led to a re-evaluation of the way in which the economy works. "Industrial ecology" studies industrial systems in analogy with natural processes. Although the biological system produces some waste, it is a self-sustaining system with solar energy being the only external input. Industrial ecology looks for changes in policy and practice that will push the industrial system towards sustainability.

23. Global material consumption of both "classic" materials (e.g., cement, steel) and "new" materials (e.g., plastics, aluminium) is increasing. Studies of material consumption (expressed as apparent consumption per capita or unit GDP 3/) in industrialized countries have shown that it increases during the initial development of society to a maximum and eventually saturates or even declines. The initial increase is caused by the large investments required in building an (industrial) infrastructure. In later stages, material substitution, competition among materials, and a shift to a more service-oriented economy decrease material intensity. Although the use of all materials

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in developing countries will certainly grow, it is likely that the ultimate per capita consumption may not be as high as in the industrialized countries. Future saturation levels will depend on many factors, including technology transfer and infrastructural (including economic structure) policy choices. The rapidly developing East Asian countries already show the growing economic importance of the services sector.

24. At several stages in the life-cycle of a material, intervention can increase the material efficiency over the total cycle - for example, good housekeeping (prevention), product design, substitution (by other or improved materials), product reuse, recycling, and quality cascading (use of recycled material for a function with lower material quality demands). Recycling of metals has a long tradition, and worldwide over 40 per cent of steel is produced from scraps. Material losses can be reduced throughout the manufacturing process. Developments in product redesign and improved steel qualities are leading to further weight reductions in cars (e.g., ultra light steel in auto bodies) and other products. Improved corrosion resistance can increase the life of products considerably.

25. Global plastics consumption is estimated at 72 Mtons, of which nearly 80 per cent is in OECD countries. Good housekeeping can reduce demand for various packaging applications. Plastics can be tailored to match product demands. The development of plastics with improved qualities can reduce the material demand. Substitution of other materials by plastics can reduce weight (e.g., in cars) or lengthen the life of a product (e.g., of bottles), saving material and energy. One study for the Netherlands estimated the short-term technical potential for reducing material demand in packaging plastics at 34 per cent of 1988 levels.

26. Fertilizer use is dissipative, and hence recycling is impossible. A variety of measures to reduce losses are available, including recommended fertilizer application levels, matching crop needs and timing of fertilization, and spreader maintenance. Estimated savings in industrialized countries can be as high as 40 per cent, and savings are also feasible in developing countries, although they are very dependent on the local situation. Case studies in India found potential reductions of 20-50 per cent.

27. Recycling of paper is well established in many countries and reduces pulp production. Increased use of recycled paper is feasible for many applications. It depends strongly on fibre quality. Waste paper recovery is estimated worldwide at 38 per cent, with the highest rates in Austria (71 per cent) and the Netherlands (63 per cent). Initiatives show achieved reduction levels in the use of paper for packaging and printing (copying) of 10-50 per cent. Studies estimate the technical reduction potential for some applications at 50 per cent.

28. Cement is mainly recycled as filler material, with only limited energy savings. The major options are the development of high strength cement types (reducing the specific cement use) and the use of waste materials as additives (reducing the clinker demand). The use of additives in cement varies widely throughout the world, and large potentials for savings exist.

29. The first integrated material energy studies, although using high aggregation levels, show that improving the efficiency of materials, changing material consumption patterns in society and chain management can all play an important role in reducing energy demand. The studies also showed that integrated material and energy policies reduce the cost of reducing CO_2 emissions.

30. Experimental programmes to develop clean processes and products have been developed in many countries and disseminated internationally by the European Community, OECD and the United Nations Environment Programme (UNEP), inter alia. They indicate potentially large reductions in the loss of materials and show that energy substitution can lead to increased efficiency and greatly reduced waste.

IV. SCENARIOS FOR REDUCING ENERGY DEMAND

31. To analyse opportunities for saving energy and materials to the year 2020, three scenarios were developed: business-as-usual, state-of-the-art, and ecologically driven/advanced technology. The business-as-usual scenario assumes the continued use of current technologies and continuing improvements in efficiency caused mainly by stock turnover and shifts to industrial activities of lower energy intensity. The state-of-the-art scenario assumes the replacement of existing stock with the current most efficient technologies available. The ecologically driven/advanced technology scenario assumes a more rapid adoption of current state-of-the-art technologies and of some advanced technologies which are now in the demonstration or development stage.

32. Under business-as-usual conditions, energy consumption will grow at an estimated average rate of 2.0 per cent/year, to 566 EJ between 1990 and 2020. The developing countries are important growing energy markets, especially in the industrial sector and in the use of energy for buildings. Energy use for transport is expected to increase globally. Direct energy consumption in agriculture, although small, will also grow in developing countries and remain nearly constant in the industrialized countries.

33. In the state-of-the-art scenario (assuming adoption of today's state-of-the-art technology in all sectors by the year 2020), energy use will grow, but be limited to 1.3 per cent/year, to 465 EJ in 2020. The strongest growth will be found in buildings and transport.

34. The ecologically driven/advanced technology scenario assumes active energy policies that lead to accelerated implementation and development of new energy-efficient technologies. Growth of global energy use can be limited to 0.6 per cent/year, to 373 EJ, with a slight growth in buildings, agriculture and transport and almost no growth in the industrial sector.

35. Improving the efficiency of materials, with exception of recycling, has not been incorporated into these scenarios. It is estimated that such improvement in the advanced technology scenario, in addition to energy efficiency measures, could decrease the growth rate of energy consumption to 0.2 per cent/year,

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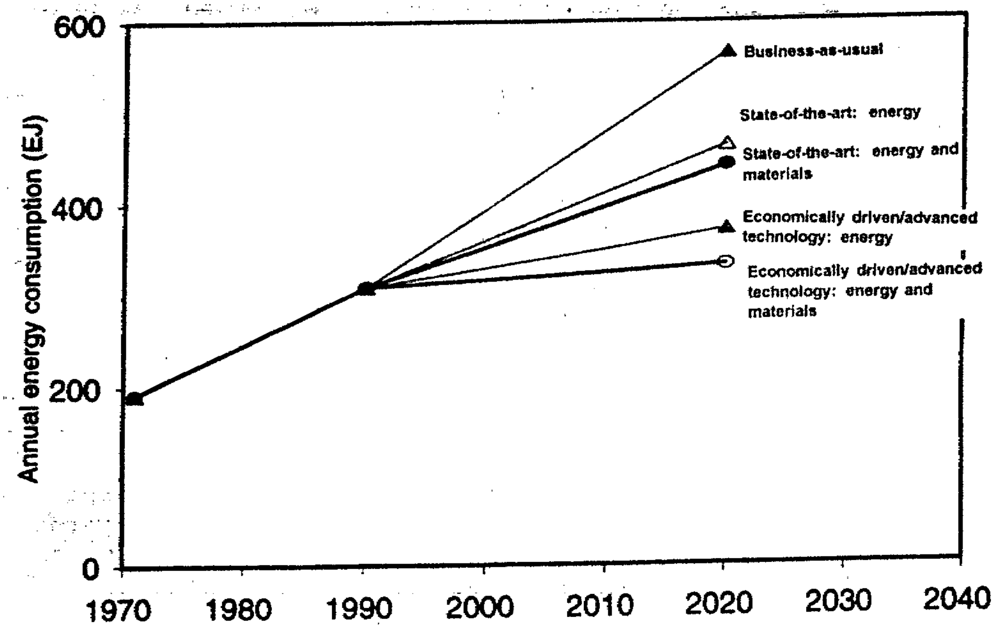
resulting in an energy consumption of 334 EJ. The scenario results are presented in figure I.

Figure I. Results of the three scenarios for aggregate world energy consumption between 1990 and 2020



36. The improvements estimated in the two efficient scenarios will not be realized without a significant increase in policies that mandate using new and innovative combinations of instruments. The review of current energy policies and instruments showed that energy is often still seen as a supply-side issue, especially in developing countries and in the allocation of research and development budgets in industrialized countries. However, large differences exist between regions and countries. For example, in Africa most energy policies and expenditures are related to expanding energy supply, while in some of the rapidly industrializing countries in Asia, improvements in energy efficiency have become an important element of energy and economic policy.

V. IMPLEMENTATION BARRIERS AND POLICY INSTRUMENTS

37. Several categories of potential for improving efficiency can be distinguished. The theoretical potential of a certain process can be determined by thermodynamic laws. The technical minimum is determined by the technological state-of-the-art and varies with the time horizon studied. The technical potential is defined as the achievable savings resulting from the most effective combination of the efficiency improvement options available in the period under investigation. Applying economic constraints, one can also identify an economic potential which is defined as the potential savings that can be achieved at a net positive economic effect (i.e., the benefits of the measure are greater than the costs). Investments are assumed to depreciate over the technical life time, at a specific discount rate. The market potential is defined as the potential savings that can be expected to be realized in practice and is determined by investment decision criteria applied by investors under prevailing market conditions.

A. Implementation barriers

38. Under perfect market conditions, all additional needs for energy services are provided by the cheapest measures, whether energy supply increases or energy demand decreases. There is considerable evidence that substantial energy efficiency investments that are lower in cost than marginal energy supply are not made in real markets, suggesting that market barriers exist. There is also compelling evidence that economic potentials for energy improvements are at least as large in developing countries as in industrialized countries. If a more balanced energy investment strategy were instituted, resulting in increased investment in energy efficiency and reduced investment in energy supply, developing countries could save significant amounts of capital-sacrificing energy services. In a case in which half of the electricity services come from new supply and half come from energy efficiency investments in developing countries and Eastern Europe, the gross reduction in investment in electricity supply over the period 1985 to 2025 was estimated to be $2.3 trillion (1990 US$), compared with a scenario meeting the same energy service demands with much lower investment in energy efficiency. Adding the cost of the efficiency investments, the net savings is $1.7 trillion over 40 years, or $42 billion per year.

39. Barriers to investment in and the implementation of energy efficiency measures that apply to all economies will be discussed below, followed by a discussion of additional barriers that are of particular importance to developing countries.

40. The decision to invest in energy efficiency improvement, like any decision, is shaped by the behaviour of individuals or of various actors within a firm. Decision-making processes in firms are a function of its rules of procedure, business climate, corporate culture, managers' personalities and perception of the firm's energy efficiency. Energy awareness as a means to reduce production costs seems not to be a high priority in many firms, despite a number of excellent examples in industry worldwide.

1. Information and transaction costs

41. Cost-effective energy efficiency measures are often rejected as a result of lack of information or knowledge on the part of the consumer, lack of confidence in the information, or high transaction costs for obtaining reliable information. Information collection and processing consumes time and resources, which is especially hard on small firms and individual households. Many individuals are quite ignorant of the possibilities for buying efficient equipment, because energy is just one of many criteria in making a purchase. Public authorities and utilities can play an important role in providing this information. However, in many developing countries, the public capacity for information dissemination, energy conservation planning and policy-making is lacking. Training is therefore essential.

2. Profitability barriers

42. There is compelling evidence that residential consumers substantially underinvest in energy efficiency or, stated differently, require high rates of return (50-80 per cent) from such investments. Many firms have high hurdle rates for energy efficiency investments, often because of limited capital availability. Capital rationing is often used within firms as an allocation means for investments, leading to even higher hurdle rates, especially for small projects with rates of return from 35 to 60 per cent, much higher than the cost of capital (~15 per cent). On the supply side, the costs of capital are much lower, leading to imperfections of the capital market. When energy prices do not reflect the real costs of energy, consumers will necessarily underinvest in energy efficiency. Energy prices, and hence the profitability of an investment, are also subject to large fluctuations. The uncertainty about the energy price, especially in the short term, seems to be an important barrier. The uncertainties often lead to higher perceived risk, and therefore to more stringent investment criteria and a higher hurdle rate.

3. Lack of skilled personnel

43. Especially for households and small and medium-sized enterprises (SME), the difficulties installing new energy-efficient equipment compared to the

simplicity of buying energy may be prohibitive. In many firms (especially with the current trend towards lean firms), there is often a shortage of trained technical personnel, since most personnel are busy maintaining production. A survey in the Netherlands suggested that the availability of personnel is seen as a barrier to investment in energy-efficient equipment in about one third of the surveyed firms. In Eastern Europe and the former Soviet Union the disintegration of the industrial conglomerates may lead to loss of expertise and hence similar implementation problems. Outsiders (consultants, utilities) are not always welcome, especially if proprietary processes are involved. In developing countries there is hardly any knowledge infrastructure available that is easily accessible for SMEs. Such knowledge is important because SMEs are often a large part of the economy in developing countries and are often inefficient.

4. Other market barriers

44. In addition to the problems identified above, other important barriers include the "invisibility" of energy efficiency measures and the difficulty of demonstrating and quantifying their impacts; lack of inclusion of external costs of energy production and use in the price of energy; and slow diffusion of innovative technology into markets. There are further barriers to energy efficiency in residential markets. For dwellings that are rented, there are few incentives for the renter to improve the property that he/she does not own; similarly, the landlord is uncertain of recovering his/her investment, either in higher rents (since it is difficult to prove that improved thermal integrity will save the renter money in utility bills) or in the utility bills, since the bills depend on the behaviour of the renter.

5. Additional barriers in developing countries

45. Developing countries suffer from all of the factors discussed above which inhibit market acceptance of energy-efficient technologies plus a multitude of other market problems. Energy costs in industrialized countries often do not reflect total costs, but the problem is especially serious in developing countries, where energy is very considerably underpriced, with the Government providing the energy supply industries (especially electric power producers) with large subsidies. Consumers often have no knowledge of energy efficiency and, if they do have such knowledge, often cannot afford even small increases in equipment costs. The problem of this knowledge gap concerns not only consumers of end-use equipment but all aspects of the market. Many producers of end-use equipment have little knowledge of ways to make their products energy efficient and even less access to the technology for producing the improved products. End-use providers are often unacquainted with efficient technology.

46. The rigid hierarchical structure of organizations and the paucity of organizations occupying the few niches in a given area lead to strong and closed networks of decision makers who are often strongly wedded to the benefits they enjoy from the status quo. The hierarchy in India led to the discontinuation of an innovative programme for a utility to lease compact fluorescent lamps to its customers. Some of the major barriers to adopting energy efficiency in India

are lack of information about products; limited ability to pay even small increased first costs; very low electricity prices; limited foreign currency (which makes the purchase of modern equipment from outside the country difficult); poor power quality (which often interferes with the operation of the electronics needed for energy-efficient end-use devices); shortage of skilled staff to select, purchase, and install efficient equipment; a large used equipment market which keeps inefficient equipment operating long after its useful life; high taxes that increase the first cost differential between efficient and inefficient products; the very high risk aversion of the lending community; and many small and/or outdated industrial activities that do not have resources to produce efficient equipment.

B. Policy instruments

1. Energy price reform and other economic instruments

47. Markets are a powerful and fundamental force in wide-scale implementation of energy efficiency. Subsidies that depress prices of energy provide a significant disincentive for energy efficiency. The removal of this barrier to low energy prices is an important step towards creating an investment climate in which energy efficiency can prosper. Between 1979 and 1991, electricity prices in developing countries were on average 40 per cent lower than electricity prices in OECD countries. The disparity grew over the period, from an average difference of 2.3 cents/kWh (1986 US$) between 1979 and 1984 to an average difference of 3.4 cents/kWh between 1985 and 1991. Energy prices in some areas are beginning to reflect more closely costs in response to commercialization of the electricity industry and investment by independent power producers.

48. The international lending organizations have been strong proponents of energy price deregulation in developing countries. The largest hurdle to such price increases involves the impact on low-income consumers. This is a serious problem in many developing countries, for low-income urban families often spend a substantial portion of their income on energy. Recent surveys in urban areas of developing countries show the poorest 20 per cent of the population spending 20 per cent of their income on energy. It should be noted that often in developing countries the poorest have no access to commercial energy use at all. The impact of higher energy prices on the urban poor can be mitigated in several ways. A low tariff for the lowest consumption block can be instituted, the so-called "lifeline rate" in the United States. Subsidies for energy efficiency improvements can be targeted at low-income urban dwellers. Such subsidies could moderate an increase in energy services. Because the lowest income population consumes a relatively small proportion of total energy in developing countries, revenue obtained from energy price increases would be expected to far exceed any subsidies to the low-income consumers. The main points are that energy price deregulation is a very important step in achieving end-use energy efficiency in most developing country economies; such deregulation is very unlikely without protection for low-income consumers; and therefore increased attention to innovative ways to protect those consumers is needed.

49. Direct subsidies and tax credits or other favourable tax treatments have been a traditional approach for promoting activities that are thought to be

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socially desirable. Incentive programmes need to be carefully justified to assure that social benefits exceed costs. An example of a financial incentive programme that has had a very large impact on energy efficiency is the energy conservation loan programme that China instituted in 1980.

50. Utility integrated resource planning (IRP), which has been applied primarily in industrialized countries, is used to assess all options for meeting energy service needs, including utility-sponsored end-use efficiency programmes. The novel feature of IRP is that it requires utilities to look beyond the utility meter and into the ways that electricity is used, in order to find the least-cost way of providing energy service. IRP programmes in the United States have shown a wide variety of end-use efficiency measures that are less costly than energy supply additions. Two major problems occur: inducing the utility to carry out end-use efficiency programmes; and designing the programmes so that they are in fact cost-effective.

51. There have been many evaluations of individual utility demand-side management (DSM) programmes, and most have been shown to be more cost-effective than energy supply. It is, nonetheless, difficult to measure accurately the performance of these programmes. Electricity used is a measurable quantity. Electricity saved is much more elusive. It was argued above that the relative invisibility of energy savings acts as a disincentive to consumer investment. It is not easy to overcome consumer scepticism, even of energy efficiency measures that perform extremely well, when evidence for success is uncertain in the absence of extensive statistical studies.

52. There has been interest in IRP and the establishment of DSM programmes in developing countries. Thailand has launched a multisectoral DSM programme to invest $180 million over five years, aimed at saving 225 MW of peak demand and 1,000 GWh annually. This is estimated to be half the cost of new supply. The programme includes design assistance for new commercial buildings and lighting retrofits in existing buildings. China has also shown considerable interest in IRP, with several utilities developing plans. Utilities in Mexico and Brazil have been active in DSM programmes.

53. Other instruments designed to achieve results similar to regulatory programmes but without a "command and control" approach have come to be known as market mechanisms. They generally have two features: they depend on market decisions for their effectiveness; and they are generally revenue neutral (i.e., do not represent any increase in governmental expenditures). It is the second attribute that has made these programmes of particular interest during times of tight governmental budgets. They have been tried as alternatives to regulation in environmental control. For example, use of pollution trading mechanisms is an innovative way of achieving environmental standards, potentially at much lower cost than with command and control approaches.

2. Regulations and guidelines

54. Regulatory programmes have proven effective in promoting energy efficiency gains. Examples include appliance energy efficiency regulations, automobile fuel economy standards, and commercial and residential building standards

programmes. In such programmes the Government passes a requirement that all products (or an average of all products sold) meet some minimum energy efficiency level. Energy efficiency standards are applied in many countries for various energy uses. Standards can be performance based or prescriptive. Performance standards do not mandate how the manufacturer is to meet them (i.e., what technologies or design options to use) and are used for appliances or cars (e.g., the Corporate Average Fuel Efficiency (CAFE) standards in the United States).

55. Appliance energy efficiency standards have been aggressively pursued in the United States. Since the passage of the National Appliance Energy Conservation Act in 1987, the Government has mandated standards for such products as refrigerators, water heaters, furnaces and boilers, central air conditioners and heat pumps, room air conditioners, clothes washers, dryers, and dishwashers, ovens, and lighting ballasts. The Act requires a periodic update on all standards, with the timing of new standards differing among products. From the viewpoint of economic and energy savings, these standards have been a major success. The standards already in effect are expected to reduce energy consumption in the United States by 1.1 EJ/year by the year 2000 and 2.75 EJ/year by 2015.

56. Energy standards for buildings may be based on performance or on components. Almost all residential standards specify the measures to be included in the building. Some of them also have a performance path, in which the builder may choose different combinations of measures to meet a specified performance. The actual energy savings are more difficult to estimate for buildings than for appliances and automobiles, since buildings are not mass-produced. Furthermore, the operation of a building (which is not affected by building energy codes), plays a major role in its actual energy performance. A survey of energy standards revealed that 27 of the 57 countries that responded, more than half of which do not belong to OECD, had mandatory standards, of which 4 were residential only and 2 were commercial only; 11 had voluntary or mixed standards, 6 had proposed standards, and only 13 (all of them developing countries) had no standard. The degree of success of these standards in buildings as built and operated is still a major issue.

3. Voluntary agreements

57. A voluntary agreement is generally a contract between the Government (or another regulating agency) and a private company, association of companies or other institution. The private partners may promise to attain, or try to attain, certain energy efficiency improvements and emission reduction targets. The governmental partner may promise to financially support the endeavour or promise to refrain from other regulating activities. For example, in Denmark companies that enter into a voluntary agreement with the Government are exempted from paying the carbon tax. The United States Environmental Protection Agency (EPA) has created voluntary programmes to reduce greenhouse gas emissions. These programmes are known as EPA's "green" programmes. The Green Lights programme, launched in 1990, involves an agreement between EPA and corporations in which the corporation commits itself to all cost-effective lighting retrofits and EPA commits itself to providing technical support. There has been much

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experience with voluntary agreements in the Netherlands, especially in the field of waste management policy and toxic emissions policy. The experiences varied strongly, from successful actions to complete failures. In some cases the result of a voluntary agreement may come close to that of regulation. In regulation, there are often aspects of "agreement", such as the negotiation between the regulating body and the regulated party. Voluntary agreements can have some advantages over regulation, in that they may be easier and faster to implement and may lead to more cost-effective solutions.

4. Information programmes

58. Information programmes are designed to assist energy consumers in understanding and employing technologies and practices that use energy more efficiently. They aim to increase consumers' awareness, acceptance, and use of particular technologies or utility energy conservation programmes. Examples of information programmes include educational brochures, hotlines, videos, home energy rating systems, design-assistance programmes, audits, energy use feedback programmes and labelling programmes. Information needs are strongly determined by the situation of the actor. Therefore, successful programmes should be tailored to meet these needs.

59. Since information programmes are often components of larger energy efficiency activities, evaluations of their effectiveness is limited. By themselves, information programmes have been shown to result in energy savings of 0-2 per cent. A United States utility that launched a two-year advertising promotional campaign for energy efficiency found that participation rates in their programmes often doubled but that savings were not necessarily persistent for long periods. Developing countries such as Brazil, China, India, Mexico and Thailand have developed large-scale information programmes to promote lighting and other residential technologies, although few detailed assessments exist on the effectiveness of these efforts. In general, information campaigns are most effective when the provider is a trusted organization and when the information is provided face to face.

60. Energy audit programmes are a more targeted type of information transaction than simple advertising. Residential energy audits performed in the United States in the 1980s have been shown to have average net savings of 3-5 per cent, with benefit/cost ratios between 0.9 and 2.1. Education and training both for customers and for industrial energy managers offers perhaps the greatest potential for achieving long-term energy efficiency savings, especially for developing countries. In industrialized countries, training has often proven to be a highly cost-effective option for achieving savings. One United States utility measured the effect of weatherization energy efficiency education for low-income customers and found annual savings 8 per cent higher than for customers who did not receive the information and training. The United States Climate Change Action Plan relies on information programmes to capture about 5 per cent of overall CO_2 emission reductions.

5. Research, development and demonstration

61. Research, development and demonstration (RD&D) comprises creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of people, culture and society, and the use of that knowledge to devise new applications. Different stages can be distinguished: basic research, applied research, experimental work, and demonstration.

62. There is consensus among economists that R&D has a payback that is higher than many other investments, and the success of directed R&D has been shown in fields such as civilian aerospace, agriculture and electronics. Still, the private sector has a propensity to underinvest in RD&D, because it cannot appropriate the full benefits of its investments, due to "free riders" (firms that imitate but don't bear the costs of the RD&D). Firms will also underinvest in RD&D that reduces costs not reflected in market prices, such as air pollution damages and climate change. Currently, widespread cutbacks in energy RD&D, both public and private, threaten the continuity of the RD&D effort. Public energy RD&D funds decreased by 65 per cent in the United States and by 33 per cent in other OECD countries between 1977 and 1992. Industrial energy RD&D expenditure in the United States decreased from 1.3 per cent to 0.7 per cent of GDP in the same period, cutting back mainly in basic research. This trend is expected to continue, since many utilities and industries are reducing costs to compete in more open markets.

63. RD&D in energy should be prioritized with climate change policy goals. Less than 6 per cent of the energy R&D budget of member countries of the International Energy Agency in 1990 was spent on energy conservation and 6 per cent was spent on renewable energy, while spending on nuclear fusion (46 per cent), nuclear fission (11 per cent) and fossil energy (18 per cent) dominated. RD&D should be a sustained activity, because large resources are necessary to build up a knowledge infrastructure and the key to success is so-called "tacit knowledge" (unwritten knowledge obtained by experience), which is easily lost. A diversified portfolio is needed, for not all RD&D will lead to commercialization. If priority is given to relatively small-scale technologies, like energy efficiency and renewables, a diversified portfolio is possible with a limited budget. A diversified portfolio also makes it possible to meet the different RD&D demands of industrialized and developing countries. Finally, long-term research should be protected against the often more costly demonstration and commercialization initiatives. Sustainable energy policies should secure continuity of RD&D funds by appropriate funding mechanisms, by public funding of valuable RD&D that it is not executed by industry, and cost-sharing of RD&D where both private and public benefits are produced.

64. An important arena for cooperation between the industrialized and developing countries involves the development and strengthening of local technical and policy-making capacity. Project-oriented agencies eager to show results commonly pay inadequate attention to the development of institutional capacity and the technical and managerial skills needed to make and implement energy efficiency policy.

65. Energy efficiency should be viewed as an integral component of national and international development policies. Energy efficiency is commonly much less

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expensive to incorporate into the design process in new projects than as an afterthought or a retrofit. In the environmental domain, we have learned that "end of pipe" technologies for pollutant clean-up are often significantly more expensive than project redesign for pollution prevention, leading to widespread use of pre-project environmental impact statements to address those issues in the planning phase. Energy efficiency should also be incorporated into the planning and design processes wherever there are direct or indirect impacts on energy use such as in the design of industrial facilities or in transportation planning.

66. There is great need for technological innovation for energy efficiency in the developing countries. The technical operating environment there is often different from that of industrialized countries. For example, poorer power quality, higher environmental dust loads, and higher temperatures and humidities require energy efficiency solutions that differ from those in industrialized countries. Technologies that have matured and been perfected for the scale of production, market, and conditions in the industrialized countries may not be the best choice for the smaller scale of production or different operating environments often encountered in a developing country.

67. Finally, joint implementation (JI) may also be a useful instrument for promoting energy efficiency. It involves a bilateral or multilateral agreement in which (donor) countries with high greenhouse gas abatement costs implement mitigation measures in a (host) country with lower costs and receive credit for (part of) the resulting reduction in emissions. To be successful, JI projects should fit within the scope of sustainable development of the host country (without reducing national autonomy and with cooperation of the national Government), have multiple (environmental) benefits, not replace development aid, be selected on the basis of strict criteria, and be limited to a (small - e.g., 15 per cent) part of the abatement obligations of an industrialized country (the most likely donors). Determination (and crediting) of the net emission reductions is also a problem that stresses the need of well-developed baseline emissions - i.e., emissions that would occur in the absence of the project. JI is not straightforward. It can prove to be a viable financing instrument to accelerate developments in economies-in-transition and in developing countries only if implemented according to the criteria discussed above. Comprehensive evaluation of pilot projects is necessary to formulate and adapt those criteria, including the issue of crediting. Hence, the role of JI in the short term will be limited but might grow in importance in the next decades.

VI. CONCLUSIONS

68. This assessment has focused on energy because of the important environmental and social implications of its use. It has shown that large potentials exist for energy savings through the improvement of energy and material efficiency in all sectors of society and that these savings can change current unsustainable consumption patterns. Three factors have played a major role in the considerable energy efficiency improvements in the past decades: increasing energy prices (except for the past 5-10 years); energy policies aimed at bringing energy efficiency into the market; and technological development.

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69. Energy and material efficiency improvement reduces air pollution (global warming, acid precipitation, and smog in the urban and industrial environment), waste production (ashes, slags), and water and thermal pollution. Efficiency improvement is a cheap energy source. Other economic benefits are the reduced costs of energy transformation and generation, reduced fuel imports, and increased energy security. Technologies do not now - nor will they in the foreseeable future - place a limit on continuing energy efficiency improvements.

70. Barriers to efficiency improvement can include: unwillingness to invest; lack of available and accessible information; economic disincentives; and organizational barriers. The degree to which a barrier limits efficiency improvement is strongly dependent on the situation of the actor (households, small companies, large industries, utilities). This means that no single instrument will "do the job". A range of policy instruments is available, and innovative approaches or combinations have been tried in some countries. Successful policy may take the form of regulation (e.g., product standards) and guidelines, economic instruments and incentives, voluntary agreements and actions, information, education and training, and research, and development and demonstration policies. Successful policies with proven track records in several sectors include efficiency standards and codes, technology development, and utility/governmental programmes and partnerships. Improved international cooperation to develop policy instruments and technologies to meet developing country needs will be necessary, especially in light of the large anticipated growth in this region. New instruments - e.g., joint implementation - are being developed but comprehensive evaluation will be needed to tailor them to specific needs.

71. Material efficiency improvement has not yet received as much attention in policy-making and analyses as energy efficiency. As a result, detailed data on the qualities and quantities of final consumption are not available, making it difficult to formulate effective policies. However, the available studies suggest the existence of large potentials for improved use of many materials in industrialized and developing countries. Efficiency improvement in industrialized countries can reduce consumption up to 40 per cent for some materials, maintaining the same service level. Many options for material efficiency improvement exist. Despite the growing demand for services in developing countries, possibilities exist to reduce their material intensity. Integrated assessments of the energy/materials system suggest that emission reductions can be achieved at lower costs through combined energy and material efficiency approaches. Current initiatives to develop clean technologies and products show that they can be successfully combined to achieve large reductions in resource inputs and emissions. The change to less energy-intensive consumption patterns should also result in reduced consumption of materials. As with energy, there are barriers to material efficiency improvement which, along with the problems mentioned above, include issues related to chain management, such as communication and linking of material/product/waste streams.

VII. RECOMMENDATIONS

72. A policy aimed at sustainable development places energy and material efficiency improvement in the middle of the economic and environmental policy

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field. Energy efficiency facilitates the introduction of renewables and buys time for the development of low-cost renewable energy sources. However, energy efficiency does not receive attention appropriate to the important role it needs to play in the development of an environmentally sustainable society. Regulatory frameworks typically do not recognize energy efficiency improvement as an energy source. A balanced approach is required in order to place supply and demand on an equal footing. Changes are needed to fulfil the promise of energy efficiency and to fulfil energy needs more sustainably, accounting for social, economic and environmental issues. A number of recommendations formulated on the basis of the study are presented below for consideration, as appropriate, by States, entities within the United Nations system, and other intergovernmental and non-governmental organizations:

(a) Cooperation in the energy efficiency field should be increased between the industrialized countries and the countries in the developing world and Central and Eastern Europe. Without such cooperation and assistance, lower energy paths (as reflected in the state-of-the-art and advanced technology scenarios described above) are not possible because so much of the world's energy growth will take place in developing countries. Cooperation should first be directed towards building public awareness and indigenous capacity (see below), which is one of the basic steps in development, and in increasing energy and material efficiency. Such awareness will lead to an increased focus on sustainability issues and can have long-term effects on policy formulation and effectiveness;

(b) Capacity-building includes education, training and information transfer on the national and international levels. Training in all aspects of energy and material efficiency is essential, ranging from energy planning to technical and engineering training. An analysis of the training needs in developing countries should be made. The efforts should be evaluated regularly so that it is possible to redirect the programmes to the needs;

(c) There is a need for detailed information regarding technical options for energy and material efficiency improvement for use in national policy-making and the development of international initiatives. However, this information is often not available or not accessible. This is especially true in developing countries which typically have more limited knowledge, information, and educational resources. The quality and availability of information on energy and material efficiency provided through Governments, energy agencies, vendors, trade and consumer associations, or other appropriate bodies needs to be improved. The training and information structure should be tailored to meet the demands of the energy customer. Continuous efforts are needed to maintain effectiveness, since knowledge infrastructure is difficult to build up but easy to break;

(d) Because of the expected high economic growth rates in developing countries, huge investments in industrial production equipment and energy infrastructure, which will determine the structure for the next few decades or even longer, are expected. These upcoming investments represent an opportunity, if acted on appropriately, to adopt the best available technologies, for those growing markets are good theatres for innovation. Tariffs and other barriers for importing and exporting energy-efficient technologies should be removed so as to enhance technology transfer. The emerging markets for new (and clean) technologies in developing countries stress the importance of considering the special demands those markets put on product and process development. Developing technologies in those countries can help them to "leapfrog" the unsustainable development path followed in the past by industrialized countries. This includes demonstrating the feasibility of advanced technologies in developing countries;

(e) Countries should establish comprehensive policy plans with clearly defined energy and material efficiency goals. Such plans set clear targets for all actors and make it possible to direct and evaluate policies. In addition, clearly defined goals improve communication, credibility, and the outlook for investors. A medium-to-long-term perspective on energy polices will reduce perceived risks. The effectiveness of comprehensive policies is illustrated by countries such as the Republic of Korea and Japan. To be effective, the policy plans should contain "hard" goals. The United Nations could play an important role in overseeing and harmonizing policy plans and in the achievement of those (as set forth in the Framework Convention on Climate Change);

(f) The development and design of new regulatory, legal, and market frameworks is needed, because current frameworks do not fully recognize the role of energy efficiency improvement. Important global changes and developments are taking place in the power sector, leading, on the one hand, to larger multinational utilities and, on the other hand, to the development of decentralized power generation by self generators and utilities. A new regulatory framework should emphasize internalization of input and emission reduction through integrated environmental auditing and development, rather than end-of-pipe measures. This can be accomplished by introducing integrated resource planning and demand-side management and considering generation technologies like cogeneration and various renewable energy sources. The establishment and strengthening of the role of energy service companies (or utilities) in developing countries can be an important step towards generating long-term interest in efficiency improvement;

(g) Mechanisms for energy and material efficiency improvement are not limited to technologies. This is because a number of technical, socio-economic, and behavioral barriers limit the market diffusion and correct application of new energy-efficient technologies. The barriers are not yet fully understood and are partly due to the issues raised above. A better understanding of the barriers, in order to formulate efficient policy instruments and incentives, is needed;

(h) With regard to implementation strategies there is no "deus ex machina"; instead, an integrated policy accounting for the characteristics of technologies and target groups addressed is needed;

(i) Subsidized energy prices in many countries provide disincentives for energy efficiency improvement or efficient use of materials. Removal of existing energy subsidies must be done carefully in order to take account of social and economic circumstances, since energy is essential for development. Price transformation should take place within a strict schedule, while mitigating the negative effects for the poorest by special efficiency

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programmes. Important incentives for energy and materials efficiency will be provided with the establishment of energy prices that reflect real costs, internalizing factors now external to the pricing structure (e.g., environmenta and social costs). Recognizing that no consensus is yet reached on this issue, planned step-wise price increases are needed as an incentive for energy efficiency improvement, which will also reduce the perceived uncertainty in energy price developments by investors;

(j) National and international standards for many products (e.g., appliances, packaging, buildings) and production equipment (e.g., electric motors, boilers), and internationally accepted testing procedures have played an important role in improving the environmental characteristics of those products and processes. Standards are likely to continue to play an important role, and widespread adoption and adaption over time is recommended to push technology development. A legal basis should be provided for product standards (e.g., energy standards for appliances) in national legislation. Standard-setting along with technology procurement programmes will strengthen R&D. Standards play a role in establishing widespread "uniform" technologies or practices. New forms and applications of efficiency standards should be investigated. Establishment of internationally accepted testing procedures would be an important step towards assisting developing countries that are willing to promote standard-setting;

(k) Financing and fiscal instruments have taken various forms (e.g., subsidies, accelerated depreciation). An important hurdle seems to be the different financing criteria for supply and demand options. Capital allocation to energy efficiency investments should use life-cycle costing for demand options or make use of innovative approaches (e.g., by energy service companies or utilities). Financial and fiscal incentives should be tailored to the markets in which the actor is operating, potentially reducing the "free-rider" problem. In line with the above, financing or fiscal incentives for end-of-pipe technologies should be phased out so as to strengthen the process of internalization of environmental costs and integrated resource planning in the design of processes, products, and infrastructures. Internationally, accessible and affordable financing for developing countries i needed - e.g., by redirecting international development funding to efficient (and renewable) energy technologies. A considerable part of the energy lending of such organizations as the World Bank should be spent on energy efficiency within the coming years. Technology procurement programmes by utilities or governmental entities can play a role in deepening the cooperation between the actors, which might take the form of organized competition;

(l) Voluntary agreements, or covenants, are currently being used to purst energy efficiency or technology development goals in several countries. They establish improved partnerships between the actors, and they may improve economic efficiencies for achieving the stated goal. Evaluation of their effectiveness is not yet feasible, but preliminary data suggest that they can effective but should generally be accompanied by other instruments. The viability of voluntary agreements in international policy-making should be investigated;

(m) Energy efficiency improvement has significant potential in the medium and long term and is generally seen as a major force for reducing environmental impacts and reconstructing the energy system. However, in OECD countries only 6 per cent of their budget allocations for energy RD&D is for energy efficiency improvement, while over 90 per cent is spent on supply-side technologies (mainly nuclear power, 57 per cent). A reallocation of RD&D budgets is needed in order to reflect better the importance of efficiency improvement in energy policy. International collaboration, where RD&D efforts among countries are aligned, can be an important way to improve the efficiency and effectiveness of RD&D programmes;

(n) To improve effectiveness, there need to be well-established and accepted analysis and monitoring instruments to evaluate and redirect policies and instruments to changing conditions and situations. (Inter-) nationally accepted analysis methodologies can help to identify the most effective options and policies in different situations and hence increase the effectiveness of international cooperation initiatives like technology transfer, development aid, and joint implementation. Assessment of the options for energy efficiency improvement should be done using a common harmonized "bottom-up" analysis methodology, enabling an international comparison of energy efficiency and improvement options and strategies. Emphasis should be on analysis starting from the specific end-uses, potentials, and costs. There is a critical need for detailed and good quality data collection, publication and analysis. It should be noted that relatively little knowledge is available with respect to the end-use of materials and products and the possibilities of changing to consumption patterns that are sustainable and more efficient in the use of materials.

73. With regard to the individual sectors assessed in this study, some specific recommendations can be made. In industry R&D, stimulation is very important, as energy efficiency improvement has often been part of technological progress. Innovation can also be accelerated by improving implementation rates of innovative environmentally sound technologies. In the building sector, standards and codes (for appliances and buildings) have been shown to be the most effective instruments. A policy of gradually increasing standards should be set to give a clear signal to builders and manufacturers (R&D). It is important to set out policies along these lines today, because of the long life-time of buildings and because renovating buildings for energy efficiency is more expensive than construction. In agriculture, energy efficiency is strongly dependent on direct and indirect energy inputs. Sustainable energy policies in agriculture should therefore aim at minimizing the inputs and environmental impact relative to the outputs, in an integrated way. With regard to transport, important infrastructural choices made today will lay out the transport needs and means in the long term. Transportation policies should therefore aim at influencing this infrastructure in a way that integrates all of the social needs involved in meeting transportation demand. Such an approach is likely to lead to reduced energy requirements for the desired transport services. Regional planning in developing countries presents a challenge and opportunity because of rapidly expanding transport infrastructure. Development of inherent clean transportation modes is important due to the wide range of problems associated with transport (e.g., energy use, pollution, dependence on one energy carrier, congestion, land use). Sustainable development could be accelerated by the

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setting of appropriate standards for automobiles and by introducing policies that promote the introduction of "clean" vehicles.

74. The United Nations can play a vital role in the transition to more sustainable development. Its role can be strengthened by emphasizing the importance of energy and material efficiency and by improving programme coordination, the exchange of information on these activities, and capacity-building within the United Nations system. Although improved use and recognition of the existing programmes of the regional commissions are essential, the United Nations could play a more important role in the organization of the international activities proposed above. This should encompass, first of all, an initiative for training and investigating the needs for information and training in developing countries. Secondly, the United Nations should play a role in the harmonization of analysis and testing methodologies, enabling developing countries and the international community to improve efficiency in policy and technology needs. Thirdly, the United Nations should play a major role in redirecting international capital spending (e.g., World Bank) into directions in line with the recommendations presented above.

Notes

1/ Official Records of the Economic and Social Council, 1994, Supplement No. 5 (E/1994/25).

2/ "Potentials and policy implications of energy and material efficiency improvement", prepared by E. Worrell, and others (Utrecht University, Department of Science, Technology and Society); Lyn Price, and others (Berkeley, CA., Energy Analysis programmes, Lawrence Berkeley National Laboratory).

3/ Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992, vol. I. Resolutions Adopted by the Conference (United Nations publication, Sales No. E.93.I.8 and corrigenda), resolution 1, annex II.

4/ Geneva, 1992.

5/ International statistical data give the apparent consumption of materials - i.e., the intermediate consumption of materials in industry. Due to increasing import and export streams of products (containing the materials), the figures represent the consumption by economic production sectors rather than by end-users. The availability and comparability of GDP data is often difficult, as shown by energy intensity analyses. Comparisons of the material intensity, expressed as material use per unit GDP, should be interpreted carefully.
