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Review of salient trends and issues on energy development and use in the context of sustainable development: energy and the residential sector

Energy and the residential sector

Report of the Secretary-General

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Introduction

1. The present report has been prepared in response to the request of the Committee on Energy and Natural Resources for Development at its first session (5-16 April 1999),[1] which was approved by the Economic and Social Council at its substantive session of 1999 (Council decision 1999/277).

2. World energy demand in the residential sector is projected to increase substantially, by more than a 2 per cent average annual rate of growth in the next decade with the total residential energy consumption having risen to over 2,200 mtoe (millions of tons of oil equivalent) by 2010 owing to increases in population, urbanization and per capita incomes. An increased penetration of energy-intensive appliances in households that have not yet reached saturation, mainly in developing countries and countries in transition, is expected as part of this trend. In Organisation for Economic Cooperation and Development (OECD) countries, electricity will be gaining in share during the period extending to 2010, rising to about 43 per cent of the total residential energy demand of over 1,200 mtoe. Energy used in the residential sector accounts for about one quarter of total energy consumed in industrialized countries, ranging from 20 per cent in France to 29 per cent in Sweden. In the rest of the world, the average annual growth rate of residential energy demand is estimated to be about 6 per cent and the total residential energy demand rising to over 1,000 mtoe, with a significant rise in the share of electricity. As a percentage of total energy consumed, residential energy varies widely among developing countries. For example, this figure was approximately 14 per cent in Egypt and China, but as high as 31 per cent in Zimbabwe and 36 per cent in India.

3. There are four principal uses of energy in this sector, namely, climate control (heating, of both space and water, and cooling of space), cooking, lighting and powering appliances. Generally, residential energy demand is affected by socio-economic development, culture and mores as well as climatic conditions. The environmental impact of increases in energy use in this sector depends largely on the type of fuel used and how it is produced. While policies undertaken to curb residential energy demand have the potential to reduce total energy used, those undertaken to promote more efficient technologies can have a significant impact on greenhouse gas emissions and pollution abatement at any given level of demand.

4. Following significant oil price increases in the 1970s, energy policies in many industrialized countries were aimed at reducing residential energy demand. Tax incentives were provided to encourage energy-saving devices in homes and buildings, and standards were applied to energy-consuming goods. Since the mid-1980s, energy price declines in real terms have relaxed the urgency of this issue for policy makers as well as for individual consumers. However, more recently, concerns about the environment and individual health have provided the impetus to refocus attention on residential sector energy use.

5. Information on residential energy use is incomplete and/or lacking in many countries. Though recent efforts at improving the gathering and compilation of disaggregated data have yielded positive results, especially in Eastern European countries, many countries still lack sufficient data to analyse residential energy use patterns. In addition, data problems exist for non-traded energy which comprises a significant portion of energy used by households in developing countries.

I. Residential energy consumption

6. The residential sector consists of a large number of consumers using similar equipment for similar purposes and, in the past, was considered, by and large, homogeneous. However, significant differences occur across socio-economic groups, regions and countries depending on income levels and use of leisure time, cultural differences and climate, all of which have an impact on final energy demanded by households. Structural and technological factors, as well as climatic factors, also affect energy demand in the household sector. Furthermore, taxes and other policy measures have an impact on final energy use in this sector. Table 1 categorizes factors affecting energy consumption with respect to consumption over time and across countries and cultures.

Table 1
Factors affecting residential energy consumption

Demographics	Household growth or decline Population growth Age of occupants
Economic factors	Energy prices Investment costs of equipment Available income
Individual factors	Attitude Awareness
Lifestyle	Time spent at work/home Mix of activities Rural/urban
Culture	Cooking/washing/heating/comfort Traditions
Structure	Saturation of equipment Dwelling area Share of central heating
Technology	Efficiency
Climate	Differences in heating degree days Building and appliance standards
Policy	Taxes, subsidies Effects of demand-side management programmes

Source: Based on R. Haas, "Energy efficiency in the residential sector", *Energy Policy*, vol. 25, Nos. 7-9, pp. 789-802.

7. In a comprehensive analysis of this sector at the national level, energy use is typically broken down and analysed by end-use components such as space heating, water heating, cooking, lighting and electric appliances. However, such analyses are often complicated by lack of adequate data about these components and/or competing trends hidden in the available aggregated data. For example, in industrialized countries, the amount of energy required to heat one square metre (m^2) of floor space fell by 20-50 per cent between 1973 and 1993,[2] yet the trend towards larger, separated housing units and smaller household sizes may have

outweighed this efficiency gain. Detailed data for a disaggregated analysis of residential energy use are unavailable in many countries.

Figure I
Residential energy consumption by fuel type and region, 1994

Source: O. Dzioubinski and R. Chipman, "trends in consumption and production: household energy consumption, Department of Economic and Social Affairs of the United Nations Secretariat Discussion Paper No. 6 New York, April 1999.

8. Concerns about growing energy demand in the residential sector have led to demand-side management policy measures undertaken in some, mostly industrialized, countries to provide energy efficiency information to users of appliances as an input in their purchase decisions. In 1987, the United States of America adopted national standards for refrigerators and freezers, boilers, air conditioning appliances and other appliances and, by 1992, such standards included fluorescent and incandescent lamps and electric motors. Consequently, a standard size refrigerator/freezer, which consumed an average of 2,000 kilowatt hours (kWh) per year in 1970, used 900 kWh per year in 1990 and 690 kWh per year in 1993.[3] However, efficiency improvements in other countries may be less dramatic depending on initial energy efficiency levels and the incidence of compliance by manufacturers. One barrier to improved residential efficiency has been that appliance energy costs are a small sum in household budgets, resulting in lack of incentive by consumers to investigate the often complicated question of energy efficiency.

9. Energy efficiency labelling has been introduced in such countries as Australia, Canada, Denmark and France, among others, and various voluntary plans exist, mostly in industrialized countries. Energy standards and/or labelling schemes, often as part of demand-side management programmes, are now under consideration and application in some developing countries as well. Such programmes may prove

effective as household incomes, and associated purchases of household appliances, increase with expected economic growth. Table 2 summarizes the status of labelling and standards programmes in selected industrialized and developing countries.

Table 2
Energy efficiency labels and standards in selected countries

	United States (1978)	*Japan (1979)*	*India (1979)*	*Australia (1986)*	*China (1989)*	*Democratic People's Republic of Korea (1992)*	*Philippines (1993)*	*Thailand (1994)*	*Switzerland (1994)*	*Mexico (1995)*	*Hong Kong, China (1995)*	*Canada (1995)*	*European Union (EU) (1995)*	*Singapore*	*New Zealand*	*Russian Federation*	*Republic of Korea*
Refrigerators	L_m, S_m	L_v, S_v	S_v	L_m	S_m	L_m, S_m		L_v	S	L, S		L, S	L				
Freezers	L_m, S_m	L_v, S_v		L_m					S			L, S	L				
Space heaters	S_m			L_m		L_m											
Ranges/ovens	S_m								S			S					
Room AC	L_m, L_v, S_m	L_v, S_v	S_v	L_m	S_m	L_m, S_m	L_m, S_m	L_v		L_m, S_m	L_v	L_m, S_m		S_m	L_v	S_m	L_m, S_m, S_v
Central AC	L_m, S_m	S_v	S_v		S_m	L_m, S_m						S					
Water heaters	L_m, S_m			L_m		L_m						S					
Heat pumps	S_m	S_v										S					
Dishwashers	L_m, S_m			L_m					S			L, S					
Clothes washers	L_m, S_m			L_m	S_m				S			L, S					
Clothes dryers	S_m			L_m					S			L, S					
Televisions		S_v			S_m				S								
VCRs		S_v							S								
Lamps	L_m	S_v				L_m											
Ballasts	L_m					L_m											
Furnaces	L_m, S_m								S			S					
Fans					S_m												
Rice cookers					S_m												
Electric kettles																S_m	
Irons					S_m											S_m	
Vacuum cleaners																S_m	
Shower heads	L_m, S_m																
Faucets	L_m, S_m																
Motors						L_m		L_v									

	United States (1978)	*Japan (1979)*	*India (1979)*	*Australia (1986)*	*China (1989)*	*Democratic People's Republic of Korea (1992)*	*Philippines (1993)*	*Thailand (1994)*	*Switzerland (1994)*	*Mexico (1995)*	*Hong Kong, China (1995)*	*Canada (1995)*	*European Union (EU) (1995)*	*Singapore*	*New Zealand*	*Russian Federation*	*Republic of Korea*
Boilers						L_m											
Computers	L_v	S_v															
Hard-disk drives		S_v															
Copiers	L_v	S_v															
Fax	L_v																
Printers	L_v																
Monitors	L_v																
Range hoods	L_v																
Transformers	L_v																
Radio receivers					S_m												

Source: Stephen Wiel, "The importance of energy efficiency labels and standards for appliances, equipment and lighting products", Lawrence Berkeley National Laboratory, presented at Energex 2000.

Note: Year in parentheses indicates year in which labels or standards were first established.

Symbols: L = labels; S = standards; L_v = voluntary labels; L_m = mandatory labels; S_v = voluntary standards; S_m = mandatory standards.

Figure II
Per capita household energy consumption in various regions, 1970-1995

Source: O. Dzioubinski and R. Chipman, "Trends in consumption and production: household energy consumption, Department of Economic and Social Affairs of the United Nations Secretariat Discussion Paper No. 6, New York, April 1999.

10. Another demand-side policy undertaken in some countries has been the encouragement of the use of compact fluorescent lamps (CFLs) in the household sector, and programmes in developing countries have received multilateral funding. Energy conserved by CFL use is considerable at up to 80 per cent of energy used in conventional lighting. Incentives have been provided in a number of countries including Brazil, Denmark, Jamaica, Lithuania, Mexico, Poland, Peru, Thailand, and the United Kingdom of Great Britain and Northern Ireland. Incentives provided have ranged from free CFLs to subsidies and rebates. The Global Environment Facility (GEF) has financed a number of CFL projects in developing countries. Moreover, global markets have expanded with developing countries' participation growing. Expiring patents are expected to result in lower prices which may make CFLs more attractive in industrialized and developing countries.

II. Regional perspectives

11. Although residential energy patterns differ across countries as the factors noted above vary, certain regional trends can be distinguished and may be useful in determining appropriate policy measures for an efficient allocation of resources in this sector. Figure I shows residential energy consumption by fuel type and illustrates the differences across regions. Most industrialized countries have reached a saturation point with regard to appliance use and consumption and are generally not responsive to energy price changes for residential energy services. Regulation and demand-side management policies may be more appropriate as policy measures in these countries than taxes and subsidies. While population growth has tapered off in many industrialized countries, the trend towards larger home sizes and smaller households points to increases in per capita energy use in this sector, though continued improvements in efficiency may continue to offset these trends.

12. Developing countries, on the other hand, are expected to record increases in per capita residential energy use as incomes increase with globalization and economic growth, and urbanization trends continue. Also, as developing countries solve the problem of energy access in rural areas, use of electricity will increase dramatically. Efficiency standards for new appliances, building codes and the elimination of energy subsidies may be appropriate policies in many developing countries, in addition to encouraging environmental standards on electricity generation facilities.

A. OECD countries

13. North American and European countries, accounting for 18 per cent of the 1997 world population, have the highest per capita household energy consumption levels, as shown in figure II. Per capita household energy consumption provides an indicator reflecting differences in lifestyles as well as income levels and prices in industrialized countries. Since the early 1970s, North America has experienced a decline in per capita household energy consumption although that consumption remains the highest in the world on a per capita basis as well as in absolute terms.

14. Recent household surveys in the United States reveal interesting changes in household energy indicators during the 19-year period between 1978 and 1997.[4] The number of households located in the southern United States increased by 44 per cent, from 25 million in 1978 to 36 million in 1997. The number of households also increased significantly in the western United States, by 57 per cent, from 8 million to 14 million. In the north-east and Mid-West regions, with colder climates, the number of households increased more modestly, by 18 per cent and 14 per cent, respectively. These changes would have a negative impact on heating fuel use, but electricity would be more likely to be used in warmer climates in the southern and parts of the western United States. Accordingly, there were significant changes in type of fuel used for heating during this period. As a proportion of total households, those using natural gas and fuel oil or kerosene declined by 3 per cent and 12 per cent, respectively, while those using electricity rose by 14 per cent over the 19-year period.[5] Given the significance of heating as an energy service in the United States and the long-term nature of the heating fuel decision, this is a significant development. Also, appliance use increased substantially during this period. Figure III shows residential fuel use in the United States having declined from 1973 to

1995, but having still remained significantly higher than that of other countries with similar income levels. Space heating fuel declines accounted for the bulk of this decrease.

Figure III

Per capita residential energy consumption by fuel type, selected countries

Source: IEA, *Energy Efficiency*, vol. 1 (Paris, OECD, 1998), chap. 3.

Note: NO = Denmark, Finland, Norway, Sweden; EUR = Italy, France, United Kingdom, and the western part of Germany; CZ = Czech Republic; JAP = Japan.

15. Per capita consumption of energy in the residential sector by European countries has remained relatively constant, as indicated in figure II, though differences among countries exist, especially between OECD countries located in Europe and non-OECD European countries, as shown in figures I and III. In OECD-Europe, energy efficiency in household appliances has improved significantly in recent years and the saturation level of household appliances is thought to be close to maximum. One recent study of consumption of household appliances in Austria showed that, though appliance electricity consumption in 1995 had been seven times higher than in 1960 and that service demand for appliances grew considerably, increases in efficiency of appliances partially counteracted these trends.[6] Income was found to be the most significant determinant of demand for household appliances, and consumers were responsive to changes in income when purchasing appliances. On the other hand, the effects of changes in electricity prices on the demand for appliances were found to be negligible. These findings point to the effectiveness of appliance standards rather than energy taxes as a means of promoting energy efficiency or a more rational use of energy for appliances in households.

Figure IV
Residential sector fuel shares in selected countries

Source: IEA, *Energy Efficiency*, vol. 1 (Paris, OECD, 1998), chap. 3.
Note: NO = Denmark, Finland, Norway, Sweden; EUR = Italy, France, United Kingdom, the western part of Germany; CZ = Czech Republic; JAP = Japan.

16. There has been some support for these findings in studies of other OECD countries. In Japan, for example, an examination of factors affecting the purchase of air conditioners (ACs) found that consumers were much more responsive to changes in the appliance price than to changes in electricity prices.[7] In a study of residential energy in Norway, it was found that income and price elasticity were both less than one (indicating that consumers were not very responsive to changes in income and prices) but that higher-income consumers were more responsive to changes in

energy prices than lower-income consumers.[8] This may reflect a change in luxury appliance use when energy prices change. Findings in Great Britain support these results.[9] A more inclusive examination of OECD countries showed that income elasticity had declined as appliance and heating saturation was approached.[10] In OECD countries, it is expected that energy consumption will not necessarily continue to rise as much as incomes increase since most households have already made major appliance purchases, especially for space and water heating and cooking.

17. These results tend to indicate that prices (or taxes on energy products and/or electricity) as a policy tool to affect residential energy demand in industrialized countries will have limited impact. As households in industrialized countries reach saturation with regard to appliances and heating and/or cooling units, turnover of appliances rather than purchase of additional appliances becomes the norm. Applying and/or regulating technical standards may be a more effective policy tool for influencing energy use in the household sector.

18. Generally, residential energy consumption in industrialized countries will depend on the continued trend towards individual detached housing units, increased efficiency of heating systems, changes in lifestyle and habits, efficiency in the provision of lighting services (such as the use of compact flourescent lamps), trends in efficiency and use of household appliances, and space and water heating needs.

B. Non-OECD European countries

19. Non-OECD European countries comprise Eastern Europe and the former Soviet Union and account for approximately 7 per cent of the world population. Their geographical location necessitates that a significant portion of household energy be used for space and water heating. Residential building size per family is typically smaller than that found in the OECD countries, with overall residential space one half to one third of that in OECD-European countries. However, heating systems and appliances may not be as efficient as those in industrialized countries with regard to energy use. District heating systems in non-OECD countries are, in many cases, outdated and inefficient.

20. Figure I shows per capita household energy consumption by energy type and indicates that, in Eastern Europe, coal and natural gas are the most used fuels in this sector, though electricity, fuelwood/charcoal and, to a lesser extent, petroleum products are also used. In 1992, approximately 20 per cent of Lithuanian households utilized coal as their main heating fuel. In Poland and Estonia, this figure amounted to approximately 50 per cent and 10 per cent, respectively. Figure III provides further details for Poland, the Czech Republic and Estonia.

21. Non-OECD European countries are undergoing a transition from largely centrally planned economies to a greater reliance on market forces. For households, this has meant higher energy prices and/or shortages of energy, especially during winter months when demand is high, though policies aimed at individual demand have not been the main thrust of policy measures in these countries. Rather, improving the efficiency of centralized equipment and distribution systems has been the focus of efforts in many of these countries. The installation of metering systems has been initiated but tariff restructuring to rationalize demand has not been initiated in most non-OECD European countries.

C. Developing countries

22. Developing countries are expected to realize a rapid growth in energy consumption both on a per capita basis and at the absolute level as their economies grow, incomes increase, lifestyles change and households switch from non-commercially traded fuels to modern energy services. Figure I shows per capita household energy consumption having remained relatively constant since 1970 in most developing regions. However, owing to population increases, total household energy consumption has increased throughout this period in all developing regions.

23. Figure I, showing residential energy consumption by energy type, indicates that sub-Saharan Africa, containing 12 per cent of the 1997 world population, uses mainly fuelwood and charcoal. Developing countries in the Asian and Pacific region, which constitute 54 per cent of the 1997 world total population, use largely fuelwood/charcoal, though some coal and petroleum products are also utilized by households. In Asia, as much as 70 per cent of the population live in rural areas needing fuelwood and depending on the integrity of the environment for basic necessities. In addition to fuelwood, 350 million tons of crop residue and 400 million tons of dung are burned annually. The Latin American and Caribbean region, containing 6 per cent of the 1997 world population, also uses mostly fuelwood/charcoal but petroleum products, natural gas and electricity are used as well.

24. The trend towards urbanization in developing countries accelerates increases in household energy consumption, and changes in lifestyles and habits associated with economic growth and urbanization have also contributed, and will continue to contribute, to increases in household sector energy use in developing countries. In 1995, the United Nations estimated that 46 per cent of the world's population (2.6 billion) resided in urban areas, and this figure is expected to increase to 50 per cent in 2006 and become more than 60 per cent by 2030. By 2030, developing countries are expected to house 80 per cent of the world's urban population and 86 per cent of the world's total population compared with 66 per cent and 79 per cent, respectively, in 1995. Urban lifestyles are associated with greater per capita energy use as more energy services for cooking, lighting, heating and cooling are demanded, and as the incidence of commercially traded energy use in developing countries increases.

25. More than 2 billion people, mostly located in rural areas of developing countries, live without access to modern energy sources. Their use of firewood, charcoal, biomass, including crop residues, and animal dung is mostly for cooking purposes, and their choice of fuel depends upon availability in the local area. Recent studies indicate that, as income increases, the type of energy used by rural households changes. In areas where annual per capita income is less than $300, 90 per cent of the people use traditional fuels for cooking.[11] As incomes increase above that level, to between $1,000 and $1,500 per year, households tend to rely entirely on conventional fuels. Also, since non-commercial fuels are typically not counted in energy balances and statistics, as households switch to these services significant increases in household energy use will be recorded. The concept of an "energy ladder", whereby households move from least efficient fuels to more efficient fuels as incomes increase and economic growth is realized, may be useful in predicting trends in energy use in the household sector in many developing countries.[12]

26. A recent survey of rural households in South Africa showed that the majority of households used a number of different fuels to satisfy their energy needs, even among those with access to electricity.[13] In fact, among those with access to electricity, only the high-income households relied mostly on electricity and this category represented only 14 per cent of electrified households. Consumption and income patterns generally fit the energy ladder concept but there was a higher incidence of multi-fuel use in middle-income rural households than expected. Also, access to electricity accelerated the move to more efficient fuels in rural-area households.

27. Though demand for energy by the household sector is rather inelastic with respect to price in industrialized countries, the effect of price is difficult to assess in developing countries. Thus, the impact of price-related polices such as taxes and subsidies in developing countries is uncertain without further study. Many basic services utilized by the household sector in developing countries, including energy, have been subsidized as a matter of social policy. However, many countries are re-examining such policies, noting that they lead to overconsumption and that they tend to benefit the middle and wealthy classes far more than the poorest strata of society. Other social policy measures may be more appropriate and more effective than energy subsidies. Recent investigations show that elimination of subsidies aimed largely at households in eight developing countries and economies in transition resulted in significant benefits to the environment.[14]

28. Renewable energy technologies may offer a solution for households in many areas where modern energy services are costly, especially rural and remote areas with widely dispersed populations. These technologies include mini- (and micro-) hydroelectric systems, solar systems (photovoltaic and solar thermal), wind energy, modern biomass including biogas systems, and geothermal systems. The feasibility of application of different renewable technologies often depends on locality and availability of energy resources as well as social factors. A recent assessment of solar cookers, for example, found that widespread adoption in appropriate areas could reduce deforestation, improve health conditions and improve the quality of life, especially of women, in many rural and remote areas.[15] However, certain cultural barriers, including food preparation methods, and misconceptions about solar cookers would have to be overcome.

III. Residential energy use and environmental issues

29. Environmental issues associated with residential use are closely linked to electricity in industrialized countries, countries in transition and, to some extent, developing countries. Electricity meets the need for lighting and powering appliances, as well as for water and space heating. Further increases in the demand for energy services in the residential sector in developing countries are expected to be satisfied with expanded electricity capacity. Environmental implications depend on many factors including the fuel type selected. Fossil fuels, nuclear fuels and hydropower can be used to generate electricity, each with vastly different environmental impacts. Also there is a range of impacts from the local level to the global level, depending on plant type and size. Decisions made in the electricity sector require long-term investments, and careful consideration of environmental impacts is important in the decision-making process.

30. Options for reducing carbon dioxide (CO_2) and other emissions in the electricity industry identified by the Intergovernmental Panel on Climate Change (IPCC) include achievement of greater efficiency by improving existing facilities with high-efficiency systems, the introduction of combined cycle power systems, and the improvement of boiler systems.[16] Also, using technologies to facilitate the co-generation of electricity and steam would lessen emissions as well as improve the operation and maintenance of systems, as would the introduction of photovoltaics, especially for local generation, and the use of fuel cells. A greater reliance on hydroelectric facilities where feasible would have a positive effect on emissions but might result in local land degradation and other social and environmental externalities. Other non-fossil fuel options include the expansion of nuclear power plants, the development of geothermal projects and wind turbines and the expansion of sustainable biomass combustion. In addition, the replacement of scrubbers and other energy-consuming technologies with more energy efficient emission control is recommended by IPCC.

31. Electricity use in the residential sector is associated with varying effects on the environment depending on the source of power for generation. Norway, for example, where 70 per cent of produced electricity is used in the residential sector, utilizes hydroelectric facilities to generate 100 per cent of its electricity. Its electricity consumption was not associated with emissions until recently when it began importing electricity from Denmark, where electricity is mainly generated with coal and has significant CO_2 emissions.[17] (To ensure that consumers pay the full environmental cost of electricity generated by coal, and to encourage conservation, taxes on electricity are now under consideration in Norway.)

32. In developing countries with large populations currently consuming relatively low levels of commercial energy in the residential sector, and that are expected to experience significant economic growth, such as China and India, decisions about how to satisfy growing residential energy demand will have an impact on local and global environmental decisions. Electricity consumption in the residential sector has increased in most developing countries, as shown in table 3. Significant increases in consumption during the five-year period from 1991 to 1996 have been recorded in highly populated countries including Bangladesh, China, Ethiopia, India, the Republic of Korea and Thailand, as well as in Chile, Israel, Jordan, Malaysia, Myanmar and Nepal.

33. Developing countries rely to a large extent on thermal power plants for their electricity generation, as illustrated in table 3, though many of those with hydro potential do utilize it for electricity generation purposes. In Africa, Côte d'Ivoire, Ghana, Kenya, Madagascar, Malawi, Mali, the Sudan, Zambia and Zimbabwe rely on hydroelectricity to meet most of their electricity demand. In South America, hydroelectric power satisfies most of the electricity demand in Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Paraguay, Peru, Uruguay and Venezuela; and in Asia, it is used to a significant extent in China, India, Nepal, Pakistan and Sri Lanka. Nuclear power facilities are used in several countries, and electricity generated from geothermal energy accounts for a small percentage of total electricity generated.

Table 3
Electricity consumption and generation type in selected countries

Country	*Household electricity consumption (millions of kilowatt hours)*			*Total production (millions of kilowatt hours), 1996*				
	1991	*1966*	*Percentage change*	*Nuclear*	*Hydro*	*Geothermal*	*Thermal*	*Total*
Algeria	4 000	4 760	19		130		20 524	20 654
Bangladesh	2 292	4 411	92		739		11 665	12 404
Barbados	426	520	22				650	650
Bolivia	986	1 410	43		1474		1 742	3 216
Botswana	185	245	32				757	757
Brazil	101 474	137 625	36	2 429	261 939		9 457	273 825
Brunei Darussalam[a]	622	805	29				1 575	1 575
Bulgaria	12 950	16 821	30	18 000	2 400		22 316	42 716
Burundi	80	87	9		118		2	120
Central African Republic	42	40	-5		82		22	104
Chile	5 281	9 950	88		18 862		12 416	31 278
China	135 240	240 000	77	13 620	187 966		879 724	1 081 310
Colombia	19 174	23 844	24		34 638		9 967	44 605
Costa Rica	2 440	3 035	24		3 630	470	753	4 853
Côte d'Ivoire	678	679	0		1 108		810	1 918
Croatia	5 801	7 391	27		7 228		3 320	10 548
Cuba	5 526	5 623	2		112		13 124	13 236
Cyprus	1 434	1 868	30				2 592	2 592
Dominican Republic	2 722	3 601	32		2 103		4 744	6 847
Ecuador	3 595	4 715	31		7 500		1 760	9 260
El Salvador	1 350	2 084	54		1 883	431	1 138	3 452
Estonia	3 185[b]	2 816	-12		2		9 101	9 103
Ethiopia (including Eritrea)	307	559	82		1 507	70	98	1 675
Fiji	89	103	16		430		115	545
Gabon[a]	477	473	-1		728		221	949
Ghana[a]	432	420	-3		6 625		6	6 631
Grenada	47	69	47				95	95
Guatemala	1 319	1 970	49		2 339		1 161	3 500
Haiti	177	162	-8		255		378	633
Honduras	1 019	1 318	29		2 585		230	2 815
Hungary	17 266	18 438	7	14 180	207		19 830	34 217
India	115 836	170 850	47	8 000	73 515	156	350 668	432 339
Israel	13 081	20 894	60		24		32 442	32 466
Jamaica[a]	1 435	1 945	36		128		5 910	6 038
Jordan	2 093	3 349	60		22		6 036	6 058
Kenya	989	1 275	29		3 120	290	335	3 745

Country	Household electricity consumption (millions of kilowatt hours)			Total production (millions of kilowatt hours), 1996				
	1991	1966	Percentage change	Nuclear	Hydro	Geothermal	Thermal	Total
Korea, Republic of	40 969	82 814	102	73 924	5 201		148 429	227 554
Latvia	3 537[b]	2 567	-27		1 860		1 263	3 123
Macao, China	663	1 220	84				1 620	1 620
Madagascar[a]	89	92	3		425		258	683
Malawi[a]	319	505	58		855		19	874
Malaysia	11 468	20 140	76		5 139		47 861	53 000
Mali	106	113	7		212		123	335
Mauritius	391	643	64		103		1 152	1 255
Mexico	41 901	50 462	20	7 878	31 692	5 734	117 222	162 526
Morocco[a]	4 338	5 100	18		765		11 413	12 178
Myanmar	932	1 565	68		1 630		2 626	4 256
Nepal	296	535	81		1 154		64	1 218
Nicaragua	838	944	13		355	600	964	1 919
Niger[a]	146	162	11				177	177
Pakistan	20 272	29 534	46	483	23 206		33 257	56 946
Panama	1 808	2 610	44		3 003		955	3 958
Papua New Guinea[a]	470	475	1		495		1 295	1 790
Paraguay	1 574	3 350	113		48 033		167	48 200
Peru	6 385	5 541	-13		16 528		3 510	20 038
Philippines	12 026	15 800	31		6 616	6 100	22 059	34 775
Poland	45 818	42 396	-7		3 910		135 880	139 790
Romania	13 356	12 889	-3	1 386	15 755		44 209	61 350
Russian Federation	208 355[b]	265 800	28	99 000	165 000	30	583 170	847 200
Senegal	189	185	-2				1 160	1 160
Seychelles	29	34	17				128	128
Sri Lanka	1 784	2 110	18		3 249		1 117	4 366
Sudan	695	728	5		946		392	1 338
Thailand	23 584	42 709	81		7 341	1	84 125	91 467
Trinidad and Tobago	1 206	1 259	4				4 541	4 541
Tunisia	2 337	3 526	51		67		7 770	7 837
Uruguay	2 592	3 655	41		6 199		467	6 666
Venezuela	21 534	26 233	22		56 000		18 968	74 968
Zambia	2 000	2 010	1		7 755		40	7 795
Zimbabwe	3 395	4 075	20		2 167		5 652	7 819

Source: Department of Economic and Social Affairs of the United Nations Secretariat, Energy balances electricity profiles, 1996 (New York, 1999).

[a] Estimate.

[b] Data for 1992.

34. In rural areas of developing countries, fuels currently used in the household sector are often associated with adverse health and environmental impacts (see report of the Secretary-General on the development and implementation of rural energy policies (E/C.13/1998/5) of 3 February 1998). The burning of firewood and dung emits carbon monoxide, particulate matter and other pollutants that are responsible for a variety of health problems including bronchitis, emphysema and other respiratory diseases, which contribute to higher mortality rates. Generally, infants and children are diversely affected, as acute respiratory infections, which cause approximately 4 million deaths each year, are at least partially attributable to smoke inhalation. Use of dung as a fuel rather than fertilizer may also reduce nutrients available in the soil. One recent study found that the use of 400 million tons of dung for energy purposes in Asia could have been used to fertilize enough soil to contribute 14 million additional tons of grain.[18]

Table 4
Comparison of air pollutant emissions of various stove types
(kilograms per unit of energy delivered)

Fuel uses and scale (efficiency)	*Amount equivalent to 1 million megajoules (MJ) delivered*	*Particulates*	*Sulphur oxides*[a]	*Nitrogen oxides*	*Hydrocarbons*	*Carbon monoxide*
Residential heating stoves (less than five kilowatts)						
Wood (tons) (50 per cent)	130	2 700	30	100	6 800	17 000
Anthracite (tons) (65 per cent)	49	48	200	250	100	1 000
Bituminous (tons) (80 per cent)	53	550	1 100	270	530	5 300
Distillate oil (liters) (90 per cent)	33 000	11	1 200	71	4	20
Natural gas (cubic metres (m^3)) (90 per cent)	30 000	7	negative	38	4	10
Cooking stoves						
Tropical wood (tons) (15 per cent)	420	3 800	250	300	3 200	34 000
Cow dung (tons) (15 per cent)	530	10 000	3 200	7	?	44 000
Indian coal (tons) (20 per cent)	220	280	2 200	460	2 200	27 000
Coconut husk (tons) (15 per cent)	480	17 000	?	7	?	54 000
Natural gas (m^3) (80 per cent)	32 000	1	negative	10	5	250

Source: United Nations Development Programme, *Energy After Rio* (New York, 1997).

[a] Sulphur emissions from fossil fuel vary widely depending on fuel quality.

35. Table 4 indicates the emissions from various types of residential heating stoves and from cooking stoves often used in developing countries along with an efficiency rating for each type of stove. Natural gas is the most efficient fuel listed and emits the least amount of each pollutant in almost every category. Solar cookers, not listed in table 4, also have the potential to provide heat for cooking in some areas without adverse environmental effects.

36. The use and overuse of wood fuels have negative environmental effects, namely, with respect to deforestation, especially in sub-Saharan Africa. Though evidence exists that some wood fuel is gathered in non-forested areas, *inter alia*, along roadsides and next to fields and houses, fuel gathering is a major cause of deforestation in some areas, including sub-Saharan Africa, especially where fuelwood is used for charcoal production.[19] Two out of three developing countries face fuelwood shortages and in some countries, such as the United Republic of Tanzania and Haiti, areas particularly hard hit by deforestation have been described as "scorched-earth" areas. Often these areas supply fuelwood for thriving commercial charcoal suppliers to urbanized or semi-urbanized areas. Furthermore, deforestation has direct implications for the time required to gather wood for household use in rural areas and a negative impact on the use of time and quality of life of women and children who undertake this task. This and other negative social impacts of deforestation on local populations are also important considerations in determining how to best provide energy for residential use with minimal adverse environmental effects so as to achieve the goal of sustainable development.

IV. Conclusions and recommendations

37. Although per capita energy consumption in the residential sector has been decreasing in industrialized countries and has levelled off in developing countries, total consumption is expected to increase as population increases, especially in developing countries. Other factors affecting demand include income, lifestyle, cultural habits, household size and climatic conditions, many of which are expected to contribute to increased demand in this sector in developing countries as they experience economic growth. The trend towards smaller households, with fewer members, in many countries will lead to increases in per capita energy demand.

38. There is evidence that a saturation in appliance and household energy use has been reached in many industrialized countries. Efficiency gains may be realized as consumers trade old appliances for new ones, if improved standards on new appliances are applied and enforced.

39. Consumers in industrialized countries appear not to be highly responsive to price changes, indicating that regulations, standards and labelling may be more effective than price policies in curbing demand, reducing emissions and ensuring that environmental goals are met in these countries, especially for electricity. Since household appliance prices appear to have greater influence over consumer decisions than electricity prices, policy makers may wish to target appliance prices when considering subsidies and taxes as a means to curb household demand for energy.

40. Demand-side management policies have been successful in curbing residential energy demand and promoting energy efficiency in this sector in some countries. These measures include dissemination of information, raising consumer awareness

about energy efficiency products, voluntary and compulsory standards on appliances and equipment, and labelling. Governments should consider such policies especially when undertaking deregulation of the electricity industry, which is expected to lower electricity prices.

41. Local governments have a role to play in setting and enforcing building codes that ensure energy efficiency in residential and other buildings. In localities served by district heating, efforts should be undertaken to improve efficiency of these systems and national Governments may wish to assist if local financing is unavailable.

42. A significant portion of households in rural areas in developing countries rely on sources of energy that are not commercially traded to meet cooking, lighting, water heating and space heating needs. Thus, they are often not considered in energy balances and subsequent analyses, and may be overlooked by decision makers. As socio-economic conditions improve, switching to more efficient fuels occurs and total energy use increases in this sector. Renewable energy technologies may be appropriate in many rural areas to meet household needs and such technologies often provide energy services with minimal environmental effects. However, incentives by Governments such as soft-term consumer loans, subsidies and various incentives to the private sector may be required to initiate renewable energy programmes in rural areas.

43. Investment decisions in the electricity industry have long-term implications for the environment, and such decisions should be made with all environmental costs and risks included in cost/benefit and accounting analyses undertaken to assist in the decision-making process. Countries undergoing privatization of their electricity industries should ensure that appropriate environmental regulations are in place and properly enforced.

44. The adoption of cleaner technologies for electricity generation should be encouraged at the national, regional and international levels.

Notes

[1] See *Official Records of the Economic and Social Council, 1999, Supplement No. 12*, (E/1999/32, chap. I, sect. B, draft decision II.

[2] L. Schipper, F. Unander and C. Marie-Lilliu, *The IEA Energy Indicators Effort: Extension to Carbon Emissions as a Tool of the Conference of Parties* (Paris, International Energy Agency, 1999).

[3] M. Colombier and P. Menanteau, "From energy labelling to performance standards: some methods of stimulating technical change to obtain greater energy efficiency", *Energy Policy*, vol. 25, No. 4 (1997), pp. 425-434.

[4] United States Department of Energy, *Residential Energy Consumption: Two Decades*, 1997.

[5] Percentage of households using liquefied petroleum gas (LPG) and wood for heating purposes remained the same at 4 per cent and 2 per cent respectively.

[6] R. Haas and others, "Impacts on electricity consumption of household appliances in Austria: a comparison of time series and cross-section analyses, *Energy Policy*, vol. 26, No. 13 (1998), pp. 1,031-1,040.

[7] I. Matsukawa and N. Ito, "Household ownership of electric room air conditioners", *Energy Economics*, vol. 20 (1988), pp. 375-387.

[8] Runa Nwsbakken, "Price sensitivity of residential energy consumption in Norway", *Energy Economics*, vol. 21 (1999), pp. 493-515.

[9] A. Henley and J. Peirson, "Residential energy demand and the interaction of price and temperature: British experimental evidence", *Energy Economics*, vol. 20 (1998), pp. 157-171.

[10] R. Haas and L. Schipper, "Residential energy demand in OECD-countries and the role of irreversible efficiency improvements", *Energy Economics*, vol. 20 (1998), pp. 421-442.

[11] D. F. Barnes, R. van der Plas and W. Floor, "Tackling the rural energy problem in developing countries", *Finance and Development*, vol. 34, No. 2 (June 1997), p. 12.

[12] United Nations Development Programme (UNDP), Department of Economic and Social Affairs of the United Nations Secretariat and World Energy Council (WEC), *World Energy Assessment* (forthcoming), chap. 10.

[13] M. Davis, "Rural household energy consumption", *Energy Policy*, vol. 26, No. 3 (1998), pp. 207-217.

[14] K. Varangu, "Global energy trends and sustainable development: an IEA perspective", presented to the first session of the Ad Hoc Open-Ended Group of Experts on Energy and Sustainable Development, New York, 6-10 March 2000.

[15] M. Tucker, "Can solar cooking save the forests?", *Ecological Economics*, vol. 31, No. 1 (1999), pp. 77-89.

[16] World Meteorological Organization/United Nations Environment Programme, *Climate Change: The IPCC Response Strategies* (1990).

[17] R. Nesbakken, "Price sensitivity of residential energy consumption in Norway", *Energy Economics*, vol. 21 (1999), pp. 493-515.

[18] K. Miller and L. Tangley, *Trees of Life: Saving Tropical Forests and Their Biological Wealth*, (Boston, Massachusetts, Beacon Press, 1991).

[19] *World Energy Assessment* ..., chap. 3.