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EFFICIENT USE OF ENERGY SOURCES IN MEETING HEAT DEMAND

The potential for energy conservation and fuel substitution in the ECE region

TKO

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ABBREVIATIONS

ach	air changes per hour
AGR	advanced gas-cooled reactor
bbl	barrel
boe	barrel of oil equivalent
Btu	British thermal unit
cf	cubic feet
BWR	boiling-water reactor
FBR	fast-breeder reactor
Gcal	gigacalorie
GCR	graphite-core reactor
GJ	gigajoule
HTR	high-temperature reactor
GNP	gross national product
kWh	kilowatt hour
LNG	liquefied natural gas
LWR	light-water reactor
mBtu	million Btu
PJ	petajoule (10^{15} joules)
EJ	exajoule (10^{18} joules)
PWR	pressurized water reactor
SGHWR	steam-generating heavy water reactor
quad	quadrillion (10^{15} Btu)
tce	ton of coal equivalent
THTR	gas-cooled high-temperature reactor
toe	ton of oil equivalent
TWh	terawatt-hour (10^{12} watt hours)

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References to dollars ($) are to United States dollars unless otherwise specified.

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SUMMARY

TOWARD A REORIENTATION OF ENERGY POLICIES

High energy prices, low rates of economic growth, changing international economic relationships, resource constraints and growing concern over the environment are exerting strong pressure on the energy economies of the countries of the Economic Commission for Europe. These countries are making a transition from growth-oriented energy systems, based on a cheap and abundant supply of oil, to systems based on a more rational use of a varied fuel supply mix.

Energy planning in the past has very largely been focused on the supply side. In keeping with the efforts to adjust to the new energy situation, the ECE countries have taken a new look at energy consumption. It has become clear that there exists an enormous and highly profitable potential for reducing wasteful consumption, for using different energy sources—not just more oil—and for slowing energy demand growth and decoupling it from the growth of the general economy.

Over the past ten years official energy demand forecasts, particularly those pertaining to future "oil gaps", have been gradually revised downward. Energy policies based upon simple extrapolations of past energy demand behaviour now appear to be unrealistic. It has become increasingly clear that sound policies can only be formulated on the basis of a detailed analysis of the specific *end-use requirements* for different kinds of energy, as well as the supply sources which are most suitable for meeting these requirements. An analysis of this kind must also be based on reasonable assumptions with regard to economic, technical, social and environmental constraints.

Until recently, analyses of this type, focusing on the end-uses of energy, have been carried out only at the expert level and, in a few cases, at the national level. Within the framework of ECE, however, a first attempt has been made to examine these matters at the intergovernmental level. The results to date of this examination are still preliminary, and much further work is required. It already seems clear, however, that these recent results will constitute a turning-point in the shaping of energy policy in the ECE region, and perhaps beyond.

What do we mean by end-use energy demand? In essence, it is the demand *by final consumers* for energy. Final consumers require energy in any of three different forms, namely:

1. Energy requirements in the form of portable liquid fuels for the transport sector (e.g. fuels for cars, buses, lorries, aircraft, etc.);

2. Energy requirements for which electricity is indispensable (e.g. for lighting, fixed-motors, electrolysis, electronic equipment, electric trains and trams, etc.). It should be noted that these "electricity-specific" needs, with few exceptions, exclude thermal uses;

3. Energy requirements in the form of heat. This latter and most important form can be conveniently considered in several temperature ranges, e.g.:

Low-temperature range (below 100° C), required mainly for the space heating of residential, public, commercial and industrial buildings, and also for hot water consumption;

Intermediate-temperature ranges (100° C - 300° C), required for heat processing in the chemical, paper, sugar, food, textile and other industries, usually in the form of steam. Cooking requirements also fall within this range;

High-temperature range (above 300° C), corresponding to a broad spectrum of industrial requirements. In some processes (i.e. in the iron and steel and cement industries), temperature requirements may exceed 1,000° C.

It should be noted that, since energy end-use demand has been defined above as the energy required by the final consumer, this demand does not include fuels used for feedstock.

Information concerning the end-use demand for energy in the ECE region has recently been obtained from a major survey [1] carried out by the ECE secretariat. The results are impressive and of transcending importance, particularly since they are not generally recognized. Highlights are:

1. Of the vast amount of energy consumed in the ECE region (80 per cent of the total world demand), well over 60 per cent is used for the purpose of *heat*. Of the remainder, about 25 per cent is for transport and less than 15 per cent is for electricity-specific purposes;

2. Of the 60 per cent end-use for heat, roughly half of it is used for *heat at less than 100° C*—i.e. a very low-grade form of energy which can be provided by a wide variety of sources;

3. This pattern of end-use demand, dominated by low-temperature heat, is generally valid with no major differences in western Europe, eastern Europe (including the Union of Soviet Socialist Republics USSR) and North America. Moreover, the pattern is generally expected to prevail over the medium and long term, i.e. up to the year 2000.

These results, together with the ramifications which would appear to emerge therefrom, warrant careful examination by all countries of the ECE and beyond. For example, with regard to the consumption of low-temperature heat (i.e. one third of the ECE's energy consumption), are we really using it properly and efficiently, or are we wasting it flagrantly? Are we, for reasons of inertia from the past, using high-grade energy

[1] See chapter I, "End-use energy demand in the ECE region".

to meet a requirement which can be satisfied by a lower-grade (and hence cheaper) form of energy? Questions of this nature seem to be of critical importance for resolving the main economic challenge which is confronting the ECE region today.

In view of the dominant importance of heat in the overall final demand, the examination of the end-uses of energy which has recently been carried out within ECE has focused on this aspect of the problem. The reason is simple: the present vast requirement for heat, particularly low-temperature heat, most of which is provided by oil and gas, offers great potentialities for:

Energy conservation (by reducing needless losses and improving the overall efficiency of energy use); and

Fuel substitution (i.e. replacing gas and oil by coal, nuclear power and renewable energy sources).

Improvement in the efficiency of energy use

In view of the sharp rise in primary energy costs during the past ten years, there has been a rapidly growing need for using energy much more efficiently. In response to this need, there have recently been a number of relevant technological developments which, as a result, have given rise to an enormous potential for improving the efficiency of energy use and hence for energy conservation. This conservation potential is particularly important in the case of end-use heat demand, which (as already pointed out) amounts to approximately one third of total final energy consumption in the ECE region.

Indeed, on the basis of a recent study,[2] it is estimated that such conservation measures, if effectively carried out, could lead to cost-effective savings of 20 per cent or more of end-use heat consumption in the ECE region taken as a whole. More specifically, this heat conservation potential is estimated to be 21 per cent in the USSR, 24 per cent in other east European countries, 24 per cent in western Europe and 32 per cent in the United States of America. In contrast, the savings to be derived from measures to conserve motor fuel and electric power in the ECE countries are estimated to be 11 per cent and 9 per cent respectively.

The kind of measures to be carried out in the case of heat conservation include: better insulation, improved end-use conversion technologies, partial recovery of heat from warm exhaust gases and liquids, greater use of heat pumps, co-generation of steam and electricity, etc. Some of these techniques are somewhat sophisticated; others, however, are relatively simple and straightforward.

As an example, an independent study[3] has shown that—in the case of low-temperature heat requirements for residences in the United States (i.e. for space heating and hot water)—3.9 quads can be saved cost-effectively out of a total residential consumption of 12.2 quads. Moreover, these savings can be achieved by the simplest of procedures—namely by retrofitting suitably selected existing houses with high-quality insulation and by weather stripping. This very significant saving of energy (32 per cent) is thus achievable through modest investments by a large number of people, i.e. homeowners and/or residents. Since such modifications would be economically viable, the modest investments involved per home would make eminently good sense to all concerned.

The application of these and other energy conservation measures would result in changes in the pattern of energy consumption and, in particular, in the mix of energy supplies for different end-uses. The largest savings potential is to be found in substitutable fossil fuels, amounting to nearly 30 per cent.

Special consideration should be given to energy sources which, while perhaps not capable by themselves of fully or continually meeting low-temperature heat needs, are at least capable of making a substantial contribution towards these needs, e.g. in the form of pre-heating. Solar energy (both passive and active) constitutes one of such sources; in most cases it requires a supplementary or back-up supply, either to provide a higher temperature or to compensate for unfavourable climatic conditions. The choice of such a supplementary back-up system will again usually be determined largely by economic considerations. Numerous possibilities exist, including electricity if its use can result in a sufficiently large reduction in total capital costs to the consumer.

Barriers that hamper progress in energy conservation

From the above (and many other) considerations, it is clear that the potential for technically feasible and cost-effective energy conservation is very important indeed, particularly with regard to end-use heat requirements. Unfortunately, however, there are a number of barriers which impede its realization.

Among them is the fact that this potential has been, and continues to be, grossly underestimated. The effective dissemination of information on this subject, especially by governments (which face less of a credibility problem than, say, manufacturers of energy-saving equipment), is indispensable for stimulating investment. As an example, services must be established to provide residential sectors with objective information and guidance concerning conservation measures in homes.

A second barrier is the problem of access to capital in a period of economic recession. Since investment in fuel savings is a better use of capital than that of developing new fuel supplies, measures can be justified to facilitate access to such capital, e.g. by government incentives such as tax rebates and low-interest loans.

With regard to new buildings, many are still being built with little concern for energy conservation, particularly if those who carry out the design and construction feel little responsibility to those who ultimately must pay the heat bills. It is thus essential that energy-related regulations be enacted in which standards are set for the thermal performance of building components, airtightness and ventilation, insulation of the building envelope, etc. Similar but less rigorous regulations and standards should also be invoked with regard to retrofitting programmes.

With regard to industry, manufacturers who are seeking to maintain their international competitiveness

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[2] See chapter II, "The role of energy conservation in reducing end-use energy demand in the ECE region".

[3] See chapter V, I, "United States of America: Cost-effective fuel savings in heating applications".

will be obliged to produce, in an energy-efficient way, less energy-intensive goods. Whether through price mechanisms or through government-planned allocations, the replacement of the present capital stock will undoubtedly be guided by such energy-conservation criteria.

Meeting end-use heat requirements with the appropriate energy source

Meeting end-use heat demand with the appropriate energy source or combination of sources requires careful consideration of the economic, technical, environmental and social aspects involved. An evaluation of the suitability of each primary energy source for satisfying specific heat requirements was carried out in 1983 at the Ohrid (Yugoslavia) Symposium by government rapporteurs in special reports. The following paragraphs present only a few of the basic features of this examination.[4]

The vast *coal* reserves of ECE member countries may be used as a substitute in the demand pattern for relatively scarce oil. However, costs associated with production, transport and environmental protection limit the viability of a massive coal substitution. Coal use will certainly be favoured if, in addition to its traditional heat markets (coking coal), centralized heating systems in urban areas (combined or not with electricity generation) are more generally adopted.

The use of *hydrocarbons* for meeting heat requirements should be considered only for those applications for which they have net advantages (e.g. gas for cooking or for industrial uses requiring specific flame characteristics; smaller industrial consumers). The burning of hydrocarbons for space heating purposes—though highly efficient—would have to be weighted against premium uses of these scarce resources in the transport sector or as feedstocks; other more abundant resources are available to meet heat requirements.

Nuclear power plants are gaining in importance as a primary source of electricity, despite obstacles of a technical, environmental and social nature. Problems remaining to be satisfactorily resolved include: the disposal of wastes and widespread public concern regarding nuclear energy, even for peaceful purposes. If they are to be viable, nuclear power plants must be used to full capacity in order to amortize the heavy capital investment and construction costs. Seasonal heat requirements, peak demands and intermittent users (whose needs often fall within the low-temperature range) require a more flexible form of supply.

One third of the technically available *hydropower* potential of the ECE region has already been harnessed; the remainder, concentrated in a few countries, presents economic and environmental difficulties which suggest that this source will not make a further significant contribution to the electricity supply system. To meet heat requirements, hydropower should be used mainly in areas with abundant hydro resources, involving large electricity systems and often in combination with thermal units or large storage capacities.

With regard to *new and renewable energy sources*, it is important to distinguish between those sources which have proved to be economically competitive and technologically mature for satisfying heat demand, and those sources which require further research and development. Passive solar applications, flat-plate solar collectors and heat pumps are sources of renewable energy which are being increasingly accepted and used by the public. Undoubtedly, their role will be of growing importance in meeting low-temperature heat requirements in the ECE region. Biomass or geothermal resources could, in certain endowed regions, constitute significant sources of heat.

Electricity continues to be a particularly convenient and flexible form of energy, and is indispensable for certain specific requirements. It can be economically produced from a variety of primary sources: hydropower, nuclear power, oil, gas and coal. Official energy supply policies of the ECE countries anticipate a rapid increase of electricity consumption. The conditions under which electricity can be economically produced and efficiently used to satisfy heat demands deserve analysis, including analysis of prevailing specific circumstances, such as losses incurred in generation and the adverse effects of plants on the environment on the one hand, and co-generation, special applications or use as a back-up source on the other.

Aspects to consider when making a comparative assessment of energy sources in meeting heat requirements

(a) *Importance of local conditions*

Heat demand patterns vary from country to country and even from region to region within each country.[5] Throughout the year, a relatively constant, albeit minor, share of low-temperature heat is used to make hot water. Space-heating requirements, which constitute the major low-temperature heat demand, are seasonal and largely a function of the climatic conditions of the various ECE countries. Moreover, heat demand will vary depending upon the level of urbanization and industrialization, and thus the pattern of requirements in cities will differ from that in rural areas. In designing supply systems, these differences need to be taken into consideration.

In general, domestic energy resources should be given preference over costly and uncertain imported energy supplies. Transport costs, both external and internal, can be greatly reduced through effective energy planning involving the maximum use of local resources. Wherever possible, industrial heat losses at higher temperatures should be recovered and applied to lower heat uses. In some regions, available hydro resources or low-priced industrial wastes or natural gas may be competitive in the heat market. In the long run a geographical redistribution of energy-intensive industries, shifting to energy-rich resource areas, could be envisaged.

(b) *Changing existing patterns of heat demand and energy supply systems*

Energy demand levels within a given country are, of course, closely tied to the consumer habits and patterns of its population, and also to the efficiency of its equipment. For effective energy planning, it is important

[4] A more complete analysis can be found in chapter III, "Evaluation of energy sources".

[5] See country case studies, chapter V.

to look ahead at least twenty years and evaluate the impact of various technical and social changes on the energy consumption pattern. These changes include: improved insulation on a large scale; more efficient and economical appliances, vehicles, equipment, etc; technological developments in industry; and changes in consumer life-styles. Conservation should not only be a short-term objective, but a long-term and continuing one. In order to cover the costs of research and development (R and D) and new equipment, a strong economic base and rate of growth is important, if not essential.

Another factor to be considered is the long lead time of innovative energy systems in general. Large, capital-intensive projects (such as the development of a new coal mine or oil field, or the building of a nuclear or hydropower plant) have an average lead time of ten years from their conception to their full capacity utilization. More decentralized energy systems (requiring less capital input per unit but each unit having lower energy output) also need a long time to develop. Governments should strive to help reduce the lead time through R and D programmes and through financial support for new energy supply systems, both large and small.

(c) *Socio-political considerations*

Questions relating to the vulnerability of energy supply systems are of paramount importance in the formulation of energy strategies. In this respect, efforts should be intensified to diversify sources and origin of supply, to decentralize the supply systems, to achieve greater source flexibility in designing energy equipment, and to develop local resources.

A controversy has arisen in recent years concerning the relative merits of centralized, as opposed to decentralized, supply systems. It can be argued that centralized systems have economic advantages because of scale economies, that they allow for greater flexibility in the choice of different energy resources, and fuller control in pursuing environmental goals. Among the economic advantages of decentralized supply systems on the other hand, are reduced transport and storage costs and more flexible reserve production capacities. In addition, decentralized systems allow for a more effective utilization of local renewable sources and reduce the above-mentioned vulnerability risks arising from large-scale energy supply units.

General recommendations

The characteristics of heat demand depend in large measure on the temperature range involved. Before selecting the appropriate supply sources (or combination of sources), it is important to examine carefully the specific characteristics of demand, the local conditions, the existing supply pattern and the socio-political considerations indicated above.

(a) *End-uses of low-temperature heat*

As stated earlier, the main end-uses of heat delivered at less than 100° C are space heating, hot water, cooling and certain industrial processes. These end-uses represent 57 per cent of total heat demand and 38 per cent of total final energy demand in the ECE region as a whole. They represent the greatest share of total energy demand.

Low-temperature heat requirements, as indicated, are a function of climatic and seasonal conditions, population density and other variables in each region. Heat demand is linked to the size of the population. Since the latter is increasing at a relatively slow rate in ECE countries in general, heat demand is also tending to increase slowly. The possibilities of energy conservation through techniques such as building insulation, passive solar energy devices, air-to-air exchanges, and the cascading of heat from higher temperatures to lower-grade energy uses are very great, and they will be exploited on an increasing scale.

Recommended supply sources for low-temperature heat requirements

In principle, low-temperature needs can be satisfied from any energy source. In choosing the most appropriate sources, however, it is important to distinguish between concentrated low-temperature heat requirements in urban areas having relatively long winter heating periods, and the heat requirements in rural areas or Mediterranean regions. In the former case, centralized heat-supply systems are likely to be advantageous, whereas in the latter case, decentralized supply systems are the ones most likely to be considered. Centralized heat systems may use a variety of sources (coal, hydrocarbons or electricity), the choice being determined largely by the availability of local resources, economic and environmental considerations. Co-generation of electricity and heat and the recycling of industrial waste heat should be encouraged. Decentralized heat systems may use hydrocarbons, electricity or renewable energy sources, and these may be suitably combined in back-up systems. Greater attention should be given to possible use of active and passive solar installations, heat pumps, biomass and geothermal sources when economically viable.

(b) *End-uses of intermediate-temperature heat*

Heat at temperatures between 100° and 300° C is used mainly for cooking and industrial processing of products such as food, sugar, tobacco, textiles and certain chemicals. Here, it generally takes the form of steam. Such heat requirements represent approximately 12 per cent of total heat requirements and 8 per cent of the final energy demand for ECE countries as a whole. Conservation possibilities in this case lie primarily in pre-heating (using low-grade heat), and in cascading higher temperature heat.

Recommended supply sources for intermediate-temperature heat

Heat requirements for cooking depend largely on social habits. Gas (including liquefied petroleum gases in regions without gas networks) has great advantages for cooking and practically no adverse environmental side effects. Biomass or liquid fuels in rural areas, and electricity in urban areas, are less competitive for cooking. They are likely to be used when gas is unavailable.

Industrial processing in this temperature range requires heat deliveries at precise temperatures. In general, the direct use of hydrocarbons in meeting these needs results in relatively high conversion efficiency.

Possibilities of substitution include:
Electric furnaces;
Biomass, including waste recycling in industries such as paper, sugar and tobacco;
Solar vacuum collectors (with back-up systems).

(c) *End-uses of high-temperature heat*

The main consumers in this temperature range are heavy industries such as chemicals, aluminium, cement, iron and steel. These requirements represent 31 per cent of total heat requirements and 21 per cent of total final energy demand in the ECE region as a whole.

High-temperature heat demand appears to be increasing more rapidly than intermediate- and low-temperature heat demand. Conservation possibilities exist here in the improvement of process, pre-heating, insulation and heat exchanges and, in general, in the modernization of industrial plants. This can be done more rapidly if economic growth is strong and allows a corresponding growth in investment. Conservation measures should also include examination of the possibilities of heat/electricity co-generation, including satisfaction of low-grade heat needs.

Recommended supply sources for high-temperature heat

In the iron and steel industry, metallurgic coke has no viable substitute in the blast furnace process. Gas could cover as much as 60 per cent of fuel requirements in the steel-making process, thus reducing the environmental problems raised by coal ($C0_2$, SO_2, ashes, etc.). Hydrocarbons are currently utilized in chemical plants, where they are a production factor and cannot be separated from the system within which they are being used. Electricity is indispensable for certain high-temperature requirements, in particular when high-heating peaks or a high-heat concentration (e.g. electric beam laser) are required. Electricity is also particularly suitable for applications where pollution at the consumer end is to be avoided, as well as for rapid-drying processes which combine mechanical and thermal action.

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Thus technologies for reducing energy demand without affecting the economic activity are already available, as are suitable supply sources to meet energy demand in an effective, economic, and environmentally acceptable way. The increase in the price of energy has improved the competitiveness of energy investments. What is missing, however, is a fundamental and conceptual reorientation of energy policies.

CONCLUSIONS AND RECOMMENDATIONS OF THE ECE SYMPOSIUM ON THE COMPARATIVE MERITS OF ENERGY SOURCES IN MEETING END-USE HEAT DEMAND

The Symposium on the Comparative Merits of Energy Sources in Meeting End-use Heat Demand was held at Ohrid, Yugoslavia from 6 to 10 September 1983, to discuss the following topics:

I. End-use heat demand in the ECE region.

II. Evaluation of energy sources:
 (*a*) Fossil fuels: hydrocarbons;
 (*b*) Fossil fuels: coal;
 (*c*) Hydro power;
 (*d*) Nuclear energy;
 (*e*) Other renewable sources (including solar, biomass and geothermal energy).

III. Comparative assessment of the suitability of energy sources for meeting end-use heat demand.

The general conclusions and recommendations were as follows:

General conclusions

The Symposium showed the usefulness of international co-operation in the field of energy, in particular exchanges of views and information and other forms of co-operation on energy demand analysis. Many of the problems discussed were common problems. There is a need to join efforts on well-defined economic, environmental, technical, scientific and statistical issues.

Noting with concern the present problems in the field of energy, the Symposium stressed that all groups of society and all countries should be concerned about and contribute toward finding appropriate solutions. The emerging energy problems call for profound structural changes of the economies throughout the ECE region.

It was underlined that the ECE countries could and should play an important role in the development of efficient and cost-effective energy technologies, and in assisting developing countries in this domain in conformity with practices accepted in the ECE.

The approach of the Symposium—that is, emphasizing the analysis of energy problems on the demand side—was considered very important for the formulation of any energy policy.

The Symposium welcomed the efforts of the Centre for Solar Energy in Skopje to develop solar energy applications; it noted with interest the possibility that this centre might become international. The secretariat was requested to explore the possibility of such a joint international undertaking.

Recommendations

The following recommendations were adopted:

(*a*) End-use heat demand is particularly policy-relevant, since it accounts for more than 60 per cent of total energy demand; this does not differ significantly in ECE countries and is not expected to change substantially over the next 20 years.

(*b*) Heat requirements at less than 100° C account for roughly half of end-use energy demand; these are essentially space-heating and hot-water requirements and all energy sources can be used to satisfy them, but for improving general energy efficiency, preference should be given to low-grade, local and environmentally harmless energy sources.

(*c*) All ECE countries dispose of a vast potential for meeting heat demand more effectively through improved economy and efficiency and through fuel substitution. The Symposium noted several independent analyses showing that 25 per cent and more of heat demand in the ECE region could be saved and that a substantial amount of hydrocarbons should be substituted for by other forms of energy. Future economic growth as well as the improvement of environmental standards depend largely on the utilization of the energy conservation potential.

(*d*) No unique solution exists for the various ECE countries. However, there exist many common approaches. For these countries taken as a whole, a need for enhanced co-operation was recognized. In particular, the Symposium recommended that:

(i) The knowledge concerning energy end-use demand as an important element in national and international energy projections and policies be improved; that at the appropriate level, international analysis of the trends of end-use demand be undertaken; and that policies and policy instruments be reviewed;

(ii) National and international statistics on energy end-uses by categories, sectors and fuels, be developed further, taking into account the documentation presented at this Symposium;

(iii) An empirical comparison be undertaken among various ECE countries on the cost-efficiency of various measures and technologies applied in their conservation programmes;

(iv) The general subject of energy end-uses and policies, including end-use demand for liquid fuels and for specific end-uses of electricity, be reviewed periodically, in an appropriate form;

(v) Joint R and D undertakings, particularly in the field of renewable energy sources be considered; that the ECE governments give more support to research on those energy sources which are efficient from the end-use point of view;

(vi) The report of the Symposium be transmitted to interested bodies of ECE, the United Nations system and other intergovernmental and non-governmental organizations.

CHAPTER I

END-USE ENERGY DEMAND IN THE ECE REGION[1]

1. Introduction

Higher energy prices, lower economic growth, new international economic relations, resource constraints and growing environmental concern are driving the energy economies of the ECE countries through a major transition. The change is becoming profound. From an abundant and cheap oil-based, growth-oriented energy system, the industrialized countries are evolving towards systems based on a more rational use of a varied fuel-supply mix.

Traditionally, energy considerations have focused on the supply side. Oil, gas, coal and electricity producers have competed for greater shares of an expanding energy market. Prices were low, little was done to economize in the use of energy; there was good reason to believe that growth in energy demand was a proper indicator of economic development.

One of the important aspects of the difficult adjustment to energy realities since the early 1970s has been an impressive effort to look carefully at the ways in which energy is being used in ECE countries, and at the outlook for the future. The clear and immediate conclusion of this major effort, not surprisingly, is that there exists an enormous and highly profitable potential for reducing wasteful consumption, for using different energy sources (not just more oil), for slowing energy demand growth and for further separating it from the growth of the over-all economy.

Official energy demand forecasts, particularly forecasts of future "oil gaps", have been successively scaled down. Energy policies based on simple extrapolations of past total energy demand behaviour now appear unrealistic. Sound policies can only be formulated on the basis of a detailed analysis of the specific end-use requirements for different kinds of energy; and of the supply sources which are most suitable for meeting these requirements. Such an analysis must be carried out in the light of plausible assumptions for the emerging economic, technical, social and environmental constraints.

An examination of the basic energy needs and their relative importance in the consumption pattern of all industrialized countries shows the dominating importance of heat demand. Furthermore, the heat market at different temperature ranges (low, medium and high temperatures) allows for full competition between practically all energy sources (coal, oil, gas, nuclear, hydro-electricity and other renewables).

These considerations have provided the foundations for preparing, within the framework of the above-mentioned Symposium, first, to examine the energy end-use demand in the ECE region particularly of heat, both now and as envisaged for the future; second, to evaluate the energy sources available and compare the relative suitability of such sources (or combination of sources) for meeting this demand; and third, to consider obstacles to rational energy use, together with policy measures which ECE governments might take to reduce losses and to encourage use of supply systems, better adapted to end-use requirements.

It is essential to clarify some concepts and definitions of energy demand (see section 1 below). In general, end-use demand is considered as the forms of energy required by final consumers. End-use demand can be broken down effectively into three basic components: energy requirements of the transport sector (most of them satisfied with portable liquid fuels); energy requirements for which electricity is indispensable (e.g. lighting, electrolysis, telecommunications, high-fidelity and television equipment); and requirements in the form of heat. The latter and most important component can be considered in several temperature ranges, as indicated in section 2.

A study of end-use heat demand has been carried out using information made available to the secretariat. On the basis of such national data it has been possible to establish ECE-wide regional patterns of end-use demand and their anticipated evolution. The national data and regional results are presented in section 2 below.

The main conclusions of the study are:

(*a*) That more than 60 per cent of total ECE end-use demand is in the form of heat, and roughly half of these thermal uses are in the temperature range below 100° C;

(*b*) That this pattern of end-use demand, dominated by low-temperature heat, is generally valid with no major differences in western Europe, eastern Europe (including the USSR) and North America;

(*c*) That this pattern of end-use demand will continue to prevail over the medium and long term (e.g. up to the year 2000).

This result has not been widely recognized but deserves closer attention because it has far-reaching policy implications. Current energy programmes might be re-oriented after an in-depth examination of the end-use needs and of the countries' energy resources. Policies of energy conservation might be developed on a more solid basis. The contribution of new and renewable sources might be re-assessed. Total energy investment in, and environmental impact of, the energy supply sources and technologies could most probably be reduced. This report presents a preliminary examination of these implications in section 4 below.

2. Some definitions

End-use energy demand

From the consumer's point of view, energy cannot be considered a homogeneous commodity. Indeed, energy

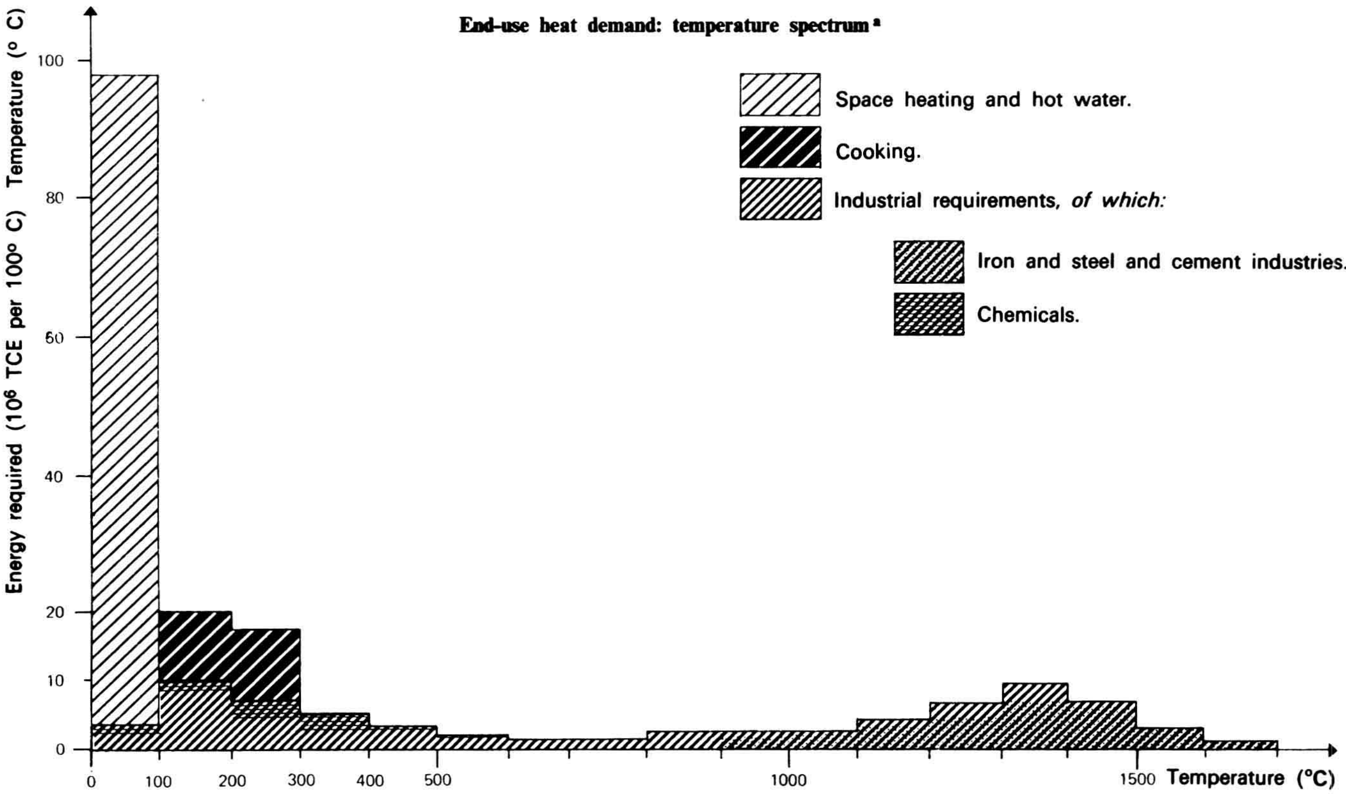
[1] Prepared by the ECE secretariat with the assistance of O. Johansson, Rapporteur nominated by the Government of Sweden.

needs are heterogeneous. The energy problem may be defined as how to meet different needs with the most appropriate energy source (i.e. the least costly, least harmful to the environment, and relatively most abundant). This implies a close look not only at the quantity of energy but also at the the quality of energy required for different end-uses.

A key distinction can be made between thermal end-uses and non-thermal end-uses. Thermal end-uses, those which refer to a demand for heat, may be broken down into three temperature ranges (see figure 1):

FIGURE 1

End-use heat demand: temperature spectrum[a]



[a] Data for the Federal Republic of Germany, 1978.

Low-temperature range (below 100° C), corresponding primarily to the space heating of residential, public, and commercial buildings and also to hot water consumption;

Intermediate-temperature range (between 100° C and 300° C), corresponding to process heat of some chemical, paper, sugar, food and textile industries, usually delivered in the form of steam. Cooking also falls into this temperature range;

High-temperature range (above 300° C), corresponding to a spectrum of industrial requirements. In some processes (i.e. iron and steel and the cement industries) temperature may exceed 1,000° C.

Non-thermal end-uses may be divided, into two categories. The first is the end-use demand for transport. With the exception of trams and trains having electrical traction, the technology available for road, air and water transport involves basically the use of portable liquid fuels.

Second, there are a large number of end-use needs for which electricity is necessarily required (lighting, electronics, electrochemistry, electrometallurgy, telecommunications, fixed motors in industry, etc.). It should be noted that these "electricity-specific" needs (with few exceptions) exclude thermal uses.

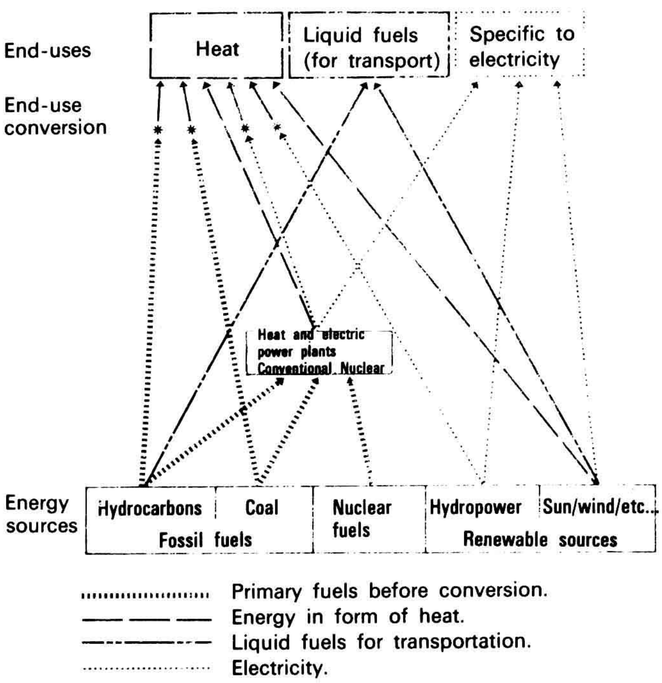
The energy chain: available statistics

By examining how energy is provided to consumers, it is possible to identify a chain which starts with the production of primary energies such as coal, hydrocarbons or uranium. Usually such forms of primary energy cannot be used directly; they must first be converted into a more convenient form. Such conversions result in a variety of losses: e.g., when electricity is generated, about 60 per cent of the primary energy is lost in the form of heat usually not recuperated. In addition, there are energy losses involved in transport, transmission and/or distribution before the energy reaches the consumer. In this report, energy end-use is defined as the energy delivered to, and used directly by, the consumer. It thus does not include fuels used for feedstocks, reductions and bunkers. Ultimately, using the delivered energy to satisfy any given need entails further conversion losses. Figure 2 illustrates this chain schematically.

Available energy statistics present primary energy production and consumption, particularly of commercial energy forms. They also present the input fuels and outputs for the major conversion stages. In addition, rather precise figures can be obtained for the chain linking energy producers and final consumers. The breakdown of final energy demand into different economic sectors (industry, transport, residential and

FIGURE 2

Energy sources and end-uses



commercial) according to fuels delivered (coal, oil products, gas, electricity, steam) is also available for practically all ECE countries. [2] What is usually lacking in energy statistics is the breakdown of final energy demand into the end-use categories described above. Section 2 below presents the results of those studies submitted to the secretariat dealing specifically with energy end-use demand (particularly in respect of heat).

3. End-use energy demand in ECE countries for the years 1978, 1990 and 2000

National data

Figure 3 presents national data on the evolution of the energy end-use demand pattern in countries of the ECE region made available to the secretariat. In addition to 1978 (or another recent year), data has been submitted, to the extent available, for the years 1990 and 2000. In addition to government submissions, other sources have been consulted, including experts in private and public agencies and in universities. For several countries, two or more independent contributions have been submitted.

Projections up to 1990 and 2000 of the absolute level of energy demand submitted by country experts differed markedly in assumptions and results. Only the end-use pattern of final energy demand has been analysed. Here, despite some differences in the energy conversion factors used by the countries' experts, heat requirements dominate the end-use energy demand pattern. At present, the share of heat ranges between 40 and 80 per cent in the ECE countries. The differences may be explained, *inter alia*, by climatic conditions (e.g. northern and southern countries), by the relative importance of road transport (e.g. market economies and centrally-planned economies), by the predominant type of industry (e.g. heavy or light), and by other factors, mainly related to the level of economic development and the standards of living (which have an influence on the specific electricity share).

According to the data submitted, heat requirements will dominate the anticipated end-use demand pattern for the years 1990 and 2000, although the percentage values diminish slightly. In the ECE countries, the growth of low-heat requirements is mainly related to the growth of population. In any case, it is clear that, throughout this period, measures for conserving energy in the low-grade form of energy are very important.

Figure 4 presents the current end-use heat demand in the ECE countries, according to the temperature ranges selected (low, intermediate and high). Despite differences among countries, the requirements of low-temperature heat (below 100° C) correspond on the average to about half of the total heat demand.

Regional results

On the basis of the national data and on secretariat estimates, it has been possible to establish the demand pattern of end-use energy, particularly for heat, for western Europe, eastern Europe (including the USSR), North America and the ECE region as a whole. Figures 5 and 6 present such results, as well as the estimated final demand evolution for the year 2000.

According to information on national energy programmes [3] final energy demand is expected to grow at an average annual rate of 1.6 per cent between 1978 and the year 2000. The share of final demand in total primary energy demand is likely to decrease from 72.2 per cent in 1978 to 69.3 per cent in the year 2000, due to a more rapid growth of conversion capacities and of the use of fuels as feedstocks.

Figure 5 shows clearly that heat requirements dominate the end-use demand pattern of the ECE countries, corresponding to more than 60 per cent of total final energy demand. In general, this pattern will remain fairly stable up to the year 2000. However, in percentage terms, heat requirements are expected to decrease slightly due to the relative higher potential for conservation, in particular for low-temperature applications. The share of liquid fuels for transport is expected to drop in the North American end-use energy demand pattern, while it would probably increase in that of eastern Europe (including the USSR). Specific electricity requirements are expected to increase in all major regions presumably as a result of the growth of the service sector and of growing automation in industry.

Among different projections, those dealing with population are the most reliable. It is interesting to note how the amounts of energy used in the form of heat per

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[2] ENERGY/R.20/Add.1 and 2.

[3] Information submitted by the Senior Advisers to ECE Governments on Energy at their Fourth Session, November 1981. It is important to note that most governments are constantly reviewing the basic assumptions of these projections (economic growth, structural changes, conservative effect, price behaviour) and progressively scaling down their forecasts of energy requirements.

FIGURE 3

Energy end-use demand