INTERNATIONAL ENERGY AGENCY

Energy Conservation in IEA Countries

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

INTERNATIONAL ENERGY AGENCY

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The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Program.

It carries out a comprehensive programme of energy co-operation among twenty-one* of the OECD's twenty-four Member countries. The basic aims of IEA are:

i) co-operation among IEA Participating Countries to reduce excessive dependence on oil through energy conservation, development of alternative energy sources and energy research and development;

ii) an information system on the international oil market as well as consultation with oil companies;

iii) co-operation with oil producing and other oil consuming countries with a view to developing a stable international energy trade as well as the rational management and use of world energy resources in the interest of all countries;

iv) a plan to prepare Participating Countries against the risk of a major disruption of oil supplies and to share available oil in the event of an emergency.

**IEA Member countries: Australia, Austria, Belgium, Canada, Denmark, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.*

Pursuant to article 1 of the Convention signed in Paris on 14th December, 1960, and which came into force on 30th September, 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April, 1964), Finland (28th January, 1969), Australia (7th June, 1971) and New Zealand (29th May, 1973).

The Socialist Federal Republic of Yugoslavia takes part in some of the work of the OECD (agreement of 28th October, 1961).

FOREWORD

Energy conservation continues to be an important component of energy policy. The 1970s showed how vital our energy resources are in maintaining the economies and lifestyles for which we have worked so hard. It also became apparent that consumers, and thus society as a whole, were capable of using each barrel of oil or each kilowatt-hour of electricity more efficiently. It was not that energy consumers had been intentionally wasteful. They had formed the habit of using energy without constraint to meet growing demand generated by decades of economic development.

Since the early 1970s consumers, energy conservation service industries, energy supply companies and governments have taken a very active role in contributing to improved energy efficiency. This improvement was one of the main contributors to our current surplus of energy supply.

This present study represents the first comprehensive analysis by the IEA of the lessons learned from our past experience and the prospects for future efficiency gains. The study is timely because we currently face a changing energy situation which makes policy making difficult and yet which confirms our need for strong thoughtful action. Because markets will tighten again, this study should be a valuable contribution to the debate.

The Secretariat was helped in the preparation of this study by officials of Member governments and by an informal group of experts drawn from outside government*. I am most grateful to all of them for help without which the study could not have been completed. The study is however published on my responsibility as Executive Director of the IEA and does not necessarily reflect the views or positions of the IEA or its Member governments.

Helga Steeg
Executive Director

* A list of members of the informal group is at Annex H.

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EXECUTIVE SUMMARY

Since the oil price increases of 1973-74 and 1979-80 energy conservation — the more efficient use of energy — has become an important component of energy policy. Until then, energy conservation had occurred but it was not an issue of central concern to government energy policies.

Even in the current easy energy markets it is important to maintain the momentum of energy conservation. Energy conservation is important for long-term economic well-being and security because:

— energy conservation will extend the availability of energy resources that are depletable;

— there is likely to be a return to tightening energy markets before the end of the century; energy conservation will delay and lessen its impact;

— energy conservation reduces the environmental consequences of energy production and use in a way which is consistent with energy policy objectives;

— investment in energy conservation at the margin provides a better return than investment in energy supply;

— investment in energy conservation can often be undertaken in small increments and is therefore flexible at a time when the energy outlook is uncertain.

The purpose of this study is to assess the role of energy conservation in the context of general energy policy after more than ten years of concerted efforts by consumers and governments. The study assesses the contribution that energy conservation has made to the current energy situation and the factors responsible for that contribution; the further economic potential for improvements in the efficiency of energy use; what, if anything, is preventing the achievement of that potential; and what measures are available to governments to promote efficiency.

Main Themes and Conclusions

Since 1973, governments, businesses and consumers have taken action. Examples abound of reductions in the energy needed to heat homes, drive cars or produce steel. For the IEA region as a whole, the amount of energy used to produce a unit of gross domestic product — referred to as energy intensity — fell by 20% between 1973 and 1985. If energy intensity had remained unaltered, energy demand would have been some 880 Mtoe higher. The biggest improvement in energy intensity was in the industrial sector mainly as a result of improvements in the efficiency with which energy was used. There were also significant improvements in the residential/commercial and transportation sector but little change in the efficiency of electricity generation. The increase in energy prices and long standing trends towards increased productivity were the driving forces in bringing about improvements but it was supplemented by government policies and programmes to promote energy conservation. Gradually declining real energy prices since 1982 have reduced, but not reversed, these trends towards lower energy intensity.

Three basic points for the future emerge from this study:

(i) There is considerable potential for further improvement on an economic basis in efficiency in energy use;

(ii) There are limitations in the energy conservation market, some inherent, some resulting from actors in the market and some resulting from government regulations, which prevent this potential from being fully realised;

(iii) Carefully planned government policies can be effective in reducing these limitations.

The key problem for government conservation policy is how to achieve more of the economic potential for energy conservation in market economics especially at times when short-term price signals do not reflect the long-term outlook. Its solution is difficult because energy conservation activities are very disaggregated. Inevitably decisions on investment and other energy conservation actions rests with industries and consumers. Government policies provide a framework to encourage such actions. Success requires a number of different approaches in order to reach and motivate a broad range of interests, for many of which conservation is a secondary activity. The major elements in such a policy are discussed below.

(i) Potential for Conservation Improvements.

While considerable energy efficiency improvements have been made since 1973, there remains a large potential for further efficiency improvements in all end-use sectors. If energy conservation measures which are now economically viable were fully implemented by the year 2000, energy efficiency would be more than 30% higher than current levels. The remaining potential for efficiency improvements is especially large in the buildings sector, but major opportunities exist in industry, transportation and transformation.

Based on current trends and government policies, up to three-fifths of this existing potential for conservation is likely to be achieved. The transportation sector and energy-intensive industries are likely to achieve more of this potential than other sectors, such as residential and commercial buildings and smaller industries. If the full potential for economically viable efficiency improvements were to be realised, energy demand in the year 2000 could be further reduced by at least 10% (more than 450 Mtoe per year from currently projected levels).

(ii) Market Limitations.

In theory, market clearing energy prices in a perfect market would produce an optimal economic allocation of resources in the energy sector, including an appropriate effort on energy conservation. In practice there are four main reasons why this does not happen:

(i) In many IEA countries proposals for investment in energy conservation are judged by investors against significantly stricter criteria than supply investment;

(ii) Market prices are inevitably affected by short-term influences and may not reflect the long-term outlook. Electricity and in some countries gas prices to consumers are not fully determined by the market. For wider policy reasons governments and other public authorities are prone to hold down energy prices, particularly those of electricity and gas;

(iii) Energy prices typically do not take fully into account the external costs and benefits, particularly the environmental and security costs, associated with energy production and use;

(iv) Many specific limitations impede the working of the energy market. They include lack of information and skills necessary to conserve energy, the invisibility of energy use, lack of confidence in new conservation services and products and separation of responsibilities for energy expenditures and conservation actions.

(iii) Conservation Policies and Measures.

(a) *Organisation of Energy Conservation Activities*

Many different individuals, businesses, and other organisations are involved in energy conservation activities. They are far more numerous and disaggregated than those involved in energy production. The organisations provide equipment, services, advice, motivation or incentives to consumers. There is scope for government policies to promote and co-ordinate their activities. In particular:

(i) Energy conservation service industries such as equipment manufacturers and installers, energy auditors, financing companies and plant builders have become more important as conservation requirements and opportunities become more complex. Governments can encourage the interests concerned to come together, and modest financial help can often play an important role in this process;

(ii) The energy supply industries in some countries play an important role in providing energy conservation services. For example, in the United States many gas and electric utilities have comprehensive conservation programmes, most of which are required through federal or state legislation. Much emphasis is being placed on a total integration of efficiency and supply options into the utility planning process;

(iii) In some cases, the industries have been ready to assume this role for their own commercial reasons, but in other cases, government encouragement or even legislation has been necessary, particularly for gas and electric utilities which are already under some form of regulation;

(iv) Non-governmental, non-profit groups such as special interest groups, service clubs or voluntary industry groups are valuable in providing services and sharing information. They understand the needs of specific localities and can link energy conservation to other regional needs such as the provision of employment. Small injection of public funds can much assist such local activities;

(v) Governments at all levels encourage energy conservation. The roles and responsibilities depend on the constitutional framework and are more complex in federal states. In governments themselves, there is a need for a strong central conservation policy group headed by a senior official who forms part of the top management of the department responsible for energy and for effective inter-departmental co-ordination of conservation activities. Strong political leadership and bureaucratic commitment is the key to the success of government conservation activities. All Member governments should re-examine energy conservation arrangements in their countries with a view to drawing upon experiences of others.

(b) *Energy Pricing and Taxation Policies*

There is general agreement among IEA countries that where world markets exist consumer prices should reflect the world market price; in other cases consumer prices should normally reflect the long-term cost of maintaining the supply of the fuel concerned; and proper weight should be given to energy policy objectives in tax policies. Energy prices should also internalise as far as possible certain externalities such as the environmental costs of energy production and use — the polluter pays principle.

Substantial progress has been made in relating the prices of oil and coal to consumers to the world market price. There are, however, still price controls, subsidies or other distortions on energy prices in a number of countries. There are arguments for and against these arrangements but, when the consumer price results in lower than world price,that will work against energy conservation.

The main problems lie with prices for electricity and gas. In theory the right basis for determining them is long-run marginal costs. There are, however, serious practical problems about applying long-run marginal cost pricing. The principle is used in a minority of IEA countries to provide an approximate basis for prices, particularly of electricity. In many IEA countries prices for electricity are based on some form of historical costs. For gas prices the most commonly used basis, particularly in Europe, is to link prices to those of competing fuels notably oil products.

Tax policies are determined by considerations going well beyond energy policy. The need to raise money is the most important. Only a few Member countries such as Denmark, Portugal and Sweden have tried to use energy taxation explicitly as an instrument to promote energy conservation. There are some instances of distortions in tax policy which work against energy conservation. For example, there are tax regimes which do not give equal treatment to supply and conservation options and also the tax regime for company cars in Sweden, the United Kingdom and to a lesser extent in other countries.

It is desirable that adequate importance be given to energy conservation in formulating prices and tax policies. In particular:

— remaining subsidies to or controls on oil prices should be eliminated or reduced as soon as possible;

— the conclusions adopted by the Governing Board on 27th March 1985[1] on electricity prices should be implemented and developed and their applicability to gas prices should be further considered where appropriate;

— adequate importance should be given to conservation in decisions on taxes;

— distortions in the tax regime which work against energy conservation should be eliminated or reduced.

1. The Governing Board urged Member Governments to strengthen policies, either directly or through discussions with other levels of government, the electricity industry and regulatory bodies, to ensure that electricity prices are set at a level which encourages efficient use, guides consumers to rational choices between electricity and other forms of energy and promotes optimal investment decisions by both producers and consumers.

(c) *Government Conservation Programmes*

Since the first major oil price increase in 1973, governments have put together a range of programmes to encourage consumers to undertake conservation actions. These include information programmes, financial incentives and regulations and standards.

Information programmes are the cornerstone of every energy conservation strategy. They motivate and create awareness, explain conservation opportunities, improve technical skills and publicise other government programmes. The major programmes include residential and industrial energy audits, appliance labelling, training and education and publicity campaigns. A summary of the use and effectiveness of information programmes is in Table A.

Financial incentives in the form of grants, tax incentives and soft loans have been valuable in improving financial attractiveness and access and introducing new technologies into the market. Initially, financial incentives were very popular among Member governments as a means to encourage consumers to take action. Since 1982, some governments have shifted emphasis away from large incentive programmes. Nevertheless, financial incentives have proven to be cost-effective if designed and implemented properly including minimising the number of free-riders (participants in a programme who would have undertaken the conservation action even in the absence of the programme). Grant programmes generally have positive benefit-cost ratios but they are often difficult to administer and have to be directed to specific audiences to be most effective. Tax incentives are easier to implement for both government and consumers. Industrial consumers particularly treat them as part of the array of tax incentives available. It is, however, more difficult to direct tax incentives than grants towards investors who would not otherwise have undertaken conservation investments. Soft loans can be valuable to consumers who need access to capital. However, they have been difficult to assess because of few national studies. A summary of the use and effectiveness of financial incentives is in Table B.

Regulation and standards are used to varying degrees in all IEA countries. They are useful because they provide long-term continuity during periods of price volatility. They can be most useful in the residential and transportation sectors where there is more standardization of equipment and where there are special segments such as the rental accommodation market or markets heavily influenced by style and advertising (e.g. automobiles). They ensure that minimum efficiency levels are met. Standards and regulations should be reviewed periodically to ensure that they are still up to date. A summary of the use and effectiveness of standards and regulations is in Table C.

Specific conclusions are:

— thorough analysis should be made of the remaining opportunities for energy efficiency improvements, the obstacles to their achievement and which decision makers will need to act;

— upon identifying areas of economic potential which are unlikely to be achieved by the market, governments should assess the full range of policy instruments in order to determine the most appropriate and cost-effective programme mix for each situation;

— in designing and implementing programmes, every effort should be made to ensure their effectiveness and maximise the incremental conservation actions that result;

— conservation programmes should be evaluated periodically to ensure they are meeting policy objectives and maximising effectiveness;

— information programmes should be the cornerstone of every conservation strategy: they can motivate and create awareness, explain conservation opportunities, improve technical skills, and publicise other government programmes;

— financial incentives should be used selectively to support the operation of the market by providing access to needed capital; motivating consumers to undertake economically viable conservation efforts; helping to introduce new technologies; and helping to develop a conservation service industry;

— regulations and standards can be valuable in some instances to maintain the long-term momentum and to overcome market limitations, particularly in special market segments (e.g. the residential sector which is the least price responsive end-use sector, rented buildings and markets heavily influenced by style and advertising (e.g. automobiles)). They ensure minimum levels of effort, are useful during periods of energy price fluctuations and should be reviewed periodically;

— energy efficiency objectives should be carefully integrated with industrial, social, fiscal and other policies that affect energy use.

(d) *Research, Development and Demonstration*

The main contribution to promoting energy efficiency over the rest of the century is likely to be made by the commercialisation and diffusion of existing technologies rather than research and development (R&D) into new technologies. Demonstration — the trial of newly developed technologies or applications under normal working conditions on a large enough scale to determine the feasibility of a full commercial application — is thus of particular importance. Further R&D is required to develop new technologies into the next century. Socio-economic research also has an important contribution to make to the formulation of energy policies.

The level and type of government activity in RD&D vary by industry and country. In the transportation sector, the automobile industry for the most part undertakes its own RD&D although governments are involved to some extent in basic fuel efficiency research and play a major role in aviation RD&D. In the industrial sector, companies often do their own R&D to improve their own efficiency. In the residential sector, the building industry performs very little R&D and faces major technology transfer problems. Extensive demonstration efforts are often necessary.

The formulation of conservation policies requires an understanding of the many non-technical factors which influence efficiency improvements and which can make policies more effective. The four main areas of research include consumer behaviour research, micro-economic research for improving evaluation of policy measures, macro-economic research to determine broad trends, impacts and influential variables, and techno-economic research to have a better understanding of how energy is used, to assess remaining potential and to develop better statistical indicators of efficiency improvements.

Specific conclusions are:

- those Member governments which do not support demonstration programmes or other appropriate forms of technology transfer should look again at their position in the light of the success of such programmes in other IEA countries and the European Community;
- the design, management and results of RD&D programmes should be carefully and regularly assessed; in the case of demonstration and technology transfer programmes, evaluations should examine

the effectiveness of the effort in overcoming market limitations to the adoption of new technologies;

- the lessons learned from assessments should be made available to other governments directly and through the appropriate international organisations;
- socio-economic research should be continued or expanded as appropriate to ensure better formulation and assessment of conservation policies and programmes;
- efforts should be made to improve the quantity and quality of data on energy consumption and to improve international comparisons of energy efficiency;
- there is a need for closer collaboration within government (since responsibility for RD&D is often in ministries that do not handle energy policy) and between government and industry to avoid unnecessary duplication and to optimise use of resources.

(e) *The Exemplary Role of Governments as Energy Consumers*

Governments use energy directly and face most of the same obstacles that confront other energy users. For example, many governments rent accommodation and face landlord-tenant concerns. In many ways, the task is more complicated than for many industries because of the autonomy of various government organisations and the lack of incentives for cutting costs. They have the opportunity to set an example of good conservation practices.

Governments also have a responsibility to manage their resources well. Like industry and commerce, many governments have developed energy management programmes. They have come to recognise that energy costs, constituting a significant proportion of operating costs, can be controlled and provide many financial benefits.

Government units have varying levels of autonomy in implementing programmes to achieve their energy efficiency goals. There remains, nevertheless, a need for the central co-ordination of government-wide programmes. Common functions of the co-ordinating body are to provide advice, guidance and assistance to the various participating organisations, to undertake training programmes, to report on total public sector energy consumption and to initiate measures to improve energy management. Often the point of co-ordination is within the ministry responsible for energy. Some governments go further by having comprehensive mandatory programmes which can require the appointment of departmental energy managers, specific energy use targets, temperature settings and speed limits for government vehicles.

Governments can and should set a positive example of good energy management. This is important since it helps motivate consumers and lends credibility to a government's conservation strategy. If a government does not take the lead, it cannot expect consumers to follow suit. Therefore, a government's own conservation measures should be both effective and well publicised. In particular:

— governments should show a commitment to energy management, including a vigorous investment programme;

— governments should centrally monitor and publicly report progress;

— responsibility for government energy programmes should be clear and the management should be held to account for results.

Table A

Summary of Information Programmes

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed	Implementation Environment	General Conclusions
Publicity Campaigns	- awareness	- most Member countries	- lack of information - invisibility	- implemented usually during period of high price increases - many countries have continued them throughout	- valuable for awareness creation
Residential Energy Audits	- awareness - motivation	- Canada, United States and Sweden primarily	- lack of information - invisibility	- implemented during period of high price increases	- valuable to increase awareness on part of consumers and show cost-effective options - problem with cost-effectiveness of comprehensive audits
Industrial Energy Audits	- awareness - motivation	- Canada, Europe, Japan	- lack of information - invisibility	- initially during periods of high price increases	- valuable to create awareness - problem of degree of sophistication and technical rigour - biggest effect on manufacturing industry - has been cost-effective means to produce energy savings
Appliance Labelling	- awareness - motivation - provide unbiased information to aid purchase decision	- Canada, United States, Europe, Japan	- lack of information - invisibility	- initially during periods of high price increases	- has worked well as voluntary programme
Transportation Fuel Efficiency Information	- awareness - motivation - provide unbiased information to aid purchase decision	- most Member countries	- invisibility - lack of information	- initially during periods of high price increases	- awareness generally high - credibility problems with fuel economy ratings

Source: IEA Secretariat analysis.

Table B: **Summary of Financial Incentives Programmes**

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed	Implementation Environment	General Conclusions
Industrial					
Grants	- stimulation of discrete conservation investment	- most countries	· financial attractiveness and access · confidence · lack of information	· largely initiated between two price increases in 1970s · some terminated when energy prices started declining	- expansion and acceleration of investment - introduced new technologies - improved financial attractiveness - good benefit-cost ratio, even given recent price declines - wide range of incremental investment - created awareness - administratively complex - targeting on incremental projects possible
Tax Incentives	"	- North America, Japan, some European countries	· financial attractiveness · confidence	"	- easy implementation - created awareness - application process fairly easy for companies - of little use for non-tax-payers
Loans	"	- Japan, Germany, Austria	· access to capital · confidence	"	- in practice, small interference in market - mainly easing access to capital (companies in poor financial situation) - incrementality difficult to assess

Source: IEA Secretariat analysis.

Table B: **Summary of Financial Incentives Programmes** *(Continued)*

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed	Implementation Environment	General Conclusions
Residential/Commercial					
Grants	- stimulation of discrete conservation investment	- about half of Member countries	- financial attractiveness and access - lack of information - confidence - separation of expenditure and benefit	- largely initiated between two prices increases in 1970s - some terminated in early 1980s when energy prices started declining	- popular and visible - created awareness - provided information to consumers - improved financial attractiveness - helped develop conservation service industry - poor results in rental market - poorer benefit-cost ratio than industrial grant programmes - administratively complex
Tax Incentives	"	- Austria, Belgium, Denmark, Germany, Japan, Switzerland, United Kingdom, United States	"	- largely initiated between two price increases in 1970s	- lower government involvement - mainly used by higher income groups
Loans	"	- Denmark, Germany, Japan, Sweden, United States	"		
Energy Transformation Sector					
Grants	- stimulation of investment into CHP and for DH	- Denmark, Germany, Ireland, Italy, Netherlands, Sweden	- financial attractiveness		- subsidies effectively reduced investment risks - benefit-cost ratio similar to industrial programmes - rather high incrementality - often lack of utility co-operation
Tax Incentives	"	- Austria	- financial attractiveness		
Loans	"	- Austria, Netherlands, New Zealand			

Source: IEA Secretariat analysis.

Table C

Summary of Regulations and Standards

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed	Implementation Environment	General Conclusions
Building Codes	- upgrade efficiency of new building stock	- all IEA countries	- invisibility of consumption - lack of information - separation of expenditure and benefit	- energy efficiency aspect of existing building codes added after major price increases - have been maintained even in periods of declining energy prices	- very effective in overcoming market limitations - low cost means of upgrading thermal quality of new building stock - provide long-term signals - easy to adapt to regional/local conditions
Appliance Efficiency Standards	- upgrade efficiency of new appliances	- Japan, United States	- invisibility of consumption - lack of information - separation of expenditure and benefit	- initially implemented when energy prices increasing	- insufficient information to draw conclusion - most countries more interested in appliance labelling programmes than efficiency standards
Fuel Economy Standards for New Passenger Cars	- upgrade efficiency of new passenger cars	- nine countries - only United States has mandatory programme	- lack of information	- initially when energy prices increasing for specific period - some kept after target period	- directed towards manufacturers and importers - work in parallel with transportation information programmes - attribution of effects is difficult yet countries have maintained momentum to improve efficiency even when energy prices declining - both mandatory and voluntary programmes have achieved targets

Source: IEA Secretariat analysis.

PART A

OVERVIEW

CHAPTER I

Introduction

Energy conservation dates back to the beginnings of energy use. Fires were built in enclosed spaces and then later replaced by ovens; man learned to build shelters for protection but also to provide warmth with less fuel. This movement towards improved efficiency in energy use, however, has often been overshadowed by increasing demands for energy services — to produce more products, to travel faster and further or to be more comfortable. Both trends continue — as they should. But over the past fifteen years there has been a new effort to examine broadly the potential economic and social benefits of energy conservation. This examination has led to the recognition of energy conservation, for the first time, as an essential national and international objective.

Energy conservation means using energy more efficiently, whether through behaviour, improved management or the introduction of new technology. It has sometimes been associated with efforts to curtail energy use at the cost of economic activity and living standards, but this study is concerned exclusively with energy conservation as a means of increasing economic benefits. The International Energy Agency (IEA) has never considered it to be desirable or appropriate, except in the event of a short-term disruption of energy supplies, to attempt to decrease final demand by either reducing economic growth or forcing changes in the types of products or services available in Member countries. By increasing efficiency, energy demand can be reduced without requiring structural changes or adversely affecting economic growth.

The high interest in energy conservation over the past fifteen years was stimulated by the oil price increases of 1973-74 and 1979-80. The current easy energy market, however, in no way lessens the importance of energy conservation. The reasons for this are that:

— most energy resources are depletable: increased energy conservation will extend their availability;

— with economic growth there is likely to be a return to tight energy markets before the end of the century: increased energy conservation will delay and lessen the impact of such tightening;

— investments in energy conservation often provide a better return than investments in energy supply: increased energy conservation will therefore improve the general efficiency of the economies of IEA countries;

— there is widespread public concern about the environmental consequences of energy production and use: increased energy conservation in general reduces those consequences in a way which is consistent with energy policy objectives;

— investment in energy conservation can often be undertaken in smaller increments than investment in energy supply: energy conservation offers needed flexibility when the energy outlook is uncertain.

These arguments do not imply that investment in energy conservation can replace investment in energy supply. Both are needed.

Since its inception in 1974, the IEA has given much attention to energy conservation. The Governing Board, meeting at Ministerial level on 6th October 1977, adopted Principles for Energy Policy which committed Member governments to allow domestic energy prices to reach a level which encourages energy conservation and to reinforce energy conservation on a high priority basis by providing the resources for and implementating conservation measures (see Annex A). These principles were developed in the Lines of Action for Energy Conservation and Fuel Switching adopted by the Governing Board at Ministerial level on 8th December 1980 (see Annex B). Ministers have since reiterated the importance of energy conservation on a number of occasions, most recently at the Governing Board meeting on 9th July 1985 (see Annex C). They then recognised that conservation remained a particularly important part of energy policy and that there was potential for further gains in all sectors of the economy which could best be realised through market forces and government policies complementing one another in a manner which depends on national circumstances. Ministers agreed that government policies remained important to continued progress in reducing energy intensity and that those policies should be selective, carefully planned, cost-effective and that their results should be periodically assessed. They also recognised that the more efficient use of energy on an economic basis was of primary importance for achieving the objectives of both energy and environmental policy.

This study is an attempt to assess the role of energy conservation in the context of general energy policy after more than a decade of concerted effort by governments and consumers. Its main purpose is to assess how resources can be used to best advantage by governments for conservation. The study has three main objectives:

— *To analyse the changes which have occurred in energy demand and efficiency since 1973 and possible developments over the rest of the century, including an assessment of the economic potential for further energy conservation.* The study attempts to answer several questions, including: what efficiency improvements have already been made and what opportunities still remain? What are the factors which have led to past efficiency improvements and what factors are likely to aid further gains?

— *To examine whether there is a role for governments in promoting energy conservation in market economies.* The study addresses the question of whether there are limitations and imperfections in energy markets which might prevent market forces alone from achieving the optimal economic investment in energy conservation.

— *To identify and assess the effectiveness of the policies adopted by Member governments of the IEA to promote energy conservation and to suggest how conservation measures could be strengthened, if the analysis shows that there is a role for government action.* The study attempts to identify the types of government efforts that are likely to be most effective in accelerating the achievement of efficiency improvements, including general energy and economic policies, as well as more focussed information, incentive, regulatory and research activities. It does not, however, attempt to prescribe the specific policies or programmes that would be most effective for individual countries.

The conclusions of the study are summarised in Chapter II. Part B begins with a discussion of developments in the energy consumption and energy intensity of IEA countries between 1973 and 1985 and the main reasons for changes over this period (Chapter III). Chapter IV assesses the potential for further energy conservation and discusses possible future trends in energy demand and efficiency. Chapter V examines market limitations for energy conservation and the external benefits and costs associated with conservation which cannot easily be reflected in prices. Part C examines the actions which governments can take to achieve greater energy conservation. Chapter VI examines the way in which energy conservation activities are organised in Member countries. Chapter VII discusses energy price and taxation policies which help give the correct market signals for the optimal allocation of resources between energy supply, energy conservation and other investments. Chapter VIII describes the main energy conservation programmes of Member governments and examines their effectiveness. Chapter IX discusses research, development and demonstration (RD&D) programmes and policies in the field of energy conservation and the contribution of socio-economic research to the formulation of conservation policy. Chapter X addresses the critical role of governments in promoting energy conservation in their own establishments.

CHAPTER II

Conclusions

Between 1973 and 1985, energy demand in Member countries of the IEA grew by only 5% while gross domestic product (GDP) grew by almost 32%. Consequently, energy intensity — the amount of energy used to produce a unit of GDP in IEA Member countries — fell by 20%. This fall has significantly improved the energy situation in IEA countries and the world. The drop in energy intensity was primarily due to more efficient use of energy, but changes in economic structure also were important. Higher energy prices have played an important role in improving energy efficiency in IEA economies, but government policies have also helped increase energy conservation. The gradual decline of real energy prices from 1982 slowed, but did not reverse, these trends through the end of 1985.

Three basic points emerge from this study:

(i) There is considerable potential for increased energy efficiency on an economic basis, although this potential varies among countries and sectors. It is conservatively estimated that with existing technologies energy efficiency could be gradually increased by more than 30%. If this were achieved, energy demand would be more than 25% (or at least 1 200 Mtoe per year) below the energy demand levels that would have resulted if today's energy efficiency levels remained unchanged. A major portion of this potential will be realised based on current trends and government policies, but if this potential were to be fully realised, energy demand beyond the year 2000 could be more than 10% (at least 450 Mtoe per year) below currently projected levels.

(ii) There are limitations in the energy conservation market which prevent this potential from being fully realised:

— in many IEA countries more stringent criteria appear to be applied to decisions on investment in energy conservation than in energy supply;

— there are serious obstacles to economic pricing of energy;

— energy conservation has certain external benefits which cannot in practice be easily reflected in prices;

— there are specific market limitations which prevent price signals from being reflected in the decisions of energy consumers.

(iii) Carefully planned and assessed government policies to promote energy conservation can be effective in reducing market barriers and providing conservation on an economic basis, although they may have unintended effects.

The key problem is how to achieve more of the economic potential for energy conservation in market economies especially at times when short-term price signals do not reflect the long-term outlook. The achievement is difficult because energy conservation activities are disaggregated. Decisions about energy investment and use are made by millions of energy consumers. Numerous types of businesses and institutions are involved in promoting energy conservation: companies providing energy conservation equipment and services, public utilities, private, non-profit groups, governments and other concerns for whom conservation activities are only a small part of their total activities. Many of the decisions that affect energy efficiency are made for non-energy reasons, such as home renovation, factory expansion and urban renewal. The environment in which these activities take place is complex and linked to wider economic, political and social factors. Conservation policies, therefore, need to be based on a combination of market forces and government action. This is the approach which has been endorsed by IEA Ministers and is, in practice, followed by all IEA governments.

Success in government energy conservation policy requires a number of different approaches in order to reach and motivate a broad range of interests, for many of which conservation is a secondary activity. Based on the study's analyses, the major elements of an effective government conservation policy include:

(a) effective involvement of the various organisations which work on energy conservation;

(b) energy price, taxation and other policies designed to give the right economic signals to consumers;

(c) programmes to reduce or counterbalance limitations which prevent the market from working effectively with respect to energy conservation;

(d) research, development and demonstration to develop and transfer more energy-efficient technologies; research in the social sciences to help provide a better understanding of factors influencing consumer behaviour and to improve the effectiveness of conservation programmes;

(e) a strong lead by governments in effecting conservation in their own organisations.

Effective energy conservation policies require a governmental organisation to oversee the conduct of the underlying policy analysis, to guide the development of specific government initiatives and ensure that objective programme evaluations are conducted. While there is no ideal method of organising government conservation efforts, it is essential that they be guided by a policy group headed by a senior official who forms part of the top management of the ministry responsible for energy. In addition, under all types of government conservation structures, there must be effective interdepartmental co-ordination of conservation activities.

(a) Organisations and services

Many groups and organisations are involved in energy conservation activities. They include the energy conservation service industries, the energy supply industries (particularly the utilities), non-profit making organisations and various levels of government. Their effectiveness in promoting conservation depends to a large extent on the groups themselves. There is, however, scope for government policies to promote and co-ordinate their activities. In particular:

— the development of energy conservation services including energy contract management companies will be increasingly important as conservation requirements and opportunities become more complex. Responsibility for this development rests mainly with the interests concerned but experience in a number of countries has shown that governments can encourage these interests to come together and that information programmes plus modest financial help can play an important part in the process;

- energy supply industries can play an important part in promoting conservation through direct contacts with consumers and their understanding of consumer needs. In some cases, the industries have been ready to assume this role for their own commercial reasons, but in other cases, government encouragement or even legislation has been necessary, particularly for gas and electric utilities which are already under some form of regulation;
- non-profit groups can be effective in promoting energy conservation, particularly through their understanding of the needs of specific communities, and their ability to link energy conservation to other local needs, such as employment. Some injection of public funds can much assist such activities;
- all Member governments should re-examine energy conservation arrangements in their countries with a view to drawing upon the experience of others.

(b) Energy price, taxation and other economic policies

Economic energy pricing is an essential prerequisite for effective energy conservation policies. As a general rule, energy prices should reflect the long-run marginal costs of supply, give the right signals to producers and consumers in order to facilitate an optimal allocation of resources, enable energy suppliers to finance economically sound capital investment and thus ensure the long-term security of energy supply. There are, however, severe theoretical and practical problems about determining and implementing economic energy prices. Policy on taxation of energy products is inevitably determined by considerations wider than those of energy policy alone. It would be unrealistic to expect Member countries to adopt uniform price and tax policies since the economic and social considerations vary among countries. It is, however, desirable that adequate importance be given to energy conservation in formulating price and tax policies. In particular:

- remaining subsidies to or controls on oil prices should be eliminated or reduced as soon as possible;

— the conclusions adopted by the Governing Board on 27th March 1985 on electricity prices should be implemented and developed and their applicability to gas prices should be further considered;
— adequate importance should be given to conservation in decisions on taxes on energy consumption;
— distortions in the tax regime which work against energy conservation should be eliminated or reduced.

(c) Government conservation programmes

A range of policy measures are used by governments to complement and strengthen market signals that stimulate conservation and to address many of the market limitations described in Chapter V. Different policy measures can be used to remove or reduce the market limitations in various ways. Their use depends on many factors including complexity and cost of implementation, traditional use of policy measures within administrations, legislative requirements and timing required for expected results. Often several policy measures or an array of programmes to suit different market segments is the most effective. For example, residential energy audits are most useful when combined with financial incentives and fuel efficiency standards accompanied by information guides, labels and brochures. Therefore, policy measures should not be considered in isolation but as part of an integrated approach.

From the analysis of policy measures:

— most policy measures have been implemented to either address the lack of information and technical skills or the lack of access to financing or the economic attractiveness of conservation activities;
— financial incentives have shown to have positive benefit-cost ratios with the best results in the industrial and transformation sectors;
— there is a wide range of incremental effects due to a variety of factors, including percentage of financial incentive, range of eligible items, implementation, and design of programme;
— more focussed programmes are more effective than general ones;

- awareness and motivation are not static and need to be reinforced periodically or through feedback mechanisms to give the consumer a better understanding of his energy use;
- standards and regulations have been most useful in the residential/ commercial and transportation sectors where there is more standardization of equipment and where there are special market segments such as rental accommodation;
- standards and regulations ensure minimum efficiency levels;
- effectiveness of programmes depends on good implementation, requiring human and financial resources, co-ordination within administrations and with other levels of government;
- in the industrial sector, a combination of programmes encourages businesses to develop good energy management. Some examples are energy audits, training, monitoring and targeting, technical materials and technology transfer programmes;
- there is still too little known about the effectiveness of programmes and evaluations that have been undertaken have generally not been sufficiently comprehensive.

The specific conclusions are:

- thorough analysis should be made of the remaining opportunities for energy efficiency improvements, the obstacles to their achievement and which decision makers will need to act;
- upon identifying areas of economic potential which are unlikely to be achieved by the market, governments should assess the full range of policy instruments in order to determine the most appropriate and cost-effective programme mix for each situation;
- in designing and implementing programmes, every effort should be made to ensure their effectiveness and maximise the incremental conservation actions that result;
- conservation programmes should be evaluated periodically to ensure they are meeting policy objectives and maximising effectiveness;
- information programmes should be the cornerstone of every conservation strategy: they can motivate and create awareness, explain conservation opportunities, improve technical skills, and publicise other government programmes;

— financial incentives should be used selectively to support the operation of the market by providing access to needed capital; motivating consumers to undertake conservation efforts; helping to introduce new technologies; and helping to develop a conservation service industry;

— regulations and standards can be valuable in some instances to maintain long-term momentum and to overcome market limitations, particularly in special market segments (e.g. the residential sector which is the least price responsive end-use sector, rented buildings and markets heavily influenced by style and advertising (e.g. automobiles)). They ensure minimum levels of effort, are useful during periods of energy price fluctuations and should be reviewed periodically;

— energy efficiency objectives should be carefully integrated with industrial, social, fiscal and other policies that affect energy use.

(d) **Research, development and demonstration**

Energy conservation RD&D is widely spread over governments and industry. Substantial progress has been made in the last ten years. More needs to be done, however, to demonstrate new technologies which are technically viable, to more effectively transfer these technologies to private manufacturers and end-users, to improve the assessment of government programmes and to develop social research relevant to the formulation of energy conservation policies and programmes. Specific conclusions to these ends are:

— those Member governments which do not support demonstration programmes or other appropriate forms of technology transfer should look again at their position in the light of the success of such programmes in other IEA countries and the European Community;

— the design, management and results of RD&D programmes should be carefully and regularly assessed; in the case of demonstration and technology transfer programmes, evaluations should examine the effectiveness of the effort in overcoming market limitations to the adoption of new technologies;

— the lessons learned from assessments should be made available to other governments directly and through the appropriate international organisations;

— socio-economic research should be continued or expanded as appropriate to ensure better formulation and assessment of conservation policies and programmes;

— efforts should be made to improve the quantity and quality of data on energy consumption and to improve international comparisons of energy efficiency;

— there is a need for closer collaboration within government (since RD&D are often in ministries that are not responsible for energy policy) and between government and industry to avoid unnecessary duplication and to optimise use of resources.

(e) An exemplary role for governments

Governments can and should set a positive example of good energy management. This is important since it helps motivate consumers and lends credibility to a government's conservation strategy. If a government does not take the lead, it cannot expect consumers to follow suit. Therefore, a government's own conservation measures should be both effective and well publicised. Specific conclusions are:

— governments should show a commitment to energy management, including a vigorous investment programme;

— they should centrally monitor and publicly report progress;

— responsibility for government energy programmes should be clear and the management should be held to account for results.

PART B

IMPROVING ENERGY EFFICIENCY TRENDS, OPPORTUNITIES AND OBSTACLES

The first step in the study of energy conservation policy is the examination of the actual opportunities for energy efficiency improvements combined with a review of past experiences and likely future trends towards the realisation of these opportunities. Such an analysis provides the basis for the development or revision of effective government conservation policies.

The following three chapters present an overview of such an examination for IEA Member countries. The chapters contain:

- a review of trends in energy demand and efficiency since 1973 by country and end-use sector (Chapter III and a more detailed examination in Annex D);
- an assessment of the remaining conservation potential and the likely future trends towards achieving this potential (Chapter IV, with data sources in Annex E);
- an analysis of the imperfections or limitations of market forces and government policies which are likely to prevent or slow the achievement of economically attractive efficiency improvements (Chapter V).

The analyses are intended to provide a basis for broad policy conclusions; they are not sufficient for the design of specific conservation policies or programmes for individual countries, which requires more detailed analysis on a national basis.

CHAPTER III

Developments in Energy Demand and Energy Efficiency 1973-1985

Between 1973 and 1985 total primary energy requirements (TPER) in IEA countries increased by 5% or 0.4% a year. At the same time gross domestic product (GDP) grew by 32%, an average of 2.4% a year. The result was a fall of 20% in energy intensity — the amount of energy used per unit of GDP (TPER/GDP). About one half of this change occurred from 1979 to 1982. Since 1982, energy intensity has continued to decline, but at a much slower rate.

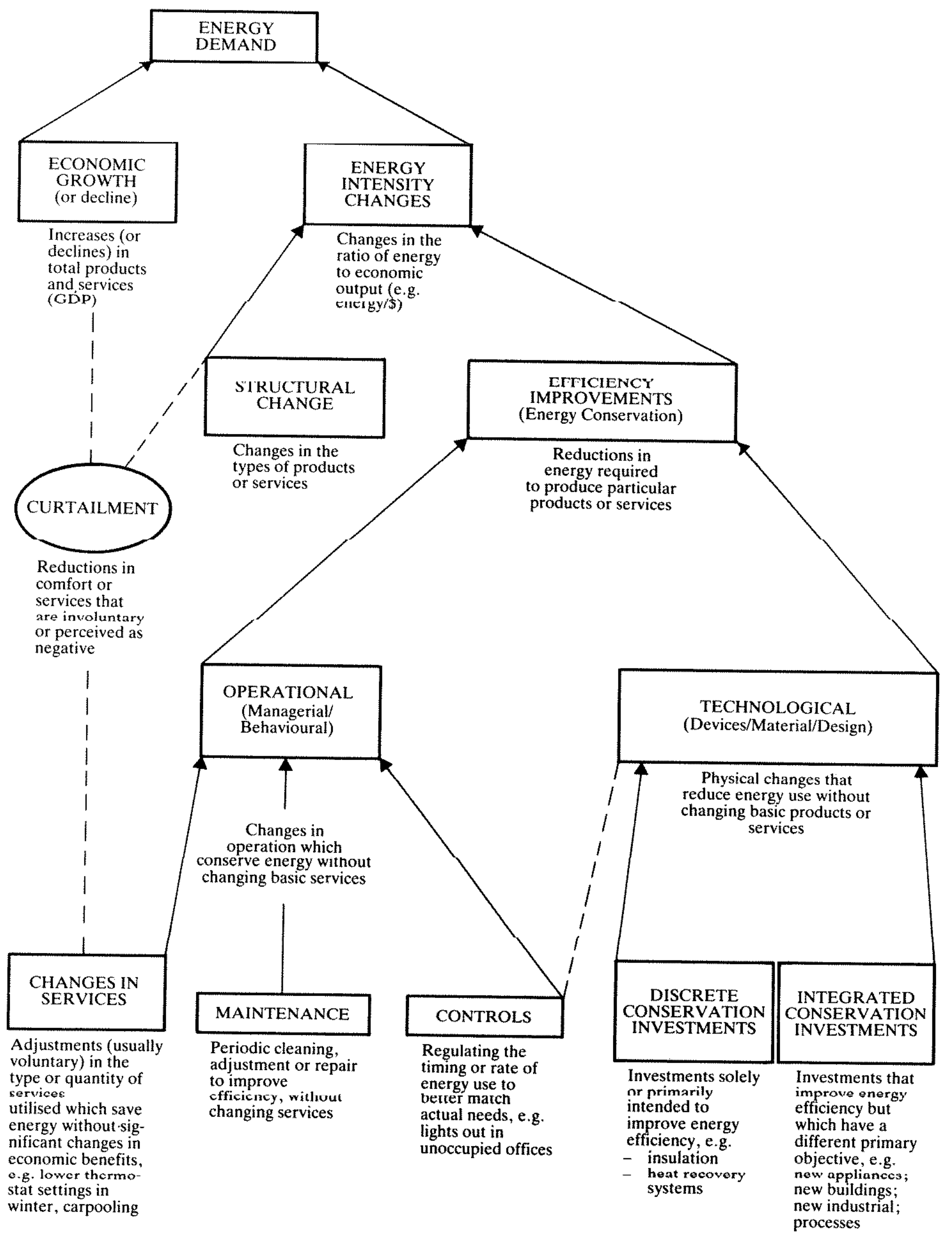
The reduction in overall energy intensity was the result of structural changes in the economies of IEA Member countries and increased levels of energy efficiency. Each factor made important contributions to lower energy intensities, although by different means. During the past ten years, improved energy efficiency has had the largest overall effect. The relationship between them and their contribution to overall energy demand is depicted in Figure 1.

Some Key Concepts

It is important to distinguish between general trends in energy demand and those resulting from efficiency improvements. Trends in energy demand, together with domestic supply, determine net energy imports and strongly influence energy prices. However, only through increased

Figure 1

Energy Demand and Efficiency
Terms and Definitions



energy efficiency can demand be reduced, without lowering economic activity or changing services. That is why this chapter concentrates on energy efficiency improvements since 1973.

Energy management represents the comprehensive application of energy conservation and fuel substitution measures. Because it includes fuel choice, energy management has a somewhat broader meaning than "energy conservation", but the basic objective is the same — the reduction of energy costs.

Energy efficiency can be measured in many ways. For automobiles, it is generally measured as litres per 100 kilometres or miles per gallon, but more technically revealing measures of automobile efficiency usually exclude the effects of changes in passenger space and performance. For the industrial production of primary materials, it is often the energy required to produce a tonne of material. The best measure of energy efficiency varies depending on the end-use and even for a single end-use, there can be several different measures. This characteristic of energy efficiency makes it impossible to develop uniform statistical measures for whole economies or even sectors. As a result, the energy efficiency improvements that have occurred since 1973 must be examined case-by-case for each type of end-use.

A rough indicator of general progress towards improved efficiency is energy intensity — usually in the form of energy demand per unit of economic output (such as TPER/GDP). However, energy intensity reflects the combined effects of structural changes in economies and energy efficiency improvements. The economic structure of Member countries of the IEA differs from one country to another. Energy intensity varies depending on industrial structures, historical price developments, availability of indigenous resources, traditional use patterns, climate and geography. Countries which have harsher climates, more heavy industries or cheaper energy sources tend to have higher energy intensities, even though they may also be comparatively energy-efficient. A further difficulty with this measure is that it has the effect of indicating an increase (or a lesser decrease) in energy intensity in countries whose demand structure includes a greater use of electricity.

Even with these limitations, the rate of change in the energy intensity of IEA Member countries is the best readily available indicator of overall progress towards improved energy efficiency. This is especially true when changes in energy intensity are compared to the rate of change previously experienced by the country and to other countries with similar characteristics.

Trends in Energy Intensity and Efficiency

Changes in energy intensities were not consistent among IEA Member countries between 1973 and 1985. As Table 1 shows, in 1973 there were wide differences among Member countries and this undoubtedly has had an effect on relative rates of change. Canada, Luxembourg and the United States have been, and still are, the most energy-intensive Member countries; Denmark, Germany, Japan and Switzerland were the least energy-intensive Member countries in 1985, although each has shown various rates of progress since 1973. The countries whose annual rates of decrease in energy intensity were smallest (or even positive) have tended to be those that had more rapidly growing industrial sectors or had access to plentiful supplies of relatively low cost electricity[1]. Those countries with the largest decreases were already comparatively energy-intensive and were also experiencing significant structural changes, usually a stable or declining industrial sector. Both trends tended to bring IEA Member countries closer together in terms of average energy intensity by 1984, although major differences still exist.

Structural changes that have contributed to lower energy intensity levels have usually been the result of long-term trends of economic development. Higher energy prices have contributed to the acceleration of these trends by depressing demand for energy-intensive products and services and boosting demand for less energy-intensive forms of economic activity. Structural changes have occurred in many forms, from changes in product types within specific industries to shifts from one sector of economic activity (e.g. industry) to another (e.g. commercial).

1. The energy lost in the generation and distribution of electricity is reflected in the total primary energy requirements of individual countries. For statistical reasons, it is assumed that the energy generated from hydroelectricity is produced from primary energy at an efficiency rate of 38.5%. Largely because of this assumption, those countries which have found it economically attractive to increase greatly electricity use (usually because of the availability of low-cost hydroelectricity) have also increased their energy intensity (based on TPER/GDP).

Table 1. **Energy Intensity in IEA Countries**[1]

	1973	1979	1983	1985	Average Annual Change Rates 1973-79	1979-83	1983-85
Canada	.85	.86	.81	.80	.2	-1.6	-.7
United States	.79	.73	.64	.61	-1.3	-3.1	-2.9
North America	.80	.74	.66	.62	-1.1	-3.0	-2.7
Australia	.48	.51	.49	.45	.9	-1.2	-3.2
Japan	.42	.37	.30	.29	-2.2	-4.9	-1.3
New Zealand[2]	.40	.46	.46	.50	2.3	.2	3.8
Pacific	.43	.39	.32	.32	-1.7	-4.2	-1.4
Austria	.38	.36	.32	.33	-1.0	-2.6	1.3
Belgium	.47	.42	.34	.36	-1.6	-5.6	2.7
Denmark	.33	.31	.24	.27	- .7	-6.5	5.1
Germany	.38	.36	.31	.31	-1.3	-3.4	.3
Greece[2]	.38	.41	.42	.44	1.5	.4	2.3
Ireland	.52	.48	.43	.44	-1.3	-2.8	1.3
Italy	.41	.38	.34	.33	-1.2	-2.7	-1.1
Luxembourg	1.15	.88	.63	.65	-4.3	-8.0	1.6
Netherlands	.44	.42	.35	.36	-1.0	-4.5	1.8
Norway	.47	.44	.42	.40	-1.2	-1.3	-2.2
Portugal[2]	.41	.48	.48	.49	2.9	.0	.3
Spain	.31	.35	.33	.32	2.1	-1.5	-1.0
Sweden	.43	.42	.38	.40	- .4	-2.5	3.2
Switzerland	.24	.25	.25	.25	.8	.3	- .7
Turkey	.63	.56	.57	.56	-1.8	.2	- .2
United Kingdom	.44	.40	.35	.35	-1.6	-3.5	.0
Europe	.40	.38	.34	.34	- .9	-3.0	.4
IEA Total	.57	.53	.47	.45	-1.1	-3.3	-1.4

1. Energy intensity is defined as TPER/GDP or toe per $1 000 of GDP at constant 1980 prices and constant exchange rates in order to reduce the distortions introduced by exchange rate fluctuations. These indicators must be qualified for countries with high proportions of comparatively inexpensive electricity, such as hydro. It is economically attractive to increase electricity demand in such countries. Rapidly increasing electricity demand has a comparatively greater impact on TPER because of actual and assumed energy losses in electricity generation. For the electricity generated from fossil fuels, the actual thermal efficiencies of conversion are used. But for hydro and nuclear generated electricity assumed values are used which approximate the equivalent amount of thermal fuel which would be required to generate the same electricity. For example, the primary energy input to the production of hydroelectricity is calculated for most IEA Member countries using a theoretical generation efficiency of 38.5% and therefore the primary energy intensity of countries with large, inexpensive hydroelectricity generation tends to be overstated.
2. In some countries such as Greece, New Zealand and Portugal, energy intensity has increased since 1973 due to an increase in energy-intensive industries.

Source: Energy Balances of OECD Countries.

There have also been changes in personal lifestyles and other social characteristics resulting from higher incomes and shifting product prices, among many other factors.

The energy efficiency improvements that are reflected in the changes in overall energy intensity have resulted from several related factors, including: rising energy prices, general increases in economic productivity and government policies to promote the more efficient use of energy. The actual efficiency improvements that have occurred fall into two broad categories:

— technological, which includes investments in equipment and materials which improve energy efficiency;

— operational, which encompasses a wide range of behavioural and managerial changes and the way in which energy is used.

There are literally thousands of different types of technological and operational conservation measures which have been applied in energy end-use sectors. The basic categories of conservation actions are also depicted in Figure 1.

Response to Movements in Energy Prices

Increases in real energy prices, especially from 1978 to 1982, have been the most important single factor behind the substantial improvements in energy efficiency over the past ten years, the corresponding reductions in energy intensity and the slowing of energy demand growth. Figure 2 depicts the changes in the relative prices of labour, capital and energy in OECD countries since the 1960s[1]. It indicates that energy prices rose by nearly 80% in just four years after 1978, while the cost of capital rose only 36% and that of labour by even less.

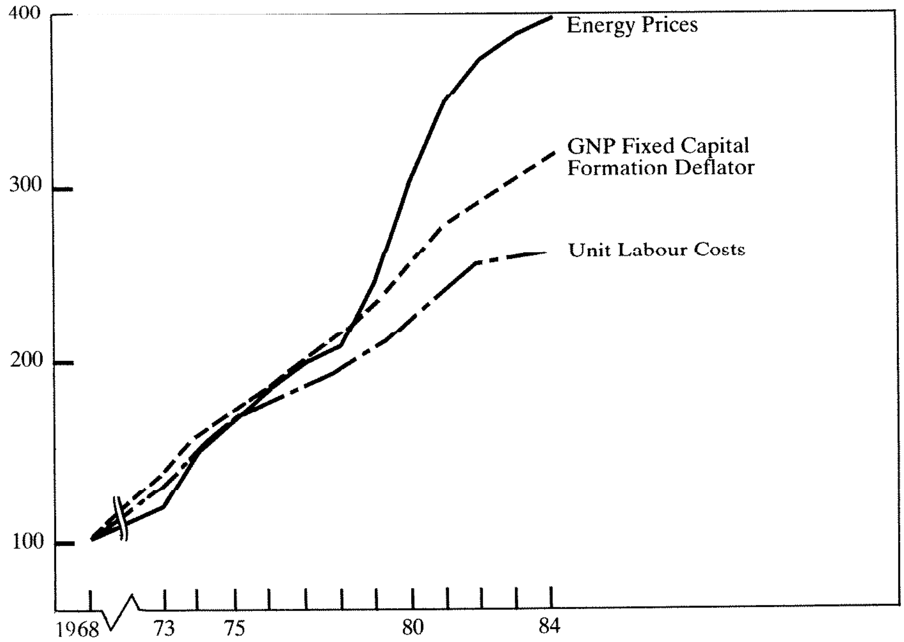
Rising energy prices have not only accelerated the adoption of energy-efficient technologies, but they have also provided added stimulus to structural shifts towards less energy-intensive technologies and slowed economic growth. In the short term, steeply rising energy prices may have had a large impact on energy demand by depressing economic growth. But over the whole of the last ten years, their greatest

1. Total OECD data are used when IEA statistics are unavailable.

impact probably has been on the basic efficiency of energy use and, to a lesser extent, the rate of structural change in the economies of IEA Member countries.

Figure 2

Trends of Production Factor Prices
(1968 = 100)



Source: "Historical Statistics 1960-1984", OECD, Paris 1986.

The responsiveness of energy demand and efficiency to rising energy prices has varied by end-use sector, region and type of price movement. Table 2 provides estimates of average own price elasticities by end-use sector for OECD and its three major regions. These average elasticities were based on a Secretariat analysis of the long-term response of energy demand during periods of rising fuel prices over the past thirty years. The analysis attempted to exclude the effects of income growth and major structural changes that were not primarily or directly dependent on end-use energy prices. The table indicates that energy demand appears to respond strongly to rising retail energy prices, especially over the long term (up to ten years), in every sector and region. On average, a 10% increase in end-use energy prices results, over time, in about a 5% decrease in demand (an own price elasticity of 0.5) and, as other analyses have shown, most of this reduction is achieved through improved energy efficiency. A similar analysis of the responsiveness of energy demand to falling energy prices indicates that the elasticities are generally significantly smaller; that is, a 10% decrease in end-use prices usually results in a long-term increase in demand of significantly less than 5%.

Table 2
Average Own Price Elasticities[1] of
OECD Energy Demand by End-Use Sector and Region

	North America	Pacific	Europe	All OECD
Industry[2]	0.34	0.50	0.49	0.42
Resid./Commercial[3] (including agriculture and other)	0.60	0.70	0.55	0.59
Transportation[4]	0.63	0.30	0.70	0.61
All Sectors	0.53	0.47	0.57	0.52

1. Based on the long-term own price elasticities of specific fuels and electricity in response to upward movements in end-use prices observed periodically over the past thirty years. The periods examined varied by fuel type and region, although most energy prices did rise during the mid-1970s and from 1979 to 1982. The long-term effects of price increases have been observed to continue to increase incrementally for up to ten years, although the size of the annual incremental effects diminishes. The specific fuel and electricity elasticities were averaged using 1980 OECD energy consumption data.
2. Industrial fuel own price elasticities were calculated using a method, which relied in part on industrial production indices, designed to exclude the effects of major structural changes and other energy intensity changes that are not directly induced by energy prices.
3. Residential/commercial own-price elasticities were also calculated by methods designed to limit the effects of non-price-induced structural changes. These methods included the use of data on the changing penetration of central heating, among others.
4. Transportation fuel own price elasticities were calculated using a method designed to reflect primarily the induced changes in the ratio of energy use to distance travelled. However, because rising prices also have some long-term effects on total distances travelled, the elasticity values indicated for transportation probably understate the true values.

Source: IEA Secretariat.

Table 2 also indicates that industrial energy demand is less price-elastic than other end-use sectors. This may be because industry's long-term trend towards improved energy efficiency is more the result of broad economic forces, than solely energy price movements. Other analyses indicate that industry is generally quicker to respond to rising energy prices than other end-use sectors, but some of these responses involve product changes, or the elimination of production in high energy cost regions which may not be reflected in energy price elasticities. Also, while the economically attractive potential for energy savings per unit of output is often smaller in industry, in terms of percentage reductions, than in other sectors, there are basic changes in industrial processes which have been gradually introduced over very long periods. These types of very long-term technological changes can have important effects on energy use, but may also not be fully reflected in price elasticities. Since 1973, industry has experienced the largest increase in end use energy prices and the greatest percentage drop in energy intensity. Although regional differences are generally small, it does appear that price elasticities are lower for industrial fuels in North America and transportation fuels in the Pacific and that they are higher for residential/commercial fuels in the Pacific. These elasticities may reflect regional differences in economic structure, climate and the influence of non-energy factors.

Analysis of End-Use Sectors

A. *Industry*

Industry is the most energy consuming end-use sector, accounting for 37% of total final energy consumption (TFC). Industrial energy consumption declined by 1.3% per year from 1973 to 1984, while industrial output increased at an average annual rate of about 2%. This resulted in an overall reduction of industrial energy intensity (the ratio of industrial energy use to value added) of 30%. From 1979 to 1983, the rate of annual decrease in industrial energy intensity was about three times higher than in 1973-79.

Energy intensity has been decreasing in the industries of most IEA Member countries for more than thirty years. For example, for manufacturing industries of OECD Member countries, the annual rate of decrease in energy intensity from 1960 to 1973 was two-thirds of the rate between 1973 and 1979.

Energy efficiency improvements appear to have been the major cause of decreased industrial energy intensity from 1973 to 1984, although structural changes within the industrial sector also played a very important role. Table 3 summarises the results of a recent study of the factors contributing to the decline in energy intensities in Europe. It indicates the major role of energy efficiency improvements. Several other studies of both United States and Japanese industries came to similar conclusions. In all cases, energy efficiency improvements

Table 3

Determinants of Energy Demand in Manufacturing Industry in Four Major European Countries[1]

(in petajoules)

	Total Final Consumption in 1979	Annual Change in TFC in 79/83	Change in TFC in 1983/84	TFC in 1984[2]
Fuels by factor:	6 590	- 375	+ 53	5 120
- Efficiency improvements		- 253	- 163	
- Structural change		- 60	+ 79	
- Changes in activity level		- 54	+ 146	
- Interfuel Substitution[3]		- 8	- 9	
Electricity by factor:	1 554	- 27	+ 64	1 510
- Efficiency improvements		- 11	+ 2.1	
- Structural change		- 3.4	+ 18.9	
- Changes in Activity level		- 12.8	+ 42.2	
- Interfuel substitution[3]		+ 0.1	+ 0.6	

1. Germany, Italy, United Kingdom, France.
2. Differences to actual TFC mainly due to stock changes.
3. Including intra industrial structural change.

Source: ISI-Karlsruhe, Germany (based on EUROSTAT).

accounted for more than half of the decline in energy intensity for the periods examined. The periods assessed varied from 1972-81 to 1979-84.

The energy efficiency improvements made in industry encompassed the full range of conservation actions, but integrated conservation investments (those which were an integral part of new industrial equipment and processes) probably made the single largest contribution. Operational improvements, discrete conservation investments and government measures also had major impacts.

A method widely used by industry to achieve efficiency gains during this period was the institution of energy management programmes. A central feature of such programmes has usually been the designation of a senior manager with a broad range of energy-related responsibilities, including the operation and maintenance of energy-using systems, the identification and evaluation of major efficiency investments and decisions on fuel choice. There has been a general trend towards the establishment of such energy management programmes in large, energy-intensive industries over the past ten years. This trend has been accelerated in several countries through both voluntary programmes promoted by the government, such as the current British efforts, and mandatory requirements, such as in Japan where industries whose energy consumption is over a fixed threshold must appoint energy managers.

The best indicator of industrial efficiency improvements is the ratio of energy consumption per unit of product output, such as gigajoules per tonne of steel. Figure 3 displays trends in the efficiency of five Japanese industries from 1979 to 1985. While Japanese industry has been particularly successful in making energy efficiency improvements, similar progress has been made by major, energy-intensive industries in most IEA Member countries. Energy-intensive industries usually have been especially quick to adopt more energy-efficient processes and equipment.

B. *Residential/Commercial Sector*[1]

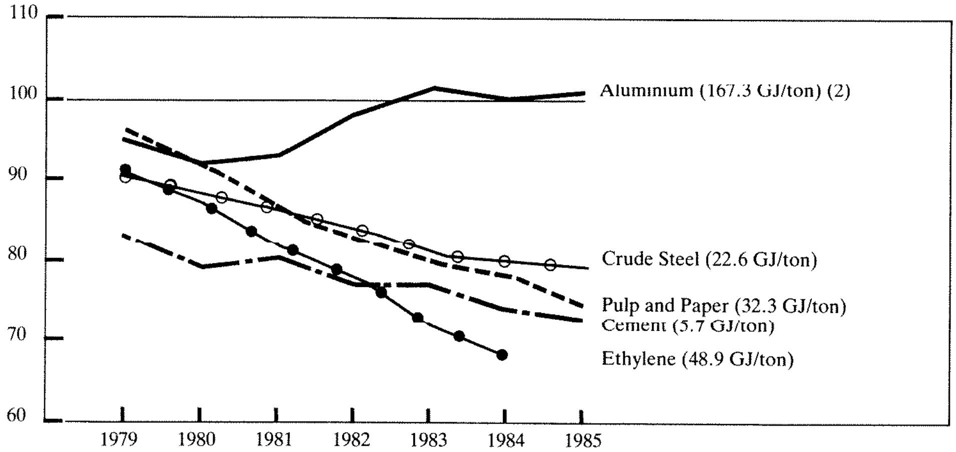
The residential/commercial sector is the second largest user of energy and the fastest growing. For the IEA as a whole, per capita energy use in

1. Includes public and agricultural use.

this sector increased by 2.5% between 1973 and 1979, but declined by about 12% between 1979 and 1984. The trend was again reversed in 1985 when per capita energy use rose by 2.1%.

Figure 3

Energy Efficiencies of Selected Industrial Products in Japan
(Index 1973 = 100)[1]



1. Specific energy consumptions in 1973 in brackets. All figures are by Japanese Fiscal Year, which is 1st March to 30th April.

2. Electricity consumption including conversion losses. The stable efficiency of the aluminium industry during this period reflects progress made in earlier years, absence of major technological advances and a period of decreasing production in Japan. In 1984, the Japanese aluminium industry was still among the most efficient in the world.

Source: Ministry of International Trade and Industry, Tokyo, Japan.

Residential Subsector. Energy use per capita in the residential subsector decreased continuously from 1973 to 1983 and increased slightly from 1983 to 1985. However, these trends masked major structural and efficiency changes. One study[1] has calculated that structural changes in the residential sector would have increased energy use per dwelling between 1972 and 1982 by about 10-15% in North America, Denmark and Sweden, 15-20% in Norway, the United Kingdom and Germany and more than 20% in Japan and Italy. However, in almost all Member countries these increases have been more than offset by large

1. Schipper and Ketoff, "Explaining Residential Energy Use by International Bottom-up Comparisons", *Annual Review of Energy,* Volume 10, 1985, p.382.

improvements in energy efficiency. As an example, Figure 4 shows efficiency improvements in specific useful energy for space heat between 1970 and 1982.

Commercial, Agricultural and Public Subsectors. The commercial subsector, which encompasses a broad range of economic activities, is the fastest growing subsector in most IEA Member countries. Unfortunately, a lack of data on energy use and the physical characteristics of this sector has hampered analysis of energy efficiency trends. Nevertheless, a recent study[1] has concluded that substantial efficiency improvements were made in this subsector from 1970 to 1982. One indicator, energy use per employee, showed:

	Percentage Change 1970-82
Denmark[1]	19
Germany	-12
Norway	-13
Sweden	-15
United Kingdom	-12
United States	-24

1. For Denmark 1972-82 was used.

The energy-efficiency measures which have contributed to these reductions include a wide range of conservation actions in both new and existing buildings. Efficiency gains in new commercial buildings have been especially large and the efficiency of certain end-use technologies, such as lighting, has also increased substantially.

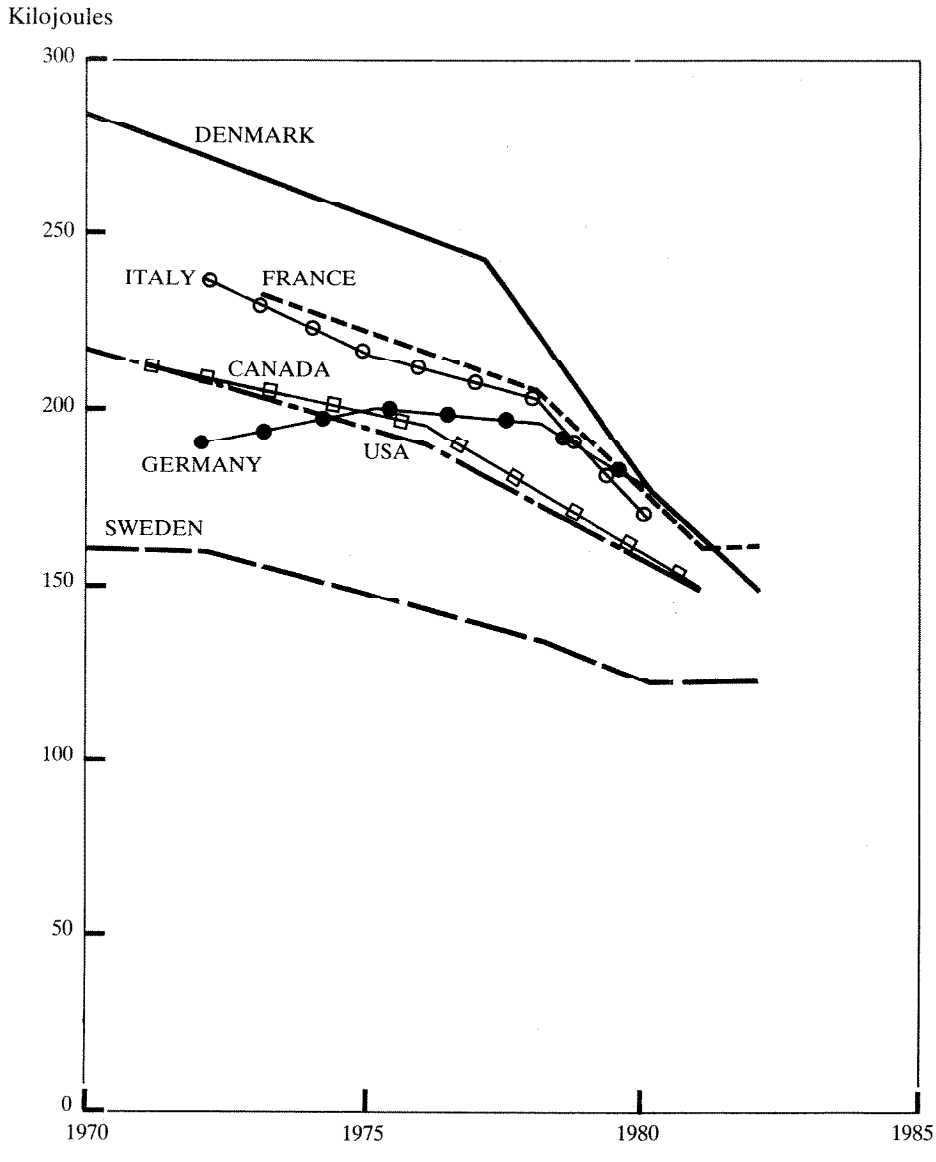
C. *Transportation Sector*

Oil accounts for close to 99% of energy consumption in this sector, and road transport is responsible for 80% of this oil use. Most measures of transportation energy efficiency have improved since 1973, but overall energy use trends have not been consistent. Transportation energy

1. Schipper, Meyers, Ketoff, "Energy Use in the Service Sector: An International Perspective", *Energy Policy,* June 1986.

Figure 4

Space Heat. Useful Energy[1] per Degree-day per Square Metre
(1970-1982)



1. Useful energy is energy consumption for space heating multiplied by an average furnace efficiency for oil/gas burners of 66%, for solids of 55%.

Source: Schipper, Ketoff and Kahane, "Explaining Residential Energy Use by International Bottom-Up Comparisons", *Annual Review of Energy* 1985. 10:341-405.

demand rose between 1973 and 1979, declined from 1979 to 1982, and has since again risen slowly. While fuel efficiency in passenger cars has improved, better economic conditions have acted as a stimulus to consumption, particularly in commercial transport. Passenger cars accounted for almost 67% of consumption in the road transport subsector in 1973, and 61% in 1983, while consumption by commercial vehicles increased from 33% to 39%. Based on analysis by the IEA Secretariat, of the 19.6% reduction in consumption per passenger and commercial vehicle observed between 1973 and 1983, 65% was due to efficiency improvements and 35% to reduced average distance travelled per vehicle.

Vehicle fuel efficiency in the passenger car subsector has improved since 1973. Voluntary and mandatory standards governing new car fuel economy in nine countries have played a role as has the comparatively rapid turnover of vehicle fleets (about every ten years). Table 4 describes the improvements made in new car fuel efficiency since 1973. There have been improvements in all weight categories, and there are now smaller differences among countries within each category. While technical efficiency improvements have been incorporated in the new vehicles in all countries, these improvements have often been offset by trends towards larger and heavier cars, especially in some European countries. For commercial vehicles, technological progress in vehicle engine design rather than fuel prices is the key. Fuel efficiency improvements have been slower because units tend to be big and have longer lifetimes. Goods vehicles have shown more improvement than buses, and also the relative use of diesel versus gasoline has been responsible for different levels of fuel economy across IEA countries. Efficiency improvements in the commercial transport subsector, however, have been more than offset by increased vehicle kilometres driven — a reflection of general economic growth.

The maritime, aviation and railway subsectors all depend on petroleum products for energy. Together they accounted for about 17% of oil consumption in the transport sector in 1973 and 1984. Higher fuel prices and other factors resulted in significant efficiency improvements in each of these subsectors during the past decade.

D. *Energy Transformation Sector*

The transformation sector encompasses the conversion of primary fuel into more useful energy forms, as well as the distribution of energy to

Table 4

Actual New Passenger Car Fuel Efficiency

(Gasoline consumption in litres per 100 kilometres)

								Projections/Targets		
	1973	**1978**	**1979**	**1980**	**1982**	**1983**	**1984**	**1985**	**1990**	**2000**
Australia	n.a.	11.8	11.2	10.1	9.8	9.5	9.5		8.5[1]	
Canada	n.a.	11.5	11.5	10.3	8.5	8.5	8.4	8.2	7.4	6.8[2]
Denmark	9.0[3]	n.a.	n.a.	8.6	n.a.	7.3	7.0	7.1		
Germany	10.3	9.6	9.4	9.0	8.3	8.0	7.7	7.5		
Italy[4]	8.4	8.3	8.3	8.1	8.3	8.0	n.a.	7.8	7.4	
Japan	10.4	8.8	8.6	8.3	7.7	7.8	7.8	7.8		
Netherlands	n.a.	9.2	8.9	8.8	8.5	n.a.		9.1	8.6	7.8
Sweden	n.a.	9.3	9.2	9.0	8.6	8.6	8.5	8.5		
United Kingdom	11.0	9.1	9.0	8.7	8.1	7.9	8.8	7.6		
United States	16.6	11.8	11.6	10.0	8.9	9.0	8.9	8.7	8.8	8.2

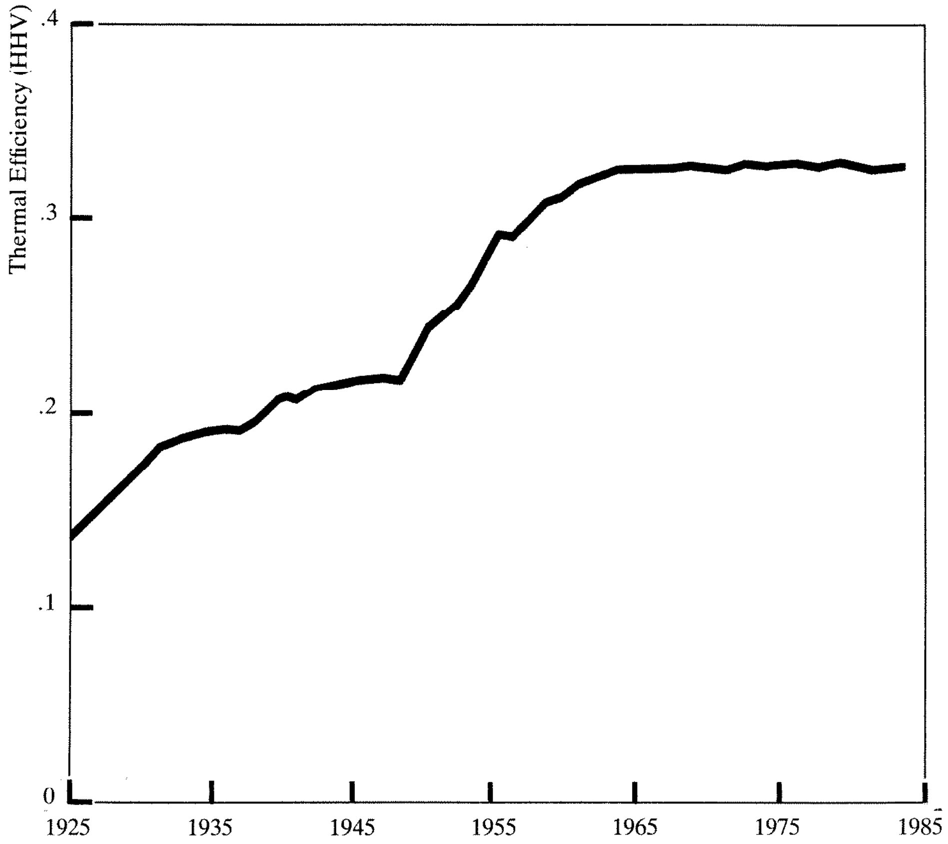
1. 1987 target.
2. 1995.
3. 1975.
4. The figures for Italy represent average efficiency of the total car fleet.

Source: IEA Country Submissions.

end-users. In IEA energy balances, the energy demand of the transformation sector is the difference between the input of primary energy (TPER) and secondary energy forms produced (TFC). It therefore represents exclusively the losses in the conversion processes and in the extraction and distribution of energy. This sector is now larger and growing faster than any of the end-use sectors. The transformation sector is dominated by electricity (close to 80%), with most of the rest accounted for by energy use and losses in oil refineries.

Figure 5

Average Efficiency of Steam-Electric Plants in the United States



Source: IEEE Technology and Society Magazine, United States, 3/86.

The rapidly increasing demand for electricity has resulted in an increase in the energy losses that make up the transformation sector. Although the early development of electric power resulted in major increases in energy efficiency, these regular gains virtually disappeared during the 1960s, as revealed in Figure 5. Since that time comparatively little progress has been made and, in a few cases, energy efficiency has actually declined as slightly less efficient coal-fired power plants have increased their share of total electricity generation.

On the other hand, in the petroleum refining sector, there have been major efficiency improvements since the mid-1970s. These resulted in a 17% decline in the percentage of refinery input consumed internally from 1973 to 1984, despite higher input requirements to maintain gasoline octane levels while phasing out lead content.

Conclusions

As a result of rising energy prices, government conservation policies and general trends towards improved productivity, energy use has become more efficient in IEA Member countries over the past ten years. Improved efficiency rates, especially from 1979 to 1983, have lowered energy intensity ratios and slowed energy demand growth. In particular:

— Since 1973, substantial improvements in energy efficiency have been achieved in all energy end-use sectors. Efficiency gains have been small only in the transformation sector.

— While the energy efficiency improvements since 1973 have been large, particularly after 1979, they represent only an acceleration of previous trends, especially in the industrial sector.

— Rising energy prices, especially after 1978, were the single most important factor contributing to the acceleration of efficiency improvements, but numerous other factors also influenced conservation actions.

— While major progress was made in all end-use sectors, the level of efficiency improvements varied considerably among different end-uses.

— In industry, the largest efficiency improvements were made by energy-intensive industries, such as primary metals, which usually had the financial resources, technical capabilities and motivation to conserve.

- In buildings, major progress has been made in new building design and certain categories of equipment. These efficiency gains were not made consistently throughout the sector and were often outweighed by increasing space conditioning and home appliances.
- In transportation, the technical energy efficiency of new cars has been improved significantly in almost all countries, but trends towards larger vehicles and increased travel have offset these gains in some regions.
- In the transformation sector, little progress has been made towards improving the efficiency of electricity generation and distribution, but large gains have been made in the efficiency of the petroleum refining industry.
- Recent energy demand data for 1984 and 1985 suggest that stable or declining world oil prices and higher levels of economic growth have reduced, but not reversed prior trends towards declining energy intensity. These most recent trends deserve further analysis.

CHAPTER IV

Potential Efficiency Improvements and Future Trends

The previous chapter has shown that substantial efficiency improvements, combined with structural changes and slow economic growth, resulted in much lower rates of growth in energy demand over the past ten years than during the previous several decades. Chapter III also identified many of the causes of these changes and some of the more recent trends towards improved technical efficiency.

The purpose of this chapter is to consider probable future progress towards improved energy efficiency that is likely to occur in response to changing energy prices, increased productivity, other market forces and current government policies. The chapter also assesses whether this progress will be sufficient to achieve the economic potential for energy savings that exists. This section begins with an assessment of the current economic potential for energy efficiency improvements. It is followed by an assessment of likely future trends in efficiency improvements. The chapter concludes with an assessment of further opportunities for efficiency improvements, in addition to those that are likely to be achieved as a result of market forces and current government policies.

A. **Current Potential for Efficiency Improvements**

Assessing the remaining potential for efficiency improvements is important because it can help determine to what extent future progress is likely or possible. But even if it can be shown that a large potential for savings still exists, it is necessary to analyse carefully where the potential exists and why in order to develop effective government policies to achieve it.

The first essential step in this analysis is to establish energy price assumptions and investment criteria to be used in determining whether or not particular actions are considered desirable. Ideally, the energy price assumptions used in calculating the economic attractiveness of conservation investments should reflect the full costs of energy supplies during the life of the investment. This is usually referred to as the long-run marginal cost of energy, including appropriate external costs, such as the security and environmental effects of energy use. Similarly, to ensure a balanced allocation of capital resources, the criteria used in assessing conservation investments should resemble those used for energy supply investments or others which are comparable. In general, estimates of conservation potential should include those actions which are less expensive than energy supplies, while still providing the desired service. Since energy prices, external costs, conservation expenses and desired services vary, the actual values used in such analyses should be based on data from individual Member countries.

For conservation actions that involve changes in energy services, such as thermostat adjustments, the only true measure of cost-effectiveness is the value placed on the change by those affected. Because it is virtually impossible to determine independently such values, most assessments of the potential for further efficiency improvements exclude those actions which result in significant changes in services to energy users.

In examining the potential for energy efficiency improvements, it is also useful to review the broad range of actions that can be taken to conserve energy and some of the factors affecting their implementation.

Changes in Services: These types of actions, such as lower indoor temperatures in winter, are often responses to higher energy costs or to the introduction of individual metering for utility costs. Sometimes they result in permanent lifestyle adjustments, such as a shift to public transport. However, changes that are perceived as undesirable tend to be replaced by other types of efficiency improvements or simply phased out over a period of years.

Maintenance: Improved maintenance of energy-using systems can increase efficiency without affecting services. Because maintenance can be improved quickly and relatively inexpensively, it is often one of the first types of measures taken in response to higher energy costs. On the other hand, unless such practices are regularly pursued the efficiency gains can also be quickly lost.

Controls (and Monitoring): Manual and automatic controls help match the timing and rate of use of energy systems to consumers' needs. In this way, energy use can be significantly reduced for a relatively low cost and without affecting the desired service. Once an automatic control system is in place and working properly, the resulting efficiency gains are likely to be long-lasting. Such control systems are often supported by meters or other types of monitoring equipment. While such feedback systems do not directly affect energy use, they do encourage improved maintenance, control and investment efforts.

Discrete Conservation Investments: These are investments that are primarily directed at improving end-use efficiency, such as installing insulation in existing houses or heat recovery equipment on industrial processes. They can range from small, very cost-effective investments, to very large outlays which have comparatively low rates of return. Once installed, the resulting efficiency gains often last for many years. Decisions on such investments are often affected by short-term energy prices or other economic changes. If lower prices threaten the economic viability of the investment, it is likely to be rejected. On the other hand, such investments are usually not time-sensitive; that is, they can be reconsidered if prices stabilize or rise again.

Integrated Conservation Investments: These types of investments are made primarily for reasons other than conservation, such as replacing an old appliance or building a new home. The category includes the manufacture and purchase of new, energy-efficient automobiles and investments in new technologies, such as industrial processes, that are primarily designed to reduce total production costs or to achieve other, non-energy objectives. It also includes many technologies, such as thermal windows, that are sometimes implemented as discrete conservation investments, but are usually more cost-effective when implemented as part of a larger investment activity, such as major building repair or renovation. Efficiency improvements from this type of investment are less likely to be affected by short-term energy price changes than are discrete investments, described above.

Examples of each type of action can be found in all energy end-use sectors. Their relationship to overall efficiency improvements is depicted in Figure 1.

A full assessment of the remaining potential for energy efficiency improvements in Member countries of the IEA would be a truly enormous task — far beyond the scope of this study. It would require current and detailed data on the number and efficiency of energy-using devices, such as appliances, buildings, vehicles, industrial processes and other energy conversion systems. It would also require information on local energy prices, climate and the characteristics of existing stocks of energy systems in order to determine their suitability for retrofit. Such a detailed analysis has seldom been performed for individual sectors or localities, and even move rarely on a national or international basis. To extend such an assessment into the future would be even more difficult, requiring projections of numerous economic and energy conditions that are inherently uncertain.

A large number of more limited studies of the potential for further energy efficiency improvements have been made. These studies fall into two broad categories:

— Technology studies which analyse the efficiency of particular categories of existing end-use technologies;

— Sectoral studies which attempt to assess the broad potential for conservation in a major end-use sector or sometimes a country or region. These studies often rely upon technology-specific analyses.

The results of a range of technology and sectoral studies are summarised in Tables 5 and 6. They indicate the broad potential for economically attractive energy savings in most IEA countries, but they are not sufficiently comprehensive or precise to represent fully the many differences among Member countries. Because most of these studies were completed before 1986, they generally do not reflect the effects of the 1986 decline in world oil prices and they do not take into account the efficiency improvements achieved since their completion. However, for the following reasons these limitations are not expected to affect substantially the basic conclusions drawn from these studies:

— the high rate of return of most conservation actions means that even significant energy price decreases would not change their cost-effectiveness;

— the actual reductions in retail energy prices have been comparatively small (about 15% on average) for most end-use sectors and energy forms;

— long-term energy price expectations have not changed substantially;

— new technologies have emerged which were not fully considered in earlier potential estimates;

— the rate of efficiency changes over the past several years has not been sufficiently great to diminish significantly the potential for savings.

The data included in the tables, while neither comprehensive nor precise, do provide some general insights. First, the remaining potential for efficiency improvements seems to be especially large in the buildings sector. Second, the potential for savings remains large for all energy forms and sectors, and most energy uses or subsectors, regardless of region. However, the efficiency of some new industrial and transportation equipment approximates the efficiency of the best available technology, which suggests that the emergence of new technologies in these sectors may be key. Finally, while the remaining potential is large in all regions, it appears to be comparatively greater in those countries or regions that have traditionally been more energy-intensive, such as North America.

While these studies often differ in scope and assumptions about economic viability, they provide support for a conservative estimate that energy efficiency improvements of 30% could be realised over the next ten to twenty years if all economically viable conservation investments were made in IEA Member countries. The estimate does not assume the development of new technologies, nor does it include the further improvements that could be achieved through the complete replacement of major physical stocks (such as existing buildings), which will still be economically useful for much more than twenty years. Also the estimate is not an indicator of potential reductions in current energy demand levels. Assuming continued economic growth, there could still be an increase in TPER during this period, even if most of the existing potential for efficiency improvements were to be achieved. This is especially true for those countries with high rates of economic growth and for those energy forms experiencing larger increases in demand, such as electricity. However, a 30% increase in energy efficiency would,

Table 5

Energy-Efficient Technologies and the Economic Potential for Conservation[1]

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	(e) % Savings	(f) Average Useful Life of Technology	(g) Notes
RESIDENTIAL	20-25%						
- U.S. (All electric)		1 501 (Watts per capita)		328	- 78%	Over 30 years	
- Sweden (All electric)		1 242 (Watts per capita)		266	- 78%		
Heating and Cooling - Building shell thermal efficiency	8-12%					Over 30 years	
- U.S. (winter)		160 (KJ per m² per degree day)	100 (- 37%)	50	- 70%		
- Sweden (winter)		135 (KJ per m² per degree day)	65 (- 52%)	35	- 74%		
Heating - Oil/Gas - System Efficiency	8-12%					10-20 years	
- U.S.		65-70% (% of TPER converted to useful heat)	75-80% (- 13%)	84-94%	-23-26%		
Cooling - Central a/c -	1-2%					10-20 years	
- U.S.		7 (Energy Efficiency Rating)	9 (- 22%)	14	- 50%		
Refrigerators/freezers	2%					10-15 years	
- U.S.		1 500 (kWh/year)	1 300 (-13%)	750	- 50%		

1. Documented in Annex E.

Table 5

Energy-Efficient Technologies and the Economic Potential for Conservation[1] *(Continued)*

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	(e) % Savings	(f) Average Useful Life of Technology	(g) Notes
- Germany		About 400 (kWh/year)	(- 20%)		At least - 20%		
- Japan		35 (kWh/month)	28 (-20%)		At least - 20%		
Water Heating	3-5%					15 years	
- U.S.		4 000 (kWh/yr)	3 600	1 700	- 57%		
COMMERCIAL	15-20%						
Heating and Cooling	10-12%					30 + years	
- U.S.		1.31 (GJ per m²/yr)	0.73 (- 44%)	0.32	- 75%		
- Sweden		1.04	0.76 (- 27%)	0.25-0.46	-55-75%		
Large Office Buildings	5%						
- U.S.		270 (KBtu/ft²year)	200 (- 26%)	100	- 63%	30 + years	
Lighting	3-5%					1-10 years	
- U.S.							
Ballast/Tubes		64 (lumens/Watt)	73 (- 12%)	86	(- 26%)		
Controls					(-20-30%)		
Total					-40-50%		
TRANSPORTATION	20-25%						
Automobiles	10-13%					10 years	40 mpg may be technically possible at cost of less than $1/ gallon saved

1. Documented in Annex E.

Table 5

Energy-Efficient Technologies and the Economic Potential for Conservation[1] *(Continued)*

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	Best Available Technology (e) % Savings	(f) Average Useful Life of Technology	(g) Notes
- U.S.		19.0 (miles per gallon)	26.1 (- 34%)	31.5	- 46%		
- Japan		[11] (km/1)	13 (- 15%)				
Other road transport	7-10%						
Air Transport	2-3%	[25] (passenger miles/gallon)	30 + (-20%)	40 +	- 40%	15-30 years	
- All							
Rail/Marine/Other	2-3%						
INDUSTRY	35-40%						
Chemicals	6-8%						
- U.K. (Inorganic)					- 13%		
Iron and Steel	5%						
- U.S./Japan/U.K./Neth.		22-24 (GJ/tonne)	17-18 (-20-25%)	N.A.	At least -20-25%	10-30 years	
Non-ferrous metals	3%						
- OECD (Aluminium)		15-17 (mWh/tonne)	13.5 (-10-20%)	N.A.	At least -10-20%	20-30 years	Technology being developed could reduce consumption 30-40%
Paper	3%						
- U.K. (Paper & Board Making)					- 30%		
Stone, Clay and Glass	2%						
- U.S./France/Switz./U.K. (Bricks/Pottery)		2.5 (MJ/kg)	1.5-2.0 (-20-40%)	N.A.	At least -20-40%	10-30 years	0.5 MJ/kg theoretical minimum

1. Documented in Annex E.

Table 5

Energy-Efficient Technologies and the Economic Potential for Conservation[1] *(Continued)*

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	Best Available Technology (e) % Savings	(f) Average Useful Life of Technology	(g) Notes
- France/U.K./Switz./Germany (Cement)		3.6-3.8 (MJ/kg)	3.3 (-8-13%)	N.A.	At least -8-13%	10-30 years	1.5 & 3.0 MJ/kg theoretical minimums for dry and wet processes
Food	1%						
Space Heating, Cooling, Water, Heating, Lighting	2-3%						
ALL SECTORS							
Electric Motors	20%	75-90% (% converted to motive power)	80-92% (-2-7%)	85-93%	(-3-12%)	10-20 years	More efficient motors
					(-10-20%)		Variable speed controls
					-15-30%		Total Potential Electric Motor Savings
Central and On-Site Electricity Generation	35%						
- U.S. (Gas Turbines)	N.A.	30% (% converted to electricity)	35% (- 15%)	39-41%	- 25%		Best combined cycle and steam injected gas turbines Projected 1990 best: 44-48% efficient; total savings: 32-37%

1. Documented in Annex E.

Table 6[1]

Sectoral Studies of Conservation Potential

Country	(a) End-Use Sector	(b) Year of Study	(c) Estimated Economic Potential for Demand Reductions %	(d) Remaining Potential After Projected Effects of Market Forces %	(e) Year in which Economic Potential could be Achieved	(g) Notes
United States	Residential/Commercial	1981	- 50%		2000	
United States/Texas	Residential/Commercial	1986	- 50%		2000	Electricity only
United States	Residential/Commercial	1985	- 27%	- 17%	2000	
United States	Transportation	1985		- 30%	2010	
United States	Industry	1984	-35-40%		2000	
		1985		- 18%	2010	
United States	All Sectors	1983		- 22%	2000	
Canada	Residential	1986	- 33%	- 21%	2000	
	Commercial	1986	- 22%	- 24%	2000	
	Industrial	1986	- 15%	- 9%	2000	
	Transport	1986	- 20%	- 18%	2000	
	All	1986	- 22%	- 17%	2000	
Japan	All	1983	- 15%		1990	
		1984	- more than 20%		1995	
United Kingdom	Industry	1984	-21-29%		2000	United Kingdom study estimates that 21-25% efficiency gain is likely to occur. 29% estimate based on "technical potential"
Netherlands	Industry	1985	- 21%		2000	
	Residential	1985	- 21%			
	Commercial	1985	- 38%			

1. Documented in Annex E.

Table 6[1]

Sectoral Studies of Conservation Potential *(Continued)*

Country	(a) End-Use Sector	(b) Year of Study	(c) Estimated Economic Potential for Demand Reductions %	(d) Remaining Potential After Projected Effects of Market Forces %	(e) Year in which Economic Potential could be Achieved	(g) Notes
Austria	Industry	1981	- 10%			Heat pumps only
	Residential	1984	- 25%			
Norway	Industry	1984		- 12%		
	Residential/Commercial	1984		- 10%	2010	
Sweden	Residential	1985	- 50%		N.A.	
	Commercial	1985	- 40%		N.A.	
	Industry	1983		-20-50%	1990	
European Community	Residential/Commercial	1984	- 30%		1995	
	Small-/Medium-sized Industry		-10-20%		N.A.	
	Industry	1986	- 25%		2000	
Western Europe (EUR-9)	All Sectors	1983		- 19%	2000	
	Industry	1985	- 30%		2000	

1. Documented in Annex E.

if achieved, reduce future energy requirements by about 25% from the levels that would have been reached if no further efficiency improvements were made. This could be the equivalent of more than 1 200 Mtoe per year in 2000.

The potential for conservation is like the potential for additional energy supplies. With stable energy prices and current end-use technology, energy efficiency improvements are limited. But as energy prices fluctuate and new technologies are developed, the potential for cost-effective efficiency improvements changes, just as the economically recoverable reserves of energy change with prices and technology.

There are many reasons why there remains a large potential for economically attractive efficiency improvements. First, a major portion of the potential for energy conservation can only be realised through integrated investments that are dependent on the gradual replacement of the existing, less efficient stocks of energy-using equipment, vehicles, processes and buildings. It is often not technically possible or economically practical to modify existing equipment to achieve the full potential for energy savings, but major energy efficiency improvements have become integral parts of many new products.

Second, new technologies always require time to be introduced and even afterwards, they usually need many years to penetrate fully any market.

Third, there are large segments of key end-use sectors that have not yet taken significant conservation actions because of distorted energy prices or market limitations, such as lack of information or absence of direct user responsibility for energy costs (see Chapter V).

These characteristics of the market for conservation technologies help explain why improvements in the energy efficiency of whole economies are gradual and not spasmodic. They also help explain why trends towards improved energy efficiency are likely to continue in the future — even without higher energy prices or expanded government efforts. The following section examines likely future trends in energy efficiency and the extent to which they will achieve the existing potential for conservation.

B. Future Trends in Energy Demand and Efficiency

Many factors will determine the levels of energy demand and efficiency in IEA Member countries over the next twenty years. The two most important are likely to be economic growth and energy intensity. Future levels of energy intensity will, in turn, be determined by the rate of structural change in the economies of IEA Member countries and the rate of energy efficiency improvements. The most important factors influencing future energy efficiency levels will be:

— *Energy costs and availability* — reflected in energy prices and the ease of access to supplies;

— *Conservation technology costs and availability* — the other half of the equation which is assessed by investors in energy conservation. Recent trends have increased the availability and reduced the costs of conservation technologies;

— *Conservation services* — the availability of the technical and financial services most energy users require in order to take effective conservation action. They range from the availability of basic information on appliance efficiency to the level of knowledge about conservation technologies held by consulting engineers to the availability of contract energy management services for building owners;

— *Turnover of capital stocks* — the rate at which existing energy using systems are replaced by new, usually more efficient systems, determined primarily by the physical characteristics of the individual systems, but influenced by the rate of economic growth. Some examples include conventional incandescent light bulbs (often less than one year), automobiles (ten years), home appliances (ten to twenty years) and commercial buildings (more than thirty years); and

— *Economic growth* — which will affect the resources available for investment in more energy-efficient systems.

Energy and related government economic policies will also have very important effects on future energy demand, usually by influencing one of the factors cited above (see Chapters VII and VIII).

Based on an assessment of recent trends and the likely future direction of the above factors, a discussion of some probable future trends in energy demand and efficiency follows. After the sector summaries, there is an assessment of the opportunities for conservation which are not likely to be achieved based on the trends currently anticipated.

I. Industry

Over the next twenty years, industrial energy demand can be expected to grow, but in most IEA countries it will probably grow at a much slower rate than total GDP and slower than other end-use sectors. This is the result of both lower overall growth in industrial production (and faster growth in the service sector), and reduced energy intensity levels. Future reductions in industrial energy intensity are likely to be caused by continued shifts towards less energy-intensive industries (i.e. industries with lower energy to value added ratios) and basic improvements in industrial process technologies. The more widespread use of existing, more energy-efficient industrial processes and equipment will probably represent the largest share of industrial efficiency improvements over the next ten years. Discrete conservation investments, which are more sensitive to short-term energy price trends, probably will have a less significant impact than they did during the past ten years, but improved operational practices already introduced are likely to be sustained and even strengthened through the wider application of computer-based control technologies.

Improvements in energy efficiency are likely to continue to occur in large, energy-intensive industries which are also experiencing moderate to rapid growth. But such industries are not very common in IEA Member countries. While these industries have the motivation and the technical and financial resources to improve energy efficiency, industries which are smaller, less energy-intensive or expanding less rapidly are likely to make efficiency improvements more slowly. One indication of this can be drawn from a survey of European industry managers which was commissioned by the IEA Secretariat. The survey indicated that industries were likely to pay significantly less attention to efficiency improvements if energy represented less than 10% of the firm's manufacturing costs.

Individual countries or regions which have well developed industrial sectors may experience significant reductions in energy intensity as a result of structural shifts towards new, less energy-intensive industries. However, these countries may also find it difficult to stimulate conservation investments in those existing industries which are stable or declining. Countries with effective mechanisms for bolstering industrial energy management programmes and otherwise encouraging the accelerated adoption of new, more energy-efficient technologies may be able to overcome some of this natural resistance. Regions that experience high growth in more traditional, energy-intensive industries are likely to experience large efficiency gains, but are less likely to witness significant overall reductions in industrial energy intensity.

Short-term decreases in world oil prices, which have a greater effect on end-use prices for industry than for other end-use sectors, will reduce the rate of improvement in industrial energy efficiency. Lower oil prices are likely to reduce significantly the expected rate of return of many discrete conservation investments, but they are not likely to have a similar effect on established operational practices or on the adoption of efficiency improvements which are an integral part of new industrial technologies and processes. Companies with established energy management programmes are not likely to abandon them because of comparatively low short-term prices. These assessments have been partially confirmed by a recent IEA survey of the response of selected European industries to the sharp drop of world oil prices in 1986. The lower product prices that result from reduced energy costs are also likely to bolster demand for energy-intensive products, but again this effect is unlikely to change basic trends towards less energy-intensive industries.

II. Residential/Commercial

As a result of growing populations, increasing incomes and a rapidly expanding service sector, energy demand in residential/commercial buildings is likely to continue to rise but, as in the other end-use sectors, these increases will probably be moderated by improving energy efficiency.

a. *Residential Buildings*

The rate of growth in energy demand in the residential subsector will vary significantly among Member countries depending on three different factors:

— the rate of growth in the number of households;

— the rate of increase in a few key energy using characteristics, including conditioned space per capita, central heating and major appliances;

— the rate of increase in overall efficiency, but especially the rate of increase in the average efficiency of new energy-using equipment installed in both new and existing buildings.

Increases in personal income will have an important but limited effect on total residential energy demand unless the rate of household growth is high or the present penetration of major energy-using residential equipment is low. In countries where neither characteristic is present, increased personal expenditures are likely to go towards substantially less energy-intensive domestic services (such as home electronic equipment) or towards non-residential energy use, such as transportation. Although the market penetration limits of certain residential energy features (such as space, central heating, and clothes washers and dryers) are very difficult to predict, analyses of major appliance penetration rates suggest that likely increases in such features over the next ten to twenty years will be smaller for most IEA Member countries than was the case during the last twenty years.

Because of more energy-efficient residential heating equipment, major appliances and new building designs, the efficiency of the residential subsector will continue to improve in the future. The more energy-efficient designs already adopted by the housing construction industry and equipment manufacturers are likely to be maintained regardless of short-term changes in market signals. On the other hand, consumer behaviour, which can have a major effect on residential energy use, and the rate of discrete conservation investments, is likely to be significantly affected by energy prices.

A number of new, more energy-efficient technologies have been or will soon be introduced in the residential market, such as pulse combustion furnaces and compact fluorescent light bulbs. The success of these technologies will have important effects on long-run residential energy efficiency and demand.

The establishment of more effective public or private services able to assist residential building owners in selecting and implementing cost-effective conservation measures could be especially influential. The development of a more effective service industry is, however, likely to be hindered by the fragmentation, lack of sophistication, and limited resources of this sector. Energy services or contract management companies have begun to serve effectively portions of the multi-family housing sector, but it is unlikely this model could be extended to small residential buildings. For smaller buildings, a first step may be the introduction of more effective energy monitoring or feedback mechanisms which would enable and encourage consumers to exercise more control over their energy use. A very conventional, but still very effective form of feedback is individual meters for utility costs. Experience in Europe and the United States has indicated that the introduction of such individual metering usually reduces energy demand by 15-25%.

Current and future government actions will have major impacts in this subsector. Many governments of Member countries have traditionally played an important role in the residential subsector through the establishment of building construction standards and the ownership or support of lower income housing. In addition, government conservation efforts, such as information programmes and financial incentives, have been particularly numerous in the residential subsector.

b. *Commercial Subsector*

The commercial subsector, which includes all non-residential and non-industrial buildings, agriculture, the public sector and other miscellaneous energy uses, encompasses a broad range of structures, energy uses, and owner/occupant characteristics. Therefore, generalisations about future trends in energy demand and efficiency are difficult. There is a segment of the commercial subsector which is likely to respond to market forces in much the same way as major industries. This segment includes those large corporations and building management companies that have available skilled technical resources and the financing and motivation necessary to pursue vigorously improved energy efficiency. But this segment represents one-third or less of the total floor space and energy use of the subsector.

Another major segment of the subsector is composed of government-owned or institutional buildings. Some governments and institutions have had access to the required technical resources, but they often do not have easy access to the necessary financing (because of annual budget restrictions and a tendency not to borrow money for these types of efficiency investments). In many cases, the agencies or individuals undertaking conservation measures do not secure financial benefit from it, thus reducing the motivation towards improved efficiency.

A third segment is made up of medium- to small-sized businesses, for which energy usually makes up only a small percentage of their total costs and which often do not own the buildings where they are located. These businesses usually have neither the technical resources nor the motivation to make significant conservation improvements. This segment probably accounts for one-fourth to one-half of energy use in the commercial subsector.

As new buildings are constructed and existing energy-using systems replaced, efficiency improvements that have already been introduced will have a larger and larger impact. These trends have been reinforced in many IEA Member countries by the establishment of energy conservation construction standards for new commercial buildings. Such standards will have a particularly large effect because of the high growth rate of the commercial sector. The extent to which energy efficiency measures are adopted during major renovations of existing commercial buildings, which often occur once or more during the building's lifetime, will also have a major effect on the long-term trends in this subsector. But such renovations are often not covered by existing energy conservation building standards. For this subsector especially, government actions will be critical because government-owned or supported buildings represent a large fraction of the total sector. Most IEA Member governments have instituted and maintained conservation programmes for these buildings. For these reasons, efficiency is likely to continue to improve in this sector, even during an extended period of stable or declining energy prices. This trend might even be accelerated if energy service or contract energy management companies penetrated a large portion of the market.

III. Transportation

Transportation energy demand will increase over the next decade or two, partially reflecting major increases in the distance travelled by road vehicles and aircraft. The overall increases in demand, however, will be reduced considerably by improved energy efficiency. Long-term trends in the energy efficiency of transportation are expected to be primarily determined by trends in petroleum prices and the emergence of new technologies, but major efficiency improvements already incorporated into many new automobiles, planes and other transportation equipment will not have their full effect for at least another ten years.

As noted in Chapter III, the transportation sector almost entirely depends on petroleum products and is heavily dominated by road vehicles, especially automobiles. In response to steeply rising oil prices in the late 1970s, major efficiency improvements were introduced in new automobiles, such as increased engine and transmission efficiency, reduced vehicle weight and improved vehicle aerodynamics. These efficiency improvements are likely to be further increased by the widespread adoption of technologies that have already begun to be introduced in some new car models. These new car efficiency improvements will continue to improve the overall fleet fuel economy of many IEA countries until the mid to late 1990s. However, in some countries the recent improvements in new car efficiency have been largely offset by shifts to larger (and heavier) vehicles. In these countries, average fleet fuel economy should remain relatively stable. Improvements in new car fuel economy beyond the mid-1990s will be determined by a mix of different factors, including energy price trends at the time, the success of current research efforts and trends in automobile sizes.

The improvements in the fuel economy of new trucks and other service vehicles are not likely to be as large, but past improvements, nevertheless have been sufficient to have some of the same effects on average fleet fuel economy over the next ten to fifteen years.

Other transportation energy uses represent less than 20% of the sector's total energy demand and, for the most part, have not experienced the major efficiency improvements that have occurred in new automobiles. One significant exception is commercial aircraft, where new planes generally consume 20% less per passenger mile than the average for existing fleets.

The rate of growth in overall transportation energy demand and the rate of change in average automobile fuel economy are expected to continue to vary greatly among IEA countries. In most European countries, vehicle sizes, the number of vehicles per capita and the annual vehicle miles travelled have all been considerably lower than in the United States and Canada. With economic growth, these measures have tended to increase more rapidly in Europe than elsewhere, and this has been reflected in increasing energy demand. In addition, higher European gasoline prices and very competitive automobile markets have resulted in the earlier adoption of fuel efficiency technologies than in North America — so future increases in European automobile fuel efficiency may be smaller.

IV. **Transformation**

Unlike the other end-use sectors, major efficiency improvements have not occurred in the transformation sector over the past ten to fifteen years. This sector is also the one which is growing most rapidly and which is likely to continue to grow the quickest in the future.

The basic energy efficiency of the transformation sector is not likely to change substantially over the next ten to twenty years, although there are several technologies which will offer opportunities for significant improvements in certain areas. The most important existing technologies that could improve the efficiency of electricity generation are combined cycle and steam injected gas turbines, and combined heat and power (CHP). These technologies could reduce the total primary energy used by 20-35% in specific applications. In the case of gas turbines, they require the use of natural gas or oil and, in the case of CHP, the siting of facilities near industrial, commercial or residential users of heat energy. These characteristics will most certainly limit their use to only a portion of total generating capacity, but these more efficient generating technologies could still make a significantly greater contribution than they do today. Combined cycle or steam injected gas turbine technologies might be effectively used in areas where gas supplies are plentiful or where siting or environmental constraints make coal or nuclear power impossible. CHP could play a larger role in serving the electricity and heat requirements of industries and large commercial or residential complexes.

Even with wider use of more efficient conversion technologies, total energy demand by the transformation sector is expected to grow as a result of increasing electricity demand. The rate of increase in electricity demand over the next ten to twenty years is likely to be considerably less than it was during much of the past thirty years. This is true not only because of increasing efficiency in the use of electricity, but also because of changes in some of the underlying factors that have led to increased electricity use in the past (such as slow growth in the electric intensity of industry and buildings, and reductions in the relative price advantage of electricity, compared to oil and gas).

D. Summary of Efficiency Trends and Remaining Opportunities

The previous sections have described the current potential for energy efficiency improvements and the extent to which this potential is likely to be achieved in the future. There also has been an identification of end-uses where substantial potential for efficiency improvements exists, but based on current and anticipated trends seems unlikely to be fully achieved. Table 6, column (d) summarises some estimates of the economic potential for conservation that will remain, even after accounting for the efficiency improvements which are likely to result from changing energy prices, general productivity improvements and other market forces. Many of the reasons why these economically attractive efficiency improvements are not likely to be achieved are discussed in Chapter V. Ways to increase the achievement of these remaining opportunities are the focus of Part C.

In order to provide an overview of the likely remaining opportunities for efficiency improvements, it is useful to review current and expected trends in three broad areas:

— the extent to which existing, more energy-efficient technologies have already been incorporated into the design or manufacture of new energy-using equipment, vehicles, buildings and processes;

— the rate at which existing buildings and energy-using systems are being modified to utilise energy more efficiently;

— the extent to which energy-efficient operating practices, especially improved maintenance and control of energy-using systems, have already been adopted.

New Product Efficiency. Table 5 is not only a useful indicator of the current potential for energy efficiency improvements, but also shows the extent to which the most energy-efficient existing technologies are being utilised in new products, including industrial processes, electric motors, home appliances and buildings. Comparisons of columns (c) and (d) indicate that in many cases market forces and existing government efforts do not appear to be resulting in the adoption of the most efficient technologies. But in a few areas, such as new buildings and home appliances, the gap appears to be especially large. On the other hand, the gap does not appear to be very large for some technologies, such as new automobiles. While Table 5 is not a comprehensive review of all technologies or energy end uses, it does tend to support the general conclusion that the buildings sector is probably less responsive to market forces than the other sectors and that government efforts to date do not appear to have fully compensated for this. It also indicates that energy-intensive industries and the transportation sector in general appear to be generally more responsive to market forces and/or government efforts. However, gaps in the data available and the major differences among Member countries mean that country specific studies are required to provide truly useful information on the most important remaining opportunities for efficiency improvements.

Retrofit of Existing Facilities. Data on the rate of conservation investments in existing energy-using systems, buildings and other facilities are very incomplete. It is also difficult to identify the economic limits to the potential for efficiency improvements through retrofit alone. Table 5 provides a broad measure by indicating the difference between the best available technologies (column (d)) and the average efficiency of the existing stock (column (b)). Again, the gap is especially large in the buildings sector. But these differences overstate the savings that could be achieved through retrofit. The investments required to make existing facilities as efficient as new facilities are often not cost-effective. In some countries, data or less quantitative information are available on the rate of efficiency improvement in existing buildings. Existing rates of annual investment appear to be well below 5% of the total economically justified investment in energy efficiency. This means that based on current trends and technologies, it would take over twenty years to achieve most of the current potential. The rate of investment also appears to vary considerably from one portion of the building sector to another and, of course, from country to country. For example, those segments of the residential/commercial sector that have a high percentage of tenant occupied space, such as multi-family buildings, have tended to make conservation investments more slowly. So again, country-specific analyses are required. Retrofit of existing facilities is also important in the industrial sector. But for industry, the data on the rate of investment are even poorer. There have been some indications that major energy-intensive industries have made very substantial investments in existing facilities. However, the remaining opportunities for economically attractive investments also appear significant. More data would be necessary to estimate the rate at which the remaining investment opportunities are being achieved.

Improved Operating Practices. Efforts to improve the operating efficiency of energy-using systems through better maintenance and controls have been under way for many years. These types of actions are usually the most economically attractive and easiest to implement. This was reflected in the strong upsurge of such activities as one of the first responses to rising energy prices. Despite strong economic incentives, however, there are still many industries, commercial businesses, institutions and individuals that have yet to adopt such improved operating practices. This fact in itself is an indication that market forces and existing government efforts have not been fully effective.

It is not possible to estimate precisely the magnitude of the efficiency improvements which are not likely to be achieved as a result of market forces and existing government policies. But based on the estimates contained in Table 6, column (d) and other available information, it is reasonable to conclude that there would be economic potential to reduce further the projected energy demand in 2000 by more than 10% (at least 450 Mtoe per year) if existing opportunities for efficiency improvements were fully exploited. Some of the ways in which government might strengthen existing market forces or programmes in order to achieve these savings are addressed in Part C.

E. **Conclusions**

Despite substantial improvements in the general energy efficiency of the economies of IEA Member countries over the past ten years, there remains a large potential for economically justified efficiency improvements in virtually every region and sector, as well as in the use of every form of energy. Some energy efficiency improvements will continue to occur in virtually every end-use sector, even without higher energy prices. Efficiency improvements, which have already been made an integral part of many new appliances, equipment, vehicles, buildings, and industrial processes, will have increasing effects for ten to twenty years, even if energy prices are stable. Behavioural conservation actions and discrete conservation investments are expected to continue, but at a slower pace because many of the easiest conservation actions have already been implemented and because future energy price increases are likely to be more moderate than those experienced during the past ten years.

The analysis suggests that the potential for economic energy conservation measures is not likely to be fully realised or even approximated in the foreseeable future. The extent of the shortfall will vary between sectors and regions:

— the residential/commercial sector has the largest current potential for energy efficiency improvements and is also the sector likely to achieve the least of its potential based on anticipated trends;

— based on available technologies and current energy prices, some industries and types of transportation equipment may approximate the limit of cost-effective efficiency improvements in new stock within the next ten years (although efficiency improvements would continue as existing stocks are replaced);

— the potential for energy conservation, while large in all IEA regions, still appears to be greatest in those regions that have been traditionally the most energy-intensive, such as North America.

CHAPTER V

Market Limitations and Externalities

The analysis in Chapter III has shown that rising energy prices were the main impetus to the improved energy efficiency of the economies of the IEA countries between 1973 and 1985. In theory, market clearing energy prices in a perfect market would produce an optimal economic allocation of resources in the energy sector, including an appropriate effort on energy conservation. In practice there are a number of reasons why this does not happen. First, in many IEA countries different criteria appear to be applied for decisions on investment in energy conservation than those used in energy supply. Second, there are obstacles to economic pricing in the energy sector. Third, energy conservation has certain external benefits which in practice cannot be easily reflected in prices. Fourth, there are specific market limitations which prevent price signals from being reflected in the decisions of energy consumers.

I. Imbalances between Investment in Energy Conservation and Energy Supply

Investment in energy supply is much higher than in conservation. This is not surprising. The expenditure of relatively small amounts of capital on conservation can often bring big savings in energy costs. Many improvements in the efficiency of energy use are obtained from more general investments in new equipment, mainly for reasons other than energy conservation. Supply investments, on the other hand, are often part of large projects with long construction periods and long lives. Very large investments in energy supply, particularly electricity generation, will be needed if IEA countries are to meet demand and maintain energy security.

There is, however, also evidence that investment in energy savings today may be more cost-effective than investment in new energy production. In particular, Canadian work undertaken in 1984 attempted to define the real resource costs of energy conservation and energy supply alternatives. The results of this work are shown in Table 7.

Table 7

Comparative Costs of some Energy Conservation and Energy Supply Options

(1983 Canadian dollars, 7% Real Discount Rate)

Cost of Energy Saved by Various Energy Conservation Investments (Primary Energy)	**$/BOE[1]**	**Value of Energy from Various Sources**	**$/BOE[1]**
		Existing Supply	
New Housing:			
Super Energy-Efficient	$15-30	Electricity	$35-65
		Natural Gas	$15-35
Existing Housing:		(Short to Long term	
Reduce Average Consumption:		Export Prices)	
By 30%	$13		
By 40%	$28	International Crude Oil at Montreal	$22
High Efficiency Gas Furnace (Compared with Moderate Efficiency Gas Furnace)	$10-13	**New Supply**	
		Oil Sands Plant	$35-60
Steam Pipe Insulation	$8-10	Offshore Oil	$30
		Nuclear Electricity	$60
High Efficiency Commercial Lighting	$15-30	Offshore Natural Gas	$35

1. BOE = Barrel of oil equivalent (energy equivalent of one barrel of oil): costs and values assumes a zero security of supply premium for oil.

Source: Energy, Mines and Resources, *Economics of Energy Conservation in Canada,* Ottawa, Winter 1984.

It is important to secure optimal allocation of resources so that in general the same criteria are applied to decisions on investments to increase energy efficiency or supply. There are grounds for thinking that, in practice, the system of decision-taking is different and that as a result conservation investment is judged against significantly stricter criteria than those for supply. This arises from the fact that investment in energy supply is central to the activities concerned, while investment in conservation is often seen as more peripheral. Thus when resources are tight, enterprises concentrate on their main activity.

Major supply projects are assessed with sophisticated techniques, such as discounted cash flow analysis. Available evidence suggests that most private companies in IEA countries require, before agreeing to such investment, nominal internal rates of return of 10 to 20% after tax, with 15% as a central value. Depending on inflation rates, this is equivalent to real rates of return of about 5 to 15%. Much large supply investment in the public sector requires real internal rates of return of between 5 and 10%. Proposals for investment in a peripheral activity like conservation, on the other hand are often judged against simpler and seemingly more stringent criteria. The payback periods for current conservation investments appear to run mainly between one and three years. In the early 1980s even shorter payback periods were often required (one to two years), but it is possible they may have lengthened with the improved economic climate in some regions. Payback periods of one to five years are equivalent to a nominal internal rate of return of close to 100% to about 15% — well above those for supply investments. Their use means that potential investors are undervaluing the stream of returns which continue after the end of the payback period until the end of the investment's life which in some cases is comparable to energy supply investment. This imbalance in favour of supply investment is reinforced by the fact that energy suppliers, particularly those which are government-owned, can often raise funds for investment more easily and at lower cost than many of those wishing to invest in energy demand.

The criteria applied by private home owners to conservation investment appear to be less stringent than those used by companies, probably involving payback periods between two and ten years. In some countries, such as the United States where the average house is sold every seven years, required payback periods are closer to the lower limit; thus many home owners are unwilling to invest with payback periods of five to seven years. The problem of raising finance, however, is probably more severe in the residential compared to the private industrial sector. Moreover, because of lack of sufficient knowledge of how to evaluate the economics of different kinds of energy investments, investment in the residential sector is often less effective than originally intended.

II. The Obstacles to Economic Pricing of Energy

At their meeting on 9th July 1985, the IEA Governing Board at Ministerial level agreed on the need for energy pricing policies which permit consumer prices to reflect world market prices. Where world markets do not exist, Ministers agreed that prices should reflect long-term costs of energy supply and which interfere as little as possible with the operation of market forces, particularly through direct controls or subsidies. However, there are difficulties in applying these principles.

First, prices are inevitably influenced by short-term market considerations and thus may not reflect the long-term outlook which is important for investment decisions. This may have more serious consequences for conservation than energy supply. The bulk of supply investment is undertaken by large energy organisations many of which have sophisticated forecasting techniques to map long-term trends in energy prices. On the other hand, decisions on conservation investment are taken by organisations which are generally small and less knowledgeable about energy trends, and by individual consumers.

Second, the energy sector has a strong tendency towards monopoly although this tendency has been mitigated by competition between different sources of energy. During the last decade energy markets have become much more competitive. This is particularly true of oil and coal where the current surplus capacity in recent years has led to tight competition and, in the case of oil, to important structural changes. However, for certain uses there is no alternative to electricity. In addition, while the organisation and regulation of the electricity industry in IEA Member countries are diverse, they generally have one thing in common — public utilities have a monopoly of the market. They control supply but must accept a measure of public regulation and an obligation of delivery to the consumer. Gas is in a middle position. Delivery to consumers is often in the hands of monopoly utilities subject to public regulation. The effects of this monopoly are reduced by the fact that gas competes with other forms of energy — oil, coal, district heat and electricity — for all end uses; also several gas suppliers are vying for the same market — the competition is intense in the United States but more limited elsewhere. Developments in a number of IEA countries show a tendency to introduce more competition in energy markets. But monopoly characteristics are likely to remain, particularly in electricity and gas distribution. The implications of this situation for energy conservation will depend on the way in which prices are set. Artificially high prices could promote conservation but could provoke a misallocation of resources. Cross subsidisation between groups of consumers on the other hand could work against conservation.

Third, there are severe practical problems about determining what economic energy prices are and how to implement them, particularly for electricity and gas, although to a lesser extent. These problems are discussed in Chapter VII.

Fourth, government and other public authorities are prone to intervene in the level of energy prices. This intervention has led to price distortions in many countries, including general attempts to hold down energy prices in the interests of other policies, such as the promotion of industrial development, the reduction of inflation or to help the poor. These attempts were particularly marked following the oil price increase of 1973-74. Despite improvements in recent years many of these policies are still in place. This subject is also discussed further in Chapter VII.

III. **Externalities and Indirect Benefits and Costs**

The market-place allocates resources on the basis of costs and benefits reflected in prices. It may not always take into account wider social costs and benefits to which economic activity gives rise. A number of such externalities are particularly relevant to energy conservation.

(a) *Energy and the Environment*

The more efficient use of energy on an economic basis is of primary importance for achieving the objectives of both energy and environmental policy. Means to promote the efficient use of energy are — with very few exceptions — free of environmental disadvantages and the environmental problems associated with energy production and consumption are therefore reduced if less energy is used.

This view was confirmed by the meeting of the IEA Governing Board at Ministerial level on 9th July 1985. The Ministers agreed to strengthen, as appropriate, their policies to promote the efficient use of energy by economic energy pricing, removing barriers to the effective operation of price signals through the market and adopting specific measures and programmes.

There are exceptions to the general rule that measures to conserve energy have no adverse effects on the environment. For example, residential conservation can be improved with more insulation. However, indoor air quality may worsen due to both the effects on indoor air quality of reduced air circulation in a "tight" building and emissions from the building construction itself (e.g. formaldehyde, glass fibres). However, this is mainly a design problem which can be overcome by improved ventilation. To an increasing extent, heat exchange in combination with ventilation has become standard in new constructions. Potential conflict also exists between controlling emissions and obtaining optimum energy efficiency in motor vehicles; however, with advancing technology, gains can be made on both fronts. Emissions of hydrocarbons and nitrogen oxides can be reduced without incurring penalties on fuel economy or engine performance. Basically, the same argument also holds for large boilers in industry and power plants and concerns continue to arise about burning waste to produce heat and/or electricity, particularly near urban areas.

An undertaking which pollutes the environment will not normally have to assume directly the costs of the clearing up that pollution causes to buildings, health or nature. Many undertakings now take into account wider social responsibilities but in every IEA country protection of the environment is necessarily dealt with by regulations or planning consent systems. These regulations often incorporate the "polluter pays principle" under which the cost of measures to limit environmental damage, for example by emission controls, falls on the polluter. That means that those costs will be internalised in prices and reflected in the decisions of energy consumers and producers. However, controls do not eliminate environmental damage. There will remain external costs which can be reduced through energy conservation measures which would not normally be accounted for in energy price systems.

(b) *Energy Security*

Heavy reliance on imported fuels from insecure or unstable sources results in external costs to national economies that are also not fully reflected in market prices. Such costs may be reflected directly in the costs of maintaining fuel stocks or indirectly in national expenditures related to defence, but they are most often only clearly visible when those imported supplies are interrupted or manipulated. The pursuit of energy conservation can reduce the burden which other energy policies (such as oil exploration, oil stock piling and the development of alternative energy sources) would otherwise assume to secure stable energy supplies.

(c) *Social Policy*

The inability of poor people to pay for energy to heat their homes adequately is a serious problem in a number of IEA countries. Programmes to insulate homes can help to reduce this problem and, in some circumstances, can also reduce government expenditure. For example in the United Kingdom, government expenditure on fuel subsidies to the poor have risen from £11 million in 1973 to £443 million in 1985 — a tenfold increase in real terms — and a further £2 billion is estimated to be spent on energy by households on supplementary benefit. On the other hand, government expenditure on capital account for the poorest households (20% to 25% of the total) was only about £15 million in 1985 for basic insulation measures. An increase in the latter expenditure, as well as helping its recipients, might significantly reduce government expenditure on revenue account. The United States Weatherization Programme is the only grant programme in the IEA which is specifically designed for low-income groups.

(d) *Employment*

To the extent that certain energy conservation activities and investments involve significant net employment creation, they can generate external social benefits not fully reflected in purely economic calculations. A number of studies in Member countries have examined the effects of energy conservation programmes on employment, and several have concluded that net gains could be expected. The findings of some of these studies are:

— In the Netherlands, official macro-economic analysis based on experience until 1983 showed that by continuing conservation subsidies alive through 1985-90, employment could be boosted (3 000 jobs per year net);

— In the United Kingdom, the employment potential of an energy conservation programme directed principally at reducing space heating has been assessed over a ten-year period for two levels of investment: £10 billion for the base case and £24.5 billion for the maximum case[1]. The annual average employment generated by the two programmes is estimated to be 50 000 for the base case (building up to 68 000) and 124 000 (building up to 155 000) for the maximum case. Of the total number of jobs created, two-thirds would be employed in installing or manufacturing energy conservation equipment and materials. The jobs created would be largely unskilled and semi-skilled, with a high proportion of the jobs occurring in areas of high unemployment. The negative employment impacts upon the energy supply industries would be small — 1 300 in the base case and 2 750 in the maximum case at the end of the period. It is estimated that the cost to the government per job created would be around £10 000, which compares favourably with the job creation cost resulting from other government policies (around £12 300 from the regional incentives policy);

— A study for the Commission of the European Communities (EC) has estimated[2] that a strong energy demand policy in the ten EC Member countries[3] may lead to an overall average yearly net employment increase of about 520 000 person years by the year 2000. Here, negative effects caused by the substitution of conventional energy technologies and by decreased energy production and distribution have already been taken into account. By including the effects of the alternative use of funds which would be made available through reduced energy costs, net effects on the economy were calculated. This estimate is based on an analysis of the effects on employment in four European countries of increased market penetration of four major energy conservation technologies as well as biogas plants and solar collectors. The results of this analysis were then extrapolated to cover the entire additional energy-savings potential which is technically feasible in the ten EC countries.

1. Association for the Conservation of Energy, *Jobs and Energy Conservation*, London, February 1983.
2. Commission of the European Communities, *Employment Effects of Energy Conservation Investments in EC Countries*, Brussels, November 1984.
3. This study was undertaken before Portugal and Spain joined the European Community.

Similar results have also been found in the United States[1] and Canada[2] in 1978. Several studies examined, to some extent, the effects of conservation on employment, after accounting for the lost jobs in supply industries. One of the reasons why there was a positive net effect is that the conservation investments considered were more cost-effective than increased energy supplies — thus they had positive effects on overall economic activity. Another reason is that conservation employment tends to be national or locally based, whereas a portion of the energy supplied is often imported. Actual employment effects will encompass a wide range of industries and vary depending on local circumstances. Further study is needed also on the employment effects of energy supply strategies. In comparing the net employment of demand strategies on a local and regional level, factors such as labour intensiveness of supply and demand investments, workforce skills and degree of subsidisation would have to be investigated. Such analysis can only be made on the basis of specific programmes in specific situations.

IV. Specific Market Limitations

Lack of information and technical skills

Adequate information about what should be done to improve energy efficiency and how to do it is essential and yet often lacking. This is true both for consumers and for those providing energy-using equipment and conservation services and equipment.

Each of the end-use sectors has particular needs for information and skills. Utilities and large energy-intensive firms are aware of their primary energy inputs and costs, and they have the information and skills necessary to minimise them. On the other hand, small- and medium-sized and even large companies in non-energy-intensive industries often lack sufficient information and probably cannot provide sufficient skills themselves to accomplish potential energy savings.

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1. Douglas L. Dacy et al., *Employment Impacts of Achieving Energy Conservation Goals Pertaining to Automobile MPG Efficiency, Home Retrofitting and Industrial Energy Usage for the Period 1978-85,* Institute for Defense Analysis, May 1978.
2. David B. Brooks, *Economic Impacts of Low Energy Growth,* Economic Council of Canada, Discussion Paper 126, Ottawa, Canada, 1978.

The residential/commercial sector has greatest diversity due to many different building types, locations and uses; different heating/cooling, lighting, and cooking systems and requirements; and different types of users. Many building users or inhabitants know little about conservation techniques and most lack the skills necessary for anything but the simplest equipment installation. Information is largely lacking, confusing or inappropriate. Help comes from a variety of sources — neighbours, merchants, utilities, consumer associations and governments — but the advice can be conflicting[1]. When that happens, consumers will commonly opt to do little or nothing. Moreover, consumers frequently do not know what measures are likely to be most cost-effective. A United Kingdom study on investment in 1982-83[2] showed that obtainable rates of return in residential conservation fell between 5% and more than 100% in 1982-83, but that the least economic investments, such as double-glazing, were implemented on a much broader scale than highly cost-effective projects because of active market pressure for the higher-cost options. Service groups such as manufacturers, builders, insulation installers, furnace repairmen, architects, engineers, and equipment operators can lack sufficient knowledge of available energy-efficient equipment and energy management techniques including total systems approaches.

Invisibility of energy consumption and conservation

Most energy consuming systems and services do not measure energy consumption. Thus there is little feedback to encourage consumers to conserve. Individual appliances used by residential consumers — including heating systems — seldom monitor energy use and the central meter for the dwelling gives poor feedback. The bill for energy use is in many cases received weeks or even several months after the event. The results from the industrial energy bus programme (see Chapter VIII) have also shown that industrial consumers also have a very poor understanding of energy flows within their enterprises. The automobile is probably the most obvious exception since the consumer must regularly refill the tank and is thus more aware of consumption.

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1. See Stern and Aronson, *Energy Use: The Human Dimension,* National Research Council, 1984, Chapter 3.
2. Evidence provided before Energy Committee of the House of Commons, 30th March 1983.

A related problem is that the results from a conservation measure may not always be obvious. Undertaking a conservation action such as retrofitting a house does not necessarily produce noticeable results in either energy savings or in energy costs since there are many variables such as climate or behavioural changes (e.g. increasing thermostat settings) or changing energy prices that can affect energy consumption or costs. Thus the consumer may not see significant changes in the energy bill.

Confidence

Since 1973 there has been a barrage of new conservation products and services trying to break into the market. Some, predictably, have not yielded the expected results in terms of costs, reliability and energy savings, and a credibility problem has developed. An example is the use of urea formaldehyde insulation in housing which was later banned in some countries because of health and performance problems. With a rapidly expanding market, many new service companies have also come into existence. While most of the industry has matured in a normal fashion (in fact, part of it was well established before the 1970s), there have been examples of fraud, misleading advertising and substandard performance which have affected consumers. Industry has tried to regulate itself through trade associations. The United States' National Association of Energy Service Companies (NAESCo), for one, has been very active in enhancing the credibility of the new third party financing industry.

Separation of expenditure and benefit

A person who uses energy often does not pay directly for his consumption. In other cases, the person who uses and pays for the energy does not own — and therefore is unwilling or unable to invest in — the building, vehicle or energy-using equipment involved. The best known examples of these problems are in rental accommodation where those who pay for a conservation measure often do not receive the full benefit. Many rental agreements stipulate that the property investment is the responsibility of the landlord whereas the benefits derived from conservation investment go to the tenant who pays the energy bill. In theory the landlord can recover his investment through higher rent and an increase in the capital value of his property. In practice this is often difficult particularly in those countries where there are rent controls. In other cases the landlord pays some or all of the energy bills and the total cost is part of the total rent. There is no incentive for the tenant to conserve energy, although the landlord can reduce operating costs by undertaking conservation improvements.

In most Member countries this separation of expenditure and benefit also arises in the public sector. In the United Kingdom, for example, a public hospital saving energy through investment may find its funding for running costs reduced. The same holds true in Spain. This was also true for the health sector and schools in the Netherlands but this has recently been reversed and replaced by a financing system which allows for energy conservation investment for hospitals or according to the type of school.

Other, perhaps less important, aspects of the separation of expenditure and benefit include the billing of costs for space heating and/or tap water according to non-consumption related parameters (e.g. apartment size). To overcome this some governments have required individual metering depending on actual energy consumption (Austria, Germany). Another example is the issue of the company car. In some countries, particularly Sweden and the United Kingdom, there is an increased use of company cars for personal use. This practice discourages energy-efficient driving habits and regular maintenance, and almost invariably lead to the purchase of vehicles larger than the individual would normally own, and to increased total mileage.

Access to Capital

There is in general no shortage of capital in IEA countries. However, in some cases consumers may have difficulties in raising funds for investment in energy conservation especially when investment has to be made in discrete blocks. For example:

— in the residential sector there are financing problems with low-income groups and the elderly, as well as some multi-unit building owners; in some countries, building societies, and other sources of finance for the purchase and improvement of houses may be reluctant to advance money for energy conservation investments;

— in the industrial and commercial sectors small and even medium-sized concerns may lack capital reserves and depending on their general financial situation may find it difficult to raise outside finance on terms which they can afford.

Obstacles to Technology Development

Market limitations which tend to slow the development and introduction of more energy-efficient technologies include:

— *Industrial fragmentation.* Many industries which are primarily concerned with the manufacture of energy-using technologies are so fragmented that no individual company can afford to support a significant research, development and demonstration effort. This is especially true in the building design and construction industries. Fragmentation also often means that individual companies find it especially difficult to capture the economic rewards of introducing more efficient products. This further reduces the incentive for innovation.

— *Long-term or high risk technologies.* With respect to a few conservation technologies, the type of research required involves commitments of resources for many years with a comparatively high risk of failure. Private companies of almost any kind are often unwilling to support such research. A recent Canadian study showed that energy conservation suppliers spent an average of 6% of sales on R&D, but the majority spent less than 2% of sales. Private support is further limited when the technology being advanced is so general that it would be difficult for the developer to capture the economic rewards of the research, even if it were successful.

Conclusions

Appropriate energy prices set the tone and provide the broad signals for conservation measures to be undertaken. There are, however, a number of factors which prevent the market for energy conservation from working with full efficiency. They include:

— different systems and criteria for taking investment decisions which would result in a bias in favour of marginal investment in energy supply rather than conservation;
— major difficulties for the energy sector to set prices at the right economic level;
— the existence of external costs in energy use and external benefits in energy conservation which are not and cannot be fully reflected in prices; they include environmental, security and social costs and benefits;
— specific market limitations such as the lack of the information or skills necessary to conserve energy, the invisibility of energy use, costs and conservation, a lack of experience with or confidence in new conservation products, the separation of responsibilities for energy expenditures and conservation actions, and a lack of access to capital by many energy users.

As a whole, these market limitations represent a formidable obstacle to future progress towards improved energy efficiency. Part C addresses how best to overcome these barriers to energy conservation.

PART C

CONSERVATION POLICIES AND THEIR EFFECTIVENESS

The preceding chapters have shown that there is substantial scope for further energy conservation on an economic basis, but that there are obstacles to achieving this potential which will not be overcome fully under present policies. The key problem is to develop policies to overcome those obstacles which are suitable for market economies.

Achievement of the potential for energy conservation depends on the combined efforts of consumers, conservation service industries, energy supply companies and all levels of government to bring about:

- better energy management;
- increased investment in proven conservation technologies;
- development and demonstration of new technologies, particularly those which are close to the commercial stage.

National governments have the task of establishing a policy framework which will encourage all concerned to strengthen their efforts to achieve energy conservation. Government policies need to be based on thorough analysis of where the main potential for energy conservation is, to identify the obstacles to achieving this potential and to examine how these obstacles can be overcome. Their implementation requires the effective involvement of organisations outside central government which can work in energy conservation. The policies themselves fall into four main areas:

— energy price and taxation policies to provide the correct economic signals necessary for the optimal allocation of resources;
— policies and programmes to remove or counterbalance other market limitations;
— research, development and demonstration to spread existing relatively unproven technologies and to develop new technologies;
— an example by government through the promotion of energy conservation in the establishments under their direct control.

The remaining chapters examine the organisation of energy conservation activities and then each of the four policy areas. An effective government conservation strategy will need to be broad and include a series of elements drawn from all of them.

CHAPTER VI

Organisation of Energy Conservation Activities

Many different individuals, businesses and other organisations are involved in energy conservation activities. They are far more numerous and disaggregated than those involved in energy production. The organisations provide equipment, services, advice, motivation or incentives to consumers. Without them, the consumer undoubtedly would not undertake conservation actions as confidently or as carefully. These organisations — whether private or public — must be effectively involved in any government effort to improve energy efficiency. For this reason, this chapter describes some of the characteristics and background of these organisations, and how they have already been involved by governments.

I. Energy Conservation Service Industries

Many types of professionals and companies are involved in providing energy conservation services, often as part of wider operations. They include insulation manufacturers and installers, energy auditors, consultants, architects, boiler retrofitters, heat pump manufacturers, financing companies and plant builders. Some of these companies have existed for a long time although they may have had to learn new techniques. Others have only developed since the mid-1970s and are now maturing. Because they have direct contact with consumers and can have a positive effect in getting consumers to take energy conservation actions, many governments have supported or encouraged their activities.

Many existing trade associations in these industries promote energy conservation. In addition, new associations specifically related to energy conservation have been formed in recent years. For example, in the United Kingdom the Association for the Conservation of Energy was formed in 1981 to represent 15 conservation service companies and the Energy System Trade Association was formed to establish and maintain high professional standards and to provide a focal point for energy users seeking information on energy efficiency goods and services. In the United States the National Association of Energy Service Companies (NAESCo) was formed in 1983 to represent "both corporate and public sector organisations concerned with developing, building, financing and managing third party financial energy projects". In early 1986 a European Federation of Energy Management Associations, representing 14 national energy management organisations in ten EC countries, was formed. The federation will encourage exchange of information and experience in Europe.

A recent innovation has been the introduction of energy contract management companies which manage energy use in enterprises by providing technical, managerial and financial resources required for a retrofit project. They receive a return on their investment from the achieved savings. These companies have become prominent in the United States in large part because of the favourable tax climate. The United States has recently enacted changes to federal procurement policies allowing government agencies to enter into multi-year contracts with energy service companies. There has been less progress in other countries, but similar companies are now beginning to develop in Canada and in Europe, where the EC is seeking to encourage their development. Their success will, however, be much influenced by tax practices, which vary among Member countries.

II. Energy Supply Industries

The energy supply industries in some Member countries play an important role in providing energy conservation services through their direct dealings with consumers and their marketing and technical skills. Conservation activities are sometimes undertaken to improve the commercial outlook particularly with respect to the need and cost of new capacity. Sometimes conservation activities occur under government pressure or legislation. Most of the time, energy supply industries provide conservation services in response to both factors.

The gas and electric utilities in the United States have by far the most comprehensive conservation programmes in the IEA. As discussed in a recent IEA study, these programmes have developed largely owing to "special difficulties and financial burdens faced ... in providing new capacity, in particular where the costs of new capacity are much higher than historical costs" [1]. The main federally mandated programme was the Residential Conservation Service (RCS) which required utilities to provide a variety of conservation services including energy audits to residential consumers. The federal law was repealed in August 1986 although many states still require such programmes. Large utilities have now been given a federal mandate to provide an audit service for small-sized commercial businesses and apartment buildings. Each of the states also has a regulatory body for utilities which also puts forward its own requirements.

A great emphasis now is being placed on an integration of efficiency and supply options into the utility planning process. For many this is considered the least-cost strategy. About 20% of all utilities in the United States now have some form of least-cost strategy and many more are considering it. Generally these strategies are being introduced through requirements of state public utility commissions. The federally-owned Bonneville Power Administration (BPA) was one of the first utilities to treat conservation as a resource similar to traditional forms of supply. BPA, for example, spends approximately $100-120 million a year on conservation activities. Many state regulatory bodies also are requiring utilities to develop distinct conservation strategies. For example, utilities in Texas are compelled to examine the role of conservation in meeting future demand through cost-effective rather than information programmes [2]. Some utilities are undertaking conservation programmes because of load management concerns.

Many other energy supply companies in Member countries have active conservation programmes. A few of the more illustrative examples are:

— the Italian Government uses its state-owned supply companies — the National Commission for Atomic and Alternative Energy Sources (ENEA), the Electricity Board (ENEL) and the Oil and Gas State Holding Company (ENI) — to implement many of the national conservation programmes. ENEA is responsible for

1. IEA, *Electricity in IEA Countries — Issues and Outlook,* Paris, 1985, p.52.
2. See Association for the Conservation of Energy, *Lessons from America: The Regulation of Gas and Electric Utilities in the USA,* London, February 1986.

training, information and advisory services for the government. These state-owned organisations have virtually taken over the government role of policy making;

— The Norwegian Government believes that the electric utilities should play a central role in encouraging energy conservation. For example, the Oslo Electricity Works has a target of 15% saving in energy consumption by the year 2000 relative to 1980. This is being achieved by a combination of information programmes, grants and loans;

— the United Kingdom Government has encouraged energy supply industries to provide conservation services. The government has solicited the support of all energy supply companies, among others, for a co-ordinated awareness campaign. For many years British Gas has had a conservation programme which includes training, information, awards and RD&D. The electricity supply industry has been active by providing information, encouraging manufacturers to develop more energy-efficient appliances and encouraging customers to use cheaper off-peak electricity. Oil companies such as Shell and British Petroleum have formed energy contract management subsidiaries.

The role of the supply companies can best be decided in the light of specific national or local circumstances. Their involvement in energy conservation activities following those developed in the United States, particularly the requirement to consider measures to reduce demand as an alternative to increasing supply, however, could be worthwhile in other Member countries.

III. Non-governmental, Non-profit Activities

Many non-governmental groups are trying to encourage improvements in energy efficiency with varying degrees of support from government. First, there are special interest organisations concerned with energy conservation that both provide services and act as pressure groups on government. A good example is the Alliance to Save Energy in the United States, which is a private, non-profit coalition of business representatives dedicated to increasing the efficiency of energy use through research, demonstration projects, public education and policy advocacy. There are also groups which have broader interests than energy: consumer groups, service clubs, building societies, non-profit companies and local initiative groups, and environmental and ecological groups. These groups offer a variety of services including information, labour to weatherize the homes of the poor and elderly, help to people applying for available government incentives, testing of appliances and even third party financing for multi-family dwellings. For example, the Citizens Conservation Corporation in Boston, Massachusetts, provides a third party financing service using funding from a variety of sources including petroleum overcharge funds, the Massachusetts Housing Finance Authority and the Federal Department of Housing and Urban Development. In the first three years, their projects covered 2 500 apartments with energy savings estimated at $3 million. In Germany, the Foundation for Comparative Testing has carried out tests on household appliances, automobile accessories and heating systems since 1978. In the United Kingdom a network of over 250 local groups has been brought together in Neighbourhood Energy Action. In addition, there are voluntary industry organisations which have been formed to share information about conservation opportunities and monitor progress within industry subsectors. The Canadian Industrial Energy Conservation Task Forces were established through a voluntary arrangement between government and industry in 1975-76 for such purposes. They set targets, monitor progress and share technical information. The Task Forces also provide an annual report to the government.

Many of these groups receive financial and technical support from governments. For example, the State of Victoria in Australia provides funds to local groups for energy-related projects such as public education, public workshops or conferences, preparation and production of submissions to government on energy issues, or planning of community projects. German federal and Länder governments provide funding for advisory services and comparative testing (e.g. for appliances and heating systems) by the Association of Consumers and the German Housewives' Association in approximately 170 towns and cities. Neighbourhood action groups in Britain receive support from the Department of Health and Social Security to help insulate the homes of the poor; they also are funded by the Manpower Services Commission to provide training for the unemployed; and the Department of Energy helps finance administrative expenses. In this way the objectives of manpower, social and energy policy are all advanced.

IV. **Government Organisations**

Governments at all levels are involved in bringing about energy conservation. Their roles and responsibilities depend on the constitutional framework. The sharing of responsibilities is generally the most complex in federal systems. In some cases the federal government has very little authority in the area of energy conservation (for example, Switzerland). In other countries the roles of central, state or local government may overlap.

Central government organisation for energy conservation has to strike a balance among conflicting requirements. A strong central organisation can ensure that conservation activities are vigorously pursued and properly co-ordinated across the whole range of government, not just as part of energy policy but also as part of other policies, such as housing. However, there is a danger that over-centralisation of responsibility may reduce the commitment of those responsible for implementing conservation measures in sectorally-oriented agencies.

Energy conservation was a relatively new field for most governments in 1973. Energy ministries were supply-oriented, and co-ordination of conservation activities across the whole range of government was lacking. Since 1973 and particularly since 1979, it has become increasingly accepted that the strategic co-ordination of government-wide conservation activities is important. For instance, after the 1982 Rayner Scrutiny in the United Kingdom[1], the British Government established the Energy Efficiency Office within the Department of Energy to increase visibility and strategic co-ordination, but did not vest the Office with the responsibility for implementing all programmes. Some countries have set up organisations for co-ordination which are independent of the normal departmental structure and which have more flexibility in developing and implementing a conservation strategy: France's Agence Française pour la Maîtrise de l'Energie (AFME) is the best known example. Austria has an independent Energy Efficiency Agency controlled by a committee headed by the Federal Chancellor and financed largely by public funds. This agency has a more limited role than the AFME and is mainly responsible for information, motivation and education in the area of energy conservation. Other bodies have less policy influence. The Netherlands has three separate agencies. SVEN

1. E.G. Finer, *Rayner Scrutiny: How The Government Handles Energy Conservation,* London: Department of Energy, September 1982.

(the Dutch Energy Conservation Information Agency) is the central agency for information on energy conservation which provides information mainly for businesses or business organisations. Non-government groups are represented on the management committee of SVEN. There is also the Dutch Energy Development Company (NEOM) for demonstration and introduction of new techniques and the Management Office for Energy Research (PEO). Denmark has the Energy Conservation Committee which undertakes information campaigns and conducts an annual survey on consumer attitudes. Japan's Energy Conservation Centre is a quasi-autonomous institution outside government, established and maintained by the major energy consuming companies. It supplements government activities through general research, information, advice and other activities.

Inter-departmental co-ordination is not easy. Many governments have experienced difficulty undertaking or re-orienting initiatives when two or more ministries are involved. The Netherlands has had a special inter-departmental steering committee for energy conservation since 1971. The question whether to centralise is an ongoing concern. Canada found that it had to centralise full responsibility for its Canadian Home Insulation Programme (CHIP) under the Department of Energy, Mines and Resources because the housing agency initially responsible did not sufficiently emphasize energy priorities. Consideration is now being given to de-centralising other federal programmes. In the United Kingdom, the Rayner Scrutiny had recommended that the Home Insulation Scheme (HIS) be given to the Department of Energy for similar reasons, but it was decided that the department responsible for housing should keep the programme as HIS was considered an integral part of the home improvement policy as a whole.

Conservation measures cannot be implemented at the national level alone. Implementation must be carried through to regions and localities. The most appropriate level of government to implement programmes depends on national circumstances but the closer implementation lies to consumers, the more effective it usually is. Many energy departments have established regional organisations. These offices can implement programmes directly with consumers (Canada and the United Kingdom), co-ordinate national programmes which are managed at the state level (United States) or provide advisory services (Switzerland). Local or state governments often administer national programmes.

There are particular problems in federal states. In Switzerland, for example, most of the responsibility for developing and implementing policies rests with the Cantons. The recent effort to combat environmental damage by stronger energy conservation policies has required effective co-ordination and co-operation between the Federal Government and the Cantons. In many federal states, the division of responsibility is not well articulated and can lead to duplication of services. With the change in the federal government in Canada in 1984, federal-provincial negotiations have led to a sharing of responsibilities between the two levels. In the United States, many states have also created autonomous programmes; public utility commissions which are under state authority have in many cases been instrumental in requiring utilities to develop conservation strategies.

Conservation programmes and strategies ultimately depend on political will. The personal commitment of Ministers can overcome many obstacles, as has been shown recently in the United Kingdom where the Secretary of State for Energy is personally leading the current conservation drive. Political leadership needs to be supported by a strong bureaucratic organisation, high quality, committed staff and an official as high-ranking as those concerned with energy supply to ensure that conservation receives as much weight as supply considerations in the formulation of energy policy.

Parliaments can play an important part in giving a political impetus to energy conservation. In the United Kingdom persistent criticism by the House of Commons Select Committee on Energy was a major factor in bringing about the establishment of the Energy Efficiency Office. The Select Committee has subsequently maintained its constructive criticism of various aspects of the Government's conservation programmes. In the United States, Congress has consistently provided greater funding for conservation activities than has been requested by the Executive Branch.

Conclusions

Success in energy conservation depends on bringing together and motivating a large number of groups and companies which are often not primarily concerned with conservation. The way in which this can best be done will vary among countries according to constitutional structures, government organisations and traditional energy conservation activities. But in all this chapter suggests:

(a) The development of energy conservation services including energy contract management companies will be increasingly important as conservation requirements and opportunities become more complex. Responsibility for this development rests mainly with the interests concerned but experience in a number of countries has shown that governments can encourage these interests to come together and that information programmes plus modest financial help can play an important part in the process.

(b) Energy supply industries can play an important part in promoting energy conservation through direct contacts with consumers and understanding of consumer needs. In some cases the industries have been ready to assume this role for their own commercial reasons but in others government encouragement, even legislation has been necessary, particularly for gas and electric utilities which are already under some form of regulation.

(c) Non-profit groups can be effective in promoting energy conservation, particularly through their understanding of the needs of specific communities and their ability to link energy conservation to other local needs, such as employment. Small injections of public funds can much assist such activities.

(d) In governments, there is a need for a strong central conservation policy group headed by a senior official who forms part of the top management of the Energy Department or related group; there should also be effective inter-departmental co-ordination of conservation activities. Strong political leadership and bureaucractic commitment is, however, the key to the success of government conservation activities.

Much progress has been made since 1973 in improving the organisation of conservation activities, but it has been uneven and in no case is it wholly satisfactory. It is important that all Member governments should re-examine energy conservation arrangements in their countries with a view to applying the organisational lessons learnt by others.

CHAPTER VII

Energy Pricing and Taxation Policies

Chapter III has shown the changes in energy prices which have occurred since 1973, and the response of energy demand to these changes. Chapter V has shown that there are a number of obstacles to economic energy pricing and to the reflection of external costs and benefits in energy prices. However, IEA governments agree that sound energy pricing and taxation policies are the basis for efficient promotion of energy conservation and further reduction of oil import dependence. This chapter considers what should be the content of such policies, focussing on energy demand and conservation rather than on energy supply.

A. **Elements of Effective Energy Pricing and Taxation Policies**

Only limited progress towards establishing a common international basis for developing appropriate energy pricing and taxation policies has been achieved in the IEA. In 1981 IEA Ministers discussed proposals for the economic pricing of energy and agreed on the need to carry forward earlier IEA decisions regarding energy pricing policies. These discussions demonstrated the importance of developing a consistent approach to consumer energy prices, and reflected widespread views that as an objective this should centre on the following elements:

(i) where world markets exist, not only for oil, consumer prices should reflect the world market price;

(ii) where world markets do not exist, consumer prices should normally reflect the cost of maintaining supply in the long term;

(iii) subsidies of consumer prices and other interventions which discourage conservation, high levels of domestic production and substitution away from oil should be avoided, and a thriving energy trade should be developed;

(iv) electricity tariffs should not prevent utilities from raising the revenues necessary to provide capacity to meet future requirements;

(v) in considering tax policies, proper weight should be given to energy policy objectives;

(vi) energy prices should be characterised by transparency so that consumers and producers can make economically efficient decisions.

National policies in this area are strongly influenced by the nature of specific fuel markets and by different energy situations. In addition, energy pricing and taxation policies are generally influenced by much broader considerations than those of energy policy alone. Broader concerns such as the short-run impact of energy prices on inflation, employment, growth prospects, international competitiveness and equity considerations must be taken into account. Energy prices must also take account of the need to internalise certain externalities, such as the general costs of energy production and use to society. This has become increasingly important with the rising concerns about environmental protection.

B. Oil Prices

Substantial progress has been made in relating the price of oil to consumers to the world price level. In many countries oil price controls and subsidies have been removed, and this has had a major impact on improving the energy position of these countries. Examples include the deregulation of oil prices in the United States and Sweden in the early 1980s, the raising of Australian crude oil prices to world levels in the late 1970s, and the deregulation of Canadian crude oil prices in 1985.

However, a number of instances still exist where consumer oil prices are distorted by government intervention, through price controls or subsidies. For instance:

- in Greece, the current level of oil product prices does not reflect fully the cost of imported crude oil;
- in Italy, despite considerable progress in liberalising price controls, there is still substantial government intervention in energy pricing;
- in Portugal, the government still controls energy prices but most of the subsidies on oil products were removed at the beginning of 1986.

There are wider policy reasons for these arrangements but from the point of view of energy conservation it is desirable that they should be reduced or eliminated.

C. Coal Prices

There are few if any instances of government policies which deliberately hold the price of coal below the world level. Where departures from the world level exist, they arise rather from the need in certain countries to retain high cost domestic coal production for social, regional and security reasons. Coal prices in Germany and the United Kingdom, and to a lesser extent Japan, are influenced by heavy subsidies and limitations on coal imports. For example, in Germany and the United Kingdom electric utilities purchase indigenous coal at prices higher than the world price partially to cover higher costs of production. There are arguments for and against these arrangements but, in general, they do not work against conserving energy.

D. Electricity and Gas Prices

(a) *Level of Tariffs*

Chapter V has pointed out that there are particular difficulties about determining and implementing economic prices for electricity and, to a lesser extent, gas. There is only limited agreement among IEA countries about the proper basis for determining prices in these cases. In many IEA countries prices for electricity are based on some form of historical costs. For gas prices the most commonly used basis, particularly in Europe, is to link prices to those of competing fuels notably oil products.

In theory, the right basis for determining prices is long-run marginal costs. In a minority of IEA countries, these are used to provide an approximate basis for prices, although the results may be adjusted, for example, to maintain consumer satisfaction or to meet revenue or funding requirements. There are, however, serious practical problems about determining long-run marginal costs. In other IEA countries, the fact that prices based on long-run marginal costs may lead to substantial profits or losses on a historic accounting basis is seen as a decisive objection to this approach. Prices are based on some form of accounting costs with adjustments for reasons similar to those applied to long-run marginal cost pricing. Prices so derived will not necessarily give the right long-term signals to consumers. Particular problems for the development of consistent national energy pricing policies exist in some countries with a federal organisation, especially Australia, Canada and the United States, where legislative and administrative responsibility regarding energy prices is divided between national and state levels.

Some governments have experimented with policies of fixed price relativities, generally to encourage substitution from oil to more abundant (often domestic) energy resources. Examples include Australian liquefied petroleum gas (LPG) policy, Denmark's natural gas pricing policy, New Zealand's compressed natural gas (CNG) policy and Swedish energy taxation. However, it is rare that prices based on arbitrary relativities can be maintained in the face of unexpected and often contrary movements in cost.

These difficulties in determining the appropriate level of electricity and gas prices have been complicated by governments and tariff regulators who have taken other factors into account such as anti-inflation policy, or the perceived needs of social equity.

(b) *Tariff Structures*

The structure and the level of tariffs for electricity and gas are important for energy conservation. Tariff structures are usually designed in two parts to reflect the capital costs (the "capacity charge") and the fuel costs (the "energy charge") of making supply available to a consumer. Tariffs in two parts like this are a useful way of passing separate price signals for the "lumpy" element of costs (investment in new capacity to meet expected peak needs) and for the more continuous energy element. From the point of view of energy supply investments, such tariffs can offer a rational approach to cost recovery. For the largest gas and electricity consumers it is possible, using complex metering, to charge separately for the capacity and the energy elements in the tariff. In practice, more approximate tariffs are designed for medium-sized and smaller consumers in the domestic, commercial and industrial sectors using simpler meters, based on two-part or multi-part tariffs. These tariffs are usually based on the time-profiles (load curve) of consumption for average consumers in each class. Typically, the average price of electricity or gas falls as consumption rises since the capacity used is spread among a greater number of units consumed. This aspect may act as a disincentive to energy conservation. Attempts have been made to modify electricity tariffs so that additional tranches of energy are priced higher than the base tranche according to social requirements such as certain amounts of heating or lighting. A conflict can arise then between the design of tariffs to reflect the costs of supply versus the promotion of energy conservation. The progressive tariff of Japan was introduced to reflect the progressivity of supply costs and they can contribute, as a result, to promoting energy conservation.

(c) *Transparency*

Another matter of concern, particularly in the area of electricity and gas tariffs, is the transparency of energy prices to consumers. Behind this broad concept is the aim of securing that price variations among classes of customers are based on the differences in service costs and that the utilities justify differences in a generally understandable way. In the case of electricity and especially gas, the cost of providing distribution and storage to supply residential consumers' seasonal heating and time of day cooking demands is much higher than the cost of supplying a large industrial user with stable annual or at least daily demand.

Therefore, it can be to the advantage of the residential customer, for example, if utilities can maintain a certain load of industrial customers, because this will reduce the cost of serving the residential customers' needs. For gas, this will remain the case even if prices to large (industrial or electric utility) customers have to be very much lower than those to residential customers in order to compete effectively against heavy fuel oil, and tariffs need to be flexible and capable of diverging enough to accommodate changes in competing fuel prices.

As a kind of check, utilities are often required to publish tariffs. With a few exceptions, complete electricity tariff schedules are published in many countries including Italy, the United Kingdom and the United States. In the United Kingdom, the Electricity Act of 1947 requires that tariffs be framed so as "to show the methods by which and the principles on which the charges are to be made". On the other hand, electricity tariffs for the largest industrial customers in Germany are not published. It is desirable that more emphasis should be given in Member countries to securing the transparency of tariffs. Although any allocation of costs between classes of customers is subject to interpretation, transparency is a prerequisite for an appropriate public control of the differentiations of tariffs between groups of customers. Transparency also makes it easier to avoid, to a substantial degree, cross-subsidisation between various groups of consumers.

(d) *Policy for Electricity and Gas Prices*

It would be unrealistic to expect all Member countries of the IEA to adopt a single tariff setting principle. The general aim should be to find pragmatic methods of fixing electricity and gas tariffs which will give the right signals according to resource allocation and enable utilities to finance economically sound capital investment. To this end prices should be fixed in a way which takes into account past and present costs, plus those expected in the future. Possible methods include relating prices to long-run marginal costs, in particular where these are increasing in real terms, using current cost accounting or allowing a substantial part of the costs of construction in progress to enter the rate base.

The Governing Board, on the basis of a study by the IEA Secretariat, adopted Conclusions in relation to electricity on 27th March 1985 [1]. These Conclusions are also generally applicable to gas prices. The Governing Board urged Member governments, either directly or through discussion with other levels of government, the electricity industry and regulatory bodies to:

1. IEA, *"Electricity in IEA Countries - Issues and Outlook"*, OECD, Paris 1985.

— see that changes in fuel and operating costs are reflected promptly in electricity tariffs;

— avoid cross-subsidisation between consumers and the use of electricity prices in a way inconsistent with energy policy in order to promote social, industrial and other policies;

— develop tariff structures which will promote optimal use of investment in the electricity industry and rational patterns of electricity demand.

The IEA has not formally adopted conclusions specifically with respect to gas pricing. However, the general principles set out at the beginning of this chapter are applicable, and the conclusions adopted for electricity have considerable relevance to gas. The separation of energy and capacity charges, and variations in tariffs to different types of consumer to reflect the cost of service as well as energy supplied, are generally recognised and applied. But the wide range of institutional circumstances relating to gas tariff policy is likely to hinder the further development of consistent pricing principles among different countries.

E. Taxation of Energy Use

Through taxation, governments can affect consumer prices and, hence, energy demand and efficiency. However, tax policies generally reflect much broader concerns than energy objectives, in particular, fiscal and different macroeconomic, social, regional and industrial considerations. Generally the need for governments to raise revenue in a convenient and effective way is the primary consideration in virtually all Member countries. As a result there is a wide variation among Member countries and among energy commodities in the proportion of final energy prices represented by taxation. Taxes are heavily concentrated on petroleum products, particularly gasoline, where they are easy to collect and where there is an easily explained justification — the need to construct and maintain roads.

So far, only a few Member countries have attempted to use energy taxation explicitly as an instrument to promote energy conservation and interfuel substitution. In Sweden, the Parliament decided in 1983 that, in order to maintain the economic incentive for conservation and fuel switching, consumer oil prices should be kept high through taxation even if the world market price decreased, and that taxes on coal and natural gas would follow proportionately. In line with this decision, Sweden decided in 1986 to raise taxes on fuel oil and coal from 1st January 1987. Denmark revised energy taxes in March 1986 to neutralise the effect of falling oil prices. The government now reviews energy taxes twice a year. In the first half of 1986, as oil prices fell, the Portuguese Government phased out subsidies on some oil products. For other products, notably gasoline, taxes were increased.

Since the accelerated decline in world crude oil prices after late 1985, a number of IEA countries besides those mentioned in the preceding paragraph have enacted or proposed changes in energy taxation, mainly for budgetary reasons. Between December 1985 and June 1986, tax increases which had immediate effects were enacted for various fuels — mainly oil — in Australia, Denmark, Ireland, Italy, Switzerland and the United Kingdom. Legislation for increases in taxation had been proposed by the former government in Norway. In July 1986 the Dutch cabinet proposed a broad increase in excise taxes on the sale of petroleum products.

In many countries coal use by industry and for electricity generation is either not taxed or the tax levied is rebated. Where a levy is applicable, coal is often favoured by having a lower level of taxation than other fuels. On the other hand, there are cases where countries try to reflect the cost of the environmental damage caused by coal use by applying an additional levy. Again, Sweden is an example. The tax on coal has been increased 50% to 75% above the tax on oil (on a heat content basis).

Despite these examples, there is no country where taxation and energy objectives are brought together in a systematic and well-balanced fashion. IEA countries could do more to improve integration of general taxation and energy objectives and to develop the necessary internalisation of externalities related to the supply and consumption of energy.

There are some instances of distortions in tax policies which act against energy conservation. Examples include tax regimes that do not give equal treatment to supply and conservation options, for example in the United Kingdom, where a value added tax (VAT) is charged on insulating material, but not on electricity and natural gas. Another example is the tax regime for company cars in Sweden, the United Kingdom and — to a lesser extent — other countries, which favours the purchase of larger cars and more profligate car use than would be the case without such tax incentives. Other examples of tax regimes which could be improved to enhance energy efficiency are motor car purchase and ownership taxes that collect vehicle charges on the basis of technical car characteristics (e.g. weight or engine size), regardless of vehicle use. These exist in most IEA countries [1]. Such charges could be collected as a tax on fuel use, thus making the user pay and promoting energy conservation.

F. Conclusions

Economic energy pricing is a prerequisite for effective energy conservation policies. As a general rule, energy prices should reflect the real costs of supply, give the right signals to producers and consumers in order to facilitate an optimal allocation of resources, and enable energy suppliers to finance economically sound capital investment and thus to ensure the long-term security of energy supply. There are, however, severe theoretical and practical problems about determining and implementing economic energy prices. Policy on taxation of energy products is inevitably determined by considerations outside energy considerations. It would be unrealistic to expect Member countries to adopt uniform price and taxation policies across the board. Wider considerations make some variation inevitable. It is, however, desirable that adequate importance should be given to considerations of energy conservation in formulating price and tax policies.

Specific conclusions are:

- remaining subsidies or controls on oil prices should be eliminated or reduced as soon as possible;
- the conclusions adopted by the Governing Board on 27th March 1985 on electricity prices should be implemented and developed and their applicability to gas prices should be further considered;
- adequate importance should be given to energy conservation in decisions on taxes on energy consumption;
- distortions in the tax regime which work against energy conservation should be eliminated or reduced.

1. For more details see *Fuel Efficiency in Passenger Cars — An IEA Report,* OECD, Paris 1984, Chapter IV.

CHAPTER VIII

Government Conservation Programmes

Since the first major oil price increase of 1973-74, all Member governments have seen a gradual evolution in their policies directed specifically at improving energy efficiency. The first government programmes to enhance conservation were broad efforts to educate consumers about simple techniques to reduce energy use and to motivate them to use such techniques. These information campaigns were sometimes supplemented by large financial incentive programmes designed to encourage conservation investments. These actions were initially taken when oil prices were escalating and fears about security of supply were high. Often these first efforts were not as concerned with efficient energy use as reducing demand for cost and security reasons.

Gradually, governments took a more long-term and cost-oriented approach, stressing programmes and measures to promote efficiency improvements. This approach included introducing new policy measures and revising existing ones (e.g. building codes) to reflect energy concerns more adequately.

Most Member countries now have a range of conservation programmes which encourage consumers in all end-use sectors to use energy more efficiently. However, since 1982, there has been a change in emphasis in some countries from subsidy schemes and broad-based information programmes to ones which are more specific.

This chapter is concerned with three categories of measures which are used by governments to encourage consumers to use energy more efficiently: information programmes, financial incentives and regulations and standards. This division is arbitrary. For example, mandatory energy labelling schemes or energy audit programmes could fall under the first and third headings.

The evaluation of conservation policy measures is complex and sometimes costly and time-consuming. But evaluation is necessary to determine whether the objectives have been achieved and is a valuable ongoing management tool to identify how programmes can be adapted to changing situations. Unfortunately, too often the methods and data for evaluating existing programmes are inadequate. Most evaluations have tended to be rather superficial and issues such as the amount of energy savings achieved, the attribution of energy savings to particular measures, incrementality [1] and cost-effectiveness are seldom fully addressed. Some of the major methodological issues are discussed in Annex F. While the existing programme evaluations have many limitations, they do offer many qualitative and quantitative insights into the effectiveness of past conservation efforts. The chapter summarises the available information.

Information Programmes

Information programmes are the cornerstone of all Members' energy conservation programmes. They are important in their own right to create awareness; motivate consumer action; and educate consumers, decision makers and those who provide energy services. Information programmes also complement all the other policy instruments and, indeed, are essential to their effectiveness.

Information programmes can be aimed either at the public-at-large or at major sectors like industry, or at specific groups of consumers or energy service groups. Immediately after the oil price increase of 1973-74, information was aimed mainly at the general public with the objective of saving energy rather than improving efficiency. But the emphasis has since changed. It has become progressively aimed at more selective

1. Incrementality is defined as behaviour which takes place as a result of a programme which otherwise would have not occurred or been delayed. Conversely, the expression "free-rider" is the participant in a programme who would have undertaken the conservation action even in the absence of the programme.

audiences and has gradually emphasized efficiency improvements. There is greater stress on consumer education which provides more precise and usable information and on training programmes to develop better conservation services.

New techniques — such as computers, videotext machines, contests, and local advisory centres — are now also being developed as ways to make information available and more interesting to various audiences. To improve credibility and effectiveness, information is often provided to consumers through local governments, utilities, local groups or conservation service industries which have more direct contact with consumers.

The main types of information programmes which have been developed in Member countries since 1974 are:

— *General publicity campaigns* which are aimed at large audiences. These were popular in the 1970s when governments were trying to introduce the concept of energy conservation. They included national campaigns in many countries, the IEA International Energy Conservation Month in 1979, the annual Energy Conservation Month in Japan and Energy Efficiency Year in 1986 in the United Kingdom. As part of the latter, the British Government undertook a high profile television advertising campaign in the autumn of 1986.

— *Energy Audits.* Many governments provide energy audits for industry, the commercial sector and the residential sector. These were done as much to increase awareness of the conservation opportunities as to conduct a detailed, technical analysis of energy use.

  In the industrial and commercial sectors, energy audits offer specific advice to consumers. The "energy bus" was one of the early forms of energy audits. First pioneered by Canada in 1977, it provides mobile computerised energy audits largely to improve awareness. The European Commission operates a comparable service in five of its Member states, and Turkey and has extended the programme until September 1987. Japan also has a similar service for small- and medium-sized companies.

  There are other types of industrial energy audit programmes. These are usually to subsidise more complex audits by private consultants rather than using government staff. For example, the United Kingdom provides two programmes for industry — the Energy

Efficiency Survey Scheme providing grants of 50% of the cost of qualified consultants and the Industrial Heat Recovery Consultancy Service for high energy users. Germany provides similar grants for small- and medium-sized businesses.

The most ambitious residential energy audit programme has been the United States' Residential Conservation Service (RCS) which has mandated gas and electric utilities to provide audit services (Class A audits) [1] for their residential customers to give consumers information about the availability and advantages of conservation measures. The regulations for the national programme have allowed each state and utility to influence the design and implementation of the audits. Canada has had a free Class B [1] residential audit since 1977. Denmark has heat inspections performed by energy consultants which were an eligible item under the subsidy scheme for residential buildings until the scheme ended in 1984. Inspections are now required upon the re-sale of a building.

— *Labels and guides* have largely been used for appliances and for the road transportation sector. A number of countries have appliance labelling programmes. The European Community's regulatory infrastructure has permitted the introduction of an appliance labelling system. The system is designed to increase market transparency and avoid national schemes which in effect create trade barriers. However, only three EC Member states which are also IEA Members have adapted the EC directives to their own legislation. Canada and the United States also have labelling programmes.

In the transportation sector, almost all Member governments consider fuel consumption information as a cornerstone of their automotive fuel efficiency programmes [2]. Most provide information on some combination of new vehicle fuel efficiency, fuel-efficient driving behaviour and fuel-efficient maintenance practices. The information is mainly in the form of labels, lists, booklets,

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1. For a Class A audit, a trained energy auditor conducts an on-site inspection of the premises, performs most of the calculations for the resident and provides recommendations for conservation measures. For a Class B audit, the resident collects the data himself, transmits the data to the auditing agency which performs the calculations and makes recommendations.
2. *Fuel Efficiency of Passenger Cars - An IEA Report,* OECD, Paris 1984.

guides and advertisements. For most countries, the programmes were instituted to reduce confusion for the consumer because no consistent data existed among different available sources. For example, in the United States there had been 15 separate measurements of fuel economy available before the federal fuel efficiency information programme was instituted. Six Member countries have specific vehicle labelling procedures and they are mandatory in Japan, Sweden, the United States and the United Kingdom. The labels usually include both the results of an urban and highway test.

— *Technical handbooks.* Governments have prepared technical materials for consumers, energy managers and conservation services. For the residential consumer, the handbooks are fairly simple and show the consumer how he can add low-cost measures such as insulation and weatherstripping. For the energy manager and conservation services, there are two types of manuals: technical manuals covering such topics as combustion controls and ventilation requirements and manuals detailing how to set up energy management systems.

— *Advisory Services.* Governments operate advisory services to provide information about available conservation programmes or various technologies and techniques. A few countries such as Canada, Switzerland and the United Kingdom have regional advice centres to provide information. Belgium uses videotext machines in municipal offices. Some countries have central telephone advisory services (Canada, Ireland).

— *Training and Education* programmes are provided for current or future consumers, energy managers and service groups. As stated in Chapter V, a lack of information and technical skills has been a major limitation to achieving the conservation potential.

Most governments that promote energy management initiatives usually include training in the form of workshops, seminars, technical manuals and conferences. Switzerland considers training as the major component of its industrial conservation efforts, and the federal government provides funds to private organisations that have training courses. Japan has an extensive training programme for energy managers through the Energy Conservation Centre. Some countries have conservation driver training courses for professional truck drivers.

Increasingly there are consumer education programmes for residential consumers. One of the conclusions of the evaluation of the Canadian Home Insulation Programme found that consumers did not have adequate knowledge of detailed energy conservation possibilities. Thus the Canadian Government started a major consumer education programme. Switzerland provides training courses for concierges. Many countries also stress programmes for elementary and secondary schools. For example, the government of the Province of Alberta in Canada has prepared an entire set of school aids for conservation issues and in the United Kingdom the government provides educational material for teachers.

Training and education for the conservation service industries are also valuable although few countries identify such activities. As was identified in Chapter VI, a strong and mature service industry is essential for increasing conservation activities. Conservation techniques and technologies have changed, and there is a need to have them diffused and applied. Sometimes providing the information is sufficient; however, in other cases, training and seminars may be the most effective means. For example, the techniques used for building the latest generation of super energy-efficient buildings are quite different. Builders who have been accustomed to traditional methods need to learn new techniques. Thus workshops and seminars are very useful. This has been the experience of the Canadian Super Energy Efficient Housing Programme. Switzerland also has a programme to train professional and maintenance staff on new energy-efficient heating technologies.

The Effectiveness of Information Programmes

The effectiveness of information programmes can be judged by two main criteria — their success in increasing awareness of the need for energy conservation and their success in producing results. Generally, information programmes are not designed to save much energy directly. Assessments have only been made in some cases. The judgement about other programmes has to be qualitative rather than quantitative.

For selected information programmes, a more in-depth review of their effectiveness has been undertaken. These programmes are summarised in Table 8.

(a) *Publicity Campaigns.* The level of consumer awareness is generally the only indicator of the success of publicity campaigns although it does not indicate whether action was actually taken. An Irish evaluation for a 1982 campaign showed that 65% of the respondents were aware of the advertising and 55% indicate they took steps to save energy between June 1982 and November 1982. It is not known how many would have undertaken the actions without seeing the campaign. In 1982 about 67% of those surveyed in Sweden said that they had read or looked at energy conservation brochures in the preceding three years. Both of these surveys were taken when energy prices were increasing.

There have been some attempts to measure the link between energy savings and information campaigns. A Belgian evaluation in 1982 showed that consumers who asked for and read the conservation brochures saved about three times the amount of energy between 1980 and 1981 as the average consumer. The evaluation showed that both making a request for a brochure and reading it attentively had a significant influence on consumption. Since the proportion of the audience that uses written material does not exceed 15%, other means of communication have to be used. That is why the Belgian Government has started applying new techniques such as computer-assisted advisory centres to increase the level of awareness.

Germany also tried to show the effects of their information programmes in terms of energy savings. The 1982 German evaluation of all its policy measures estimated that the three main information programmes brought about on average close to 1% of overall annual energy savings. These programmes accounted for about 20% of all information and education activities.

The United Kingdom has had a series of general publicity campaigns. However, as was proven in the 1984 "Lift a Finger" campaign, they are not all successful and that particular campaign had to be terminated because of the poor consumer reaction. The United Kingdom also has a targeted publicity campaign, in the form of breakfast meetings for senior executives. As of September 1986, the meetings attracted over 20 000 senior executives. From surveys of those attending the first twelve meetings:

— 78% subsequently monitored their energy use;
— 44% arranged an energy survey of their premises;
— 34% appointed a manager responsible for energy efficiency.

Much of the success of these briefings has been attributed to the personal attention of the Secretary of State for Energy. The United Kingdom followed on with a general campaign for Energy Efficiency Year in 1986.

(b) *Energy Audits*

(i) Industrial

The energy bus is a very popular type of energy audit which has been well received by both industry and commerce. But it is a most effective tool for increasing awareness, rather than as an audit procedure. There have been some interesting findings from Canadian analyses. First, surveys have shown that there is still a very low level of awareness of energy use and of the technical possibilities for improving energy efficiency, and that the energy bus is very useful in increasing awareness. Second, with the data available, it appears that the energy bus has been reasonably cost-effective. Benefits probably exceeded programme costs by a factor of at least two. Unfortunately, there have not been sufficient return visits to see how much activity was generated by the first audit. Although a full-scale evaluation has not been undertaken, some preliminary calculations showed that about 25% of the recommendations implemented could be attributable to the audit activities.

Between 1980 and September 1985 the European Community's energy buses had made over 10 000 audits. The programme has been targeted to small- and medium-sized undertakings. A common data base in Ispra, Italy, contains the results of 4 576 audits of industrial premises and over 4 600 audits in the service industry. Potential energy savings of 10-20% of normal consumption in a plant for each energy bus visit were identified. This is equivalent to 130 toe per audit. Over 1 million toe were saved per year. To date there have been no follow-up visits to see whether potential savings were actually achieved. The EC has extended the programme until 1988 to have in-depth audits concentrating on areas of high potential (ceramics, abattoirs, dairies, breweries and malt-houses, textile finishing, the leather industry and industrial washeries). For those seven areas, more accurate and specific audit procedures have been prepared in order to get a better understanding of the remaining potential. A more comprehensive evaluation of the programme is planned.

The energy bus programme, both in Canada and Europe, has had many shortcomings. For example, the energy bus is not equipped to analyse process energy which is mainly what industries want to reduce. The audit has not measured the energy used for a company's transportation purposes (e.g. truck fleets) which can be a high proportion of total energy use. Also the audit has looked specifically at energy savings and many felt it has not considered the economics of the recommendations adequately. Because of these concerns, the energy bus is of benefit to fewer firms than had been originally intended. The extended programme in Europe will overcome many of the shortcomings.

(ii) Residential

The results of home energy audits have been mixed. They vary with design and implementation approaches. In the United States, where the programme was undertaken by utilities, those firms that were aggressive and strongly promoted the programme had much better results. In fact, only 40 states implemented the programme, of which 37 conducted evaluations prior to the cut-off date for the federal evaluation. It was widely agreed that the original design of the RCS programme lacked enough flexibility [1]. One problem for utilities was that the audits often contributed to saving oil (in space heating) which was of no concern to the utility, thus there was little incentive for the utility to promote the programme. Cost was also a problem (about $120 per visit on average), with the consumer often paying $10-15 of the cost and the utility paying the rest. Recently revised audit programmes have been more effective because they are more targeted to electricity and/or gas use. Some analysis has shown that audits are more effective if linked with financial incentives [2].

Energy savings attributed to the RCS audits spanned a wide range, from zero to 9%. An evaluation in one of the states showed that participants realised 32% of the identified potential savings for space heating compared to 12% for non-participants. That programme also had one of the highest participation rates — 10% of eligible households for the first

1. For more details see Walker, Rauh and Griffin, "A Review of the Residential Conservation Service Program", *Annual Review of Energy,* 1985, 10: pp.285-315.
2. See, for example, Stern et al., "The Effectiveness of Incentives for Residential Energy Conservation", in *Evaluation Review,* Vol. 10, No. 2, April 1986, pp.147-176.

two years. Only six states audited more than 10% of their eligible customers. They were in the north with high heat loads. Some evaluations have shown that the audit had an impact on the decision of approximately 67-80% of the households. In the evaluation of the Connecticut programme, participants "were more likely to install measures with longer lifetimes than were control households (eleven as opposed to eight years, on average)" [1]. Most of the evaluations showed that mainly middle-income home owners participated and that low-income groups had very low participation rates.

An evaluation of the Canadian Class B audit "Enersave" showed that the programme did influence consumer decision-making. There was positive incrementality for actions to insulate attics and overall, negative incrementality for walls and no significant difference for basements. Analysis showed that payback and cost information was an "overwhelming explanator of incrementality of insulation activity. When Enersave results indicated low payback and/or low costs for a given activity, there was a major stimulative effect ...".

Both the United Kingdom and Canada have had pilot programmes for full Class A audits. The United Kingdom felt that it was not cost-effective and thus did not follow through with a full programme. Canada is still analysing whether to follow through because of the cost of implementation and the lack of a clear-cut assessment of the cost-effectiveness.

(c) *Labels and Guides*

(i) Appliances

Appliance labelling programmes have been used to upgrade the appliance stock through influencing manufacturers and providing consistent, comparative information to consumers. The Canadian Energuide programme was reasonably successful. Although few consumers used the labels in their purchase decision, the programme was considered incremental and cost-effective in improving the efficiency of

1. Hirst et al., "Connecticut's residential conservation service: an evaluation", *Energy Policy*, February 1985.

appliances, particularly refrigerators and freezers, through introducing competition among manufacturers [1]. An evaluation of the United States' appliance labelling programme concurred with the findings of the Canadian study.

The programme has resulted in significant savings in energy and expenses. Consumers save on energy costs and get a good return on any increased cost of appliances, and Canadian appliances remain competitive with imports. But members of the evaluation team differed in their views on the extent of further economic savings available and on whether improvements to date would be eroded if the programme were terminated.

Currently the Canadian Government is considering options for its programme, including continuation of the programme on a voluntary basis in close co-operation with the appliance industry, electrical utilities and consumer groups.

(ii) Transportation

Fuel efficiency information in transportation was assessed in an earlier IEA study. It concluded that "fuel consumption information is considered a cornerstone of all automotive energy conservation programmes. Without credible information the market cannot be expected to make fuel-efficient choices" [2].

Only the United States has conducted a comprehensive review of the effectiveness of the information programmes [3]. The review was undertaken several times during a period when consumers were more conscious of higher energy prices. The evaluation concluded that:

— About 70% of new car and light truck buyers were aware of labels on vehicles, while less than 20% knew a more comprehensive guide was available;

— Among the aware buyers, about half in each group used the fuel economy information for comparison shopping;

1. See Canada, Consumer and Corporate Affairs, *Evaluation of Energuide,* Ottawa, March 1985 and *Energuide Evaluation: Background Study Modules,* 1985.
2. IEA, *Fuel Efficiency in Passenger Cars — An IEA Report,* Paris, 1984, p.104.
3. *Ibid,* pp.99-103.

- New vehicle buyers were very critical of the accuracy of the Environmental Protection Agency (EPA) ratings with 70% of the respondents believing that the EPA ratings overstate actual fuel economy. Nonetheless, 75% of the respondents still believed the ratings were useful for comparisons;
- The lack of credibility of the ratings perceived by consumers was the major cause of non-use by new car and light truck buyers.

As a result of the assessments, the United States took corrective action to improve the programme beginning with model year 1985.

The main conclusions from the assessment of the effectiveness of information programmes are described in Table 8. Some of the conclusions relevant to all the measures are:

- information programmes form the cornerstone of all policy programmes and are valuable in ensuring the success of other types of policy measures;
- energy audits, particularly in the residential sector, can be more effective if combined with financial incentives;
- information programmes can help ensure continuity of conservation momentum, even in periods of changing short term market conditions;
- information programmes should be adapted to new market situations, consumer needs, and new communication technologies;
- awareness and motivation are not static and need to be reinforced periodically;
- limited, more specific programmes are more effective than broad-based programmes although there is also a role for the latter from time to time.

ii) **Financial Investment Incentives**

A financial investment incentive has been defined as any measure "designed to influence an investment decision and increasing ... the profit accruing to the potential investment or altering the risks attaching

Table 8

Summary of Information Programmes

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed[1]	Implementation Environment	General Conclusions
Publicity Campaigns	- awareness	- most Member countries	- lack of information - invisibility	- implemented usually during period of high price increases - many countries have continued them throughout	- valuable for awareness creation
Residential Energy Audits	- awareness - motivation	- Canada, United States and Sweden primarily	- lack of information - invisibility	- implemented during period of high price increases	- valuable to increase awareness on part of consumers and show cost-effective options - problem with cost-effectiveness of Class A audits[2]
Industrial Energy Audits	- awareness - motivation	- Canada, Europe, Japan	- lack of information - invisibility	- initially during periods of high price increases	- valuable to create awareness - problem of degree of sophistication and technical rigour
Appliance Labelling	- awareness - motivation - provide unbiased information to aid purchase decision	- Canada, United States, Europe, Japan	- lack of information - invisibility	- initially during periods of high price increases	- biggest effect on manufacturing industry - has been cost-effective means to produce energy savings - has worked well as voluntary programme
Transportation Fuel Efficiency Information	- awareness - motivation - provide unbiased information to aid purchase decision	- most Member countries	- invisibility - lack of information	- initially during periods of high price increases	- awareness generally high - credibility problems with fuel economy ratings

1. Refer to market limitations described in Chapter V.
2. Refer to page 122 for definition.

to it" [1]. Most conservation incentives are given by governments although in some countries utilities also offer a range of financial incentives — often as a requirement of regulatory bodies.

Most governments offer a wide range of financial incentives for an equally large number of national objectives. This section is concerned with those intended specifically to promote energy conservation. Other incentives, such as general industrial financial incentives, which may help encourage energy conservation indirectly, are not considered.

Initially, financial incentives have been very popular among Member governments as a means to encourage consumers to take action and address some of the market limitations described in Chapter V. But since about 1982 there has been a change in emphasis in some countries away from large incentive programmes [2] because of budgetary constraints, changes in government policy and indications that direct incentive schemes are less effective after a number of years of use. With the energy situation improving, a few countries have perceived less need for financial support; however, other countries recently have started making use of incentive schemes to overcome existing market limitations. These include Italy, which introduced various incentives through its Law 308 in 1982, Norway which now provides incentives as a result of a major policy report to Parliament in November 1984 and Spain which also introduced new schemes under its 1983 National Energy Plan.

Incentives have been used differently in the industrial and residential sectors [3]. Incentives in the industrial sector are available for energy audits or consultants, feasibility studies, CHP and district heating (DH), heat recovery systems, refuse incineration plants, insulating materials, energy-efficient heating systems, heat pumps, control systems and RD&D. In general, industry incentives apply to about 7% and 30% of

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1. *Investment Incentives and Disincentives and the International Investment Process,* OECD, Paris 1983, p.10.
2. Since 1982, some programmes that have ended include the United States industrial and residential energy conservation tax credits, the Canadian Home Insulation Programme, the Danish and Swedish grant programmes for industrial energy-savings investments, the Danish residential retrofit scheme, the Swedish residential retrofit scheme for single-family dwellings and the German home retrofit programme.
3. Except for public transport, there are few direct incentives for the transportation sector and, therefore, it has not been included in this part of the study.

the investment. Very few industrial incentive programmes have required a specific payback criterion that eligible conservation investments must meet. In most cases eligibility is determined by lists of acceptable equipment. Some programmes, however, are more selective. For instance, under the Canadian Atlantic Energy Conservation Investment Programme (AECIP), projects with payback periods between three and eight years were eligible for an increasing rate of assistance (10% for short payback and up to 50% for longer payback periods). Other examples are the Danish industrial grants, which were seen after an individual examination and were dependent on the ratio of investment cost and energy savings, and Japan where eligible equipment for a tax credit is required to save at least 30% of the energy used.

For residential programmes, incentives are usually provided for insulating materials and weather-stripping, including labour for installation. Incentives for energy audits, heat pumps, control devices, double- or triple-glazed windows and connections to district heating grids are less common. Generally, incentives apply to 15% to 100% of investment costs, with the average probably being in the 30-40% range. In some cases the percentage varies according to the consumer's financial status [1]. Some residential programmes are specifically targeted to rental accommodation (Netherlands) or to low-income groups (United States). Unlike some more selective industrial grant schemes, the percentage of the grant is usually fixed for the full range of eligible items regardless of the payback. Eligible investments in the commercial sector are similar to those in the residential sector. Eligible investments in the transformation sector resemble those in industry although they have only been available in a few countries.

There are three main types of financial incentives used by Member countries: grants, tax incentives (preferential taxing, e.g. tax credits, and accelerated depreciation), and low-interest ("soft") loans and guarantees. Although they all have the same ultimate objective and can all be adjusted to produce the same financial results, the incentives vary substantially as well as how they are applied. The types of incentives are:

(a) *Grants.* Grants are usually intended to stimulate conservation investment in end-use sectors by covering part of the total investment costs. Grant programmes have been and still are widely

1. For example, the United Kingdom's Home Insulation Scheme gives a much more favourable percentage (almost the entire cost) for the elderly and disabled on low incomes.

used in most IEA countries. Direct grants represent about 60% of all incentive programmes used by IEA Members in 1984. Most grant programmes have been in the residential and industrial sectors although there are a few in the commercial/institutional and the transformation sectors.

Grants have been primarily effective to improve the rate of return on investment, particularly in the industrial and transformation sectors. Grants have helped provide access to capital for some consumer groups, have encouraged the development of a conservation service industry, have provided technical information to consumers and had demonstrated confidence in new products. Grant programmes can be selective but usually have more complex application and approval processes than other types of financial incentives. Therefore, considerable administrative work is often required which can be fairly expensive, especially in the residential sector [1]. Many companies have been reluctant to accept government assistance because of the bureaucratic procedures involved. For small companies, the amount of administrative effort required is often prohibitive.

(b) *Tax Incentives.* Tax incentives represent about 20% of all financial incentives. Among the great variety of tax reductions and exemptions, tax credits appear to be the most widely used form of fiscal incentives. Investment allowances, for example, are less frequently used as are reductions in tax rate of taxable income and accelerated depreciation. Tax incentives for energy conservation investments usually fit easily into the larger array of general tax incentives available to consumers, particularly in the industrial sector. Some unique programmes include: the Netherlands offers a premium of 10%, on top of its tax incentive for general investments, for investments in energy conservation equipment in the industrial/commercial sectors; in Belgium, companies may claim up to 20% of the cost of energy conservation investment (equivalent to about 10% actual tax reduction) or in case of unprofitability for three years, may receive interest free loans of

1. In the Canadian CHIP programme, administrative costs were approximately 7-8% of total costs once the programme was fully operational.

about 6%. Some countries, for example Austria, allow accelerated depreciation for conservation investments in end-use sectors as well as the transformation sector.

From a government's point of view, tax credits and allowances have been generally easier to administer but harder to control in financial terms because of the complexity of accounting within the tax system. They appear to be best used now in conjunction with or integrated within the general tax system. Industrial investors are used to the process and benefits involved and are eager to take advantage of such a system. For large- and medium-sized companies access to capital is less a problem and tax incentives provide a means of reducing corporate taxes. Tax incentives do not, however, help firms which run or have accumulated losses and therefore have no tax obligation to reduce. In a few cases, there has been some confusion because some investments are eligible for tax credits in more than one industrial tax classification. Available residential tax incentives have been used mainly by higher income groups. It is generally difficult to make tax incentive programmes selective.

(c) *Loans.* In the case of soft loans, the interest rate in most cases is just a few percentage points below the market interest rate. This difference can be as low as 0.15 percentage points (as in the loan programme of the Japan Development Bank at the end of 1985). Favourable loans for industry are used by only a few countries. In the residential sector, Sweden has a unique loan system which promotes construction of energy-efficient buildings. In the energy transformation sector, the Netherlands has a system of government guaranteed loans to support expansion of CHP/DH. Austria operates a system of soft loans and fiscal incentives.

In principle, soft loans have some of the characteristics of grants. In both cases, the necessary finance is provided at the investment's start. In practice, the grant element of soft loans is often small due to the small difference from interest rates on commercial loans. The beneficial subsidy effect is, however, spread over the loan period. Therefore, loans are possibly a less attractive form of subsidy than grants for companies with enough liquidity, since companies prefer "quick money". Due to the small grant element in each case, it has been possible to reach more investors with the same amount of subsidy money than with grants.

Effectiveness of Financial Incentives

Although evaluations of financial incentive programmes often received comparably high priority, a rather limited number of programmes has been evaluated. Clearly, the environment in which programmes were initiated has an impact on the programmes' effectiveness and the level of concern about programme evaluations. Many of the programmes were instituted in a period of rapidly escalating energy prices and security concerns. In such periods, governments were less concerned with analysing the incremental effects of programmes than they were in taking quick and strong action to help reduce the negative effects of the "energy crisis".

The fundamental issues concerning the effectiveness of financial incentives include:

- their ability to overcome market limitations;
- their ability to encourage incremental conservation investment;
- the improvement they induce in energy efficiency;
- their cost-effectiveness.

In analysing these factors it is important not to apply stricter standards to financial incentives for energy conservation than to other financial incentives. The problem of incrementality for example arises just as much with tax incentives for energy production as for conservation. Unfortunately, many of the programmes that have been evaluated have not been assessed thoroughly.

Cost-effectiveness has been calculated by the IEA Secretariat using the present value (PV) of the total accumulated energy cost saving during the whole life-cycle of the equipment (real discount rate of 5% per annum, 1984-85 energy price levels). As lifetimes of different efficiency technologies vary widely, rather rough assumptions had to be made. The same procedure has also been applied for the annual government funds spent in order to end up with an indicator for the benefit-cost ratio, excluding external benefits such as environmental gains. As both the shares of genuine free-riders as well as of genuine incremental investors have been rather small, with a large "grey" zone in between, incrementality has been assumed as 50%. However, no real distinction could be made between highly economic "easy" investments (with lower incrementality) and less attractive investments (with higher incrementality) due to the lack of sufficient data.

(a) *Grant Programmes*

Industrial Sector

In industry, grant programmes have generally been more attractive to both non-tax-paying (including new ventures) and tax-exempt companies. They were less attractive to tax-paying companies, although that depended on the specific tax regime.

In general, incrementality ranged from 20% to 80% depending on the eligibility criteria and the percentage of the investment provided. More narrowly defined programmes had better results.

The benefit-cost ratio for each of the programmes analysed [1] was about five to one. This means that for every unit of government funds spent on the programme, there were five units of benefit during the total lifetime of the energy conservation equipment. This indicates very good cost-effectiveness. Recent price declines seem to decrease the benefit-cost ratio by about one-third to about 3.5. The most cost-effective schemes were those which were aimed at specific sectors or in which the percentage of the grants varied depending on the ratio of investment cost and energy savings. For example, the maximum grant allowed under the Danish Industry Scheme was 40% of investment cost up to a certain maximum, but the average was 26%. There was an investment threshold above which energy savings practically doubled.

A Swedish evaluation of grants [2] found, contrary to the other programmes, no systematic correlation between subsidies and improved energy efficiency. The effects of government incentives were difficult to assess because the total grants provided were only a small fraction of total industrial investment due to the high turnover rate of capital stock in Swedish industry. Most of the funds were given to energy-intensive industries in which the motives to invest in energy conservation were strong anyway. This apparently reduced the incremental effect. There is also some evidence that due to the exclusion of the most profitable

1. These include the Canadian AECIP programme, the Danish Industry Incentive Scheme and the German Investment Allowance Programme (Secretariat analysis based on IFO evaluation).
2. *Energihushallnings — programmets effekter* (Effects of the Energy Conservation Programme), Statens energiverk (National Energy Administration), 1984:2.

projects from eligibility, industry actually implemented less economic projects. However, frequent changes of the subsidy programmes actually spread information about their availability and also facilitated contact with sources of finance.

Residential Sector

Grant programmes in the residential sector have been very popular with consumers and government officials largely because they are visible and are useful to motivate consumers who did not invest significantly, even in periods of escalating energy prices. Even though grant programmes had the highest participation rates of all financial incentives for residents, it was estimated that the mean was 7% of eligible participants per year [1]. Thus it takes several years to reach a large segment of the population. Programmes had positive incremental effects, although usually lower than industrial grant programmes. In some cases the low incrementality was possibly due to lax eligibility criteria. The benefit-cost ratio for the total lifetime of the equipment on average is about 3:1, with about 1:1 as the worst case. This is lower than that for grant programmes in the industrial sector but is still beneficial. Recent price declines should lower the ratio by about one-third.

Administration of the programmes can also require inspection and auditing procedures. Many countries use state or local governments as part of the administration. This facilitates having regional variations of the programmes. Because these programmes are often large there can be delays in the administrative process such as approving eligible items or issuing cheques. These delays can affect the overall effectiveness of the programme.

Some programmes did have a positive effect in supporting energy conservation service industries. In Canada, the CHIP evaluation showed that the programme was responsible for increasing sales of attic insulation; and the insulation manufacturing industry grew from nine plants in 1976 with a capacity of 200 000 metric tons per year to 13 plants in 1982 with a capacity of 370 000 metric tons per year. About 50% of the insulation was used for retrofit and it was estimated that 29% of all retrofit activity in Canada was due to CHIP. Many of the retrofit grant programmes were instrumental in improving thermal efficiency by about

1. Stern et al., "The Effectiveness of Incentives for Residential Energy Conservation", *Evaluation Review*, Vol. 10, No. 2, April 1986.

12% per household, about half the 25–30% predicted. There was a large range of efficiency improvements in individual households, partially explained by behavioural changes such as thermostat setbacks.

It is still debatable how effective grants have been in the residential sector. For example:

— Subsidy programmes can make expensive investments more lucrative. Unfortunately, for some programmes, many participants favoured measures such as window replacement, storm doors or attic insulation that did not optimise cost-effective energy savings. This was true in Canada, Germany and the United Kingdom. Consumers were often enticed by grants but were less concerned about saving energy. The list of items eligible for grants needs to be chosen carefully and reviewed periodically, and information programmes such as audits can complement these programmes and better explain conservation opportunities.

— Some programmes encouraged participants to choose eligible items with longer paybacks. For example, conservation measures taken under the Danish Space Heating Scheme had simple paybacks of seven years on average. These would have been marginal investments for consumers without such incentives [1]. The Danish results are very impressive and can only partially be explained by information campaigns and the public's awareness of conservation due to the familiarity with the majority of energy projects under way in the country.

— Programmes have had difficulty penetrating the rental market which is a large segment in many countries. The Netherlands reoriented its programme solely towards rental accommodation to overcome the problem. Although general grants were abolished after 1984, Sweden also kept grants for the rental market.

Commercial Sector

The evaluation of the Institutional Conservation Programme in the United States showed that the average grant recipient saved 13% of his energy consumption or about a total of 5.2 trillion British thermal units (Btus) (0.025 Mtoe). The cost of saving 1 million Btus during the

1. Denmark, Ministry of Energy, *Energy in Denmark: A Report on Energy Planning 1984,* Copenhagen, 1984.

ten-year span of the measures was estimated to be $1.37, compared to government funding of $0.68. Paybacks averaged less than two years, rather than the four years originally predicted.

Transformation Sector

Several government programmes are targeted towards expanding the application of CHP/DH technologies. Financial support is limited to a few European countries [1]. Despite the importance of this sector, only the German Government has evaluated its programmes.

While various evaluations have given conflicting results [2], the German grant programmes have been effective in improving financial viability according to IEA Secretariat analysis. Incrementality has been estimated at one-third, and this has produced a benefit/cost ratio of total cost savings and public expenditures of close to three to one. Total energy savings are expected to be about 25 Mtoe until the year 2000, although this depends on the progress of the expansion of the DH grid. Recent price declines in 1986 lower the benefit/cost ratio to around two and one-half to one — still quite cost-effective.

While there are no specific evaluations, subsidies in Denmark and Sweden for large DH systems (10% for DH pipes) have had an acceleration effect. In both countries the environment has been favourable: practically no gas in the heat market, the existence of rather high levies on oil products, and co-operative utilities. Governments also enhanced the programmes through certain measures. Through the Danish Heat Supply Act, Denmark established price controls for grid-based energy forms to promote DH. Accordingly, for new projects, the total savings in energy costs were related to heat. Over time, however, savings are reduced and even reversed as are efficiency ratios. In mid-1986, Denmark implemented further supportive measures to improve investment conditions by reducing the impact of the high initial outlay through an "index arrangement" with fixed yearly payments based on 1986 Danish kroner and by allowing the total investment to be spread over a period of twenty years.

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1. The countries include Austria, Denmark, Germany, the Netherlands and Sweden.
2. The four evaluations reviewed were by P. Suding — Cologne, IFO — Munich (two studies; the first, published in 1982, was ordered by the government), and the German Institute for Economic Research, Berlin. They were done between 1982 and 1984.

(b) *Tax Incentives*

Industrial Sector

Tax incentives have generally not been very effective in encouraging incremental investments in North America. In Canada, only 4% of certified capital cost was incremental whereas in the United States there were no incremental projects at all [1]. However, the incentives have had an important symbolic role. On the other hand, once they are in place, it is difficult to remove the incentives without apearing to give a signal to industry that government is no longer interested in conservation.

However, in Japan, a survey of all industrial investors showed two-thirds took the tax credits: close to half expanded or accelerated their investment. Only one-third did not consider the tax credit at all. A macro-economic simulation by the Ministry for International Trade and Industry with the Nikkei-Needs Macro-economic Model suggests tax incentives are highly effective in Japan, with the increase in the investment in eligible equipment about three times the total tax reduction. IEA Secretariat benefit-cost analysis for the Dutch Investment Account Act shows a ratio similar to the analysed industrial grant programmes, i.e. about five to one.

Residential Sector

Although about one-third of IEA Member governments had or still have tax incentives for individual householders, only the United States has evaluated these credits. Some studies in the United States have shown that tax credits had a very low incremental effect (as little as 10%). This was explained in one analysis [2] by the relatively low percentage of the incentive and the fact that the conservation measures usually involved relatively small amounts of money.

1. See Canada, Energy, Mines and Resources, *Class 34 Capital Cost Allowance: Programme Evaluation, Final Report,* Ottawa, November 1984.
2. H. Petersen, "Solar Versus Conservation Tax Credits", *Energy Journal,* Volume 6, Number 3, pp.134-135.

(c) *Loans*

Industrial Sector

The effectiveness of loan programmes in industry has not yet been thoroughly investigated. But in Japan, for example, favourable industrial loans are often given in parallel with tax credits, which forms the largest part of the financial incentive, thereby masking the loan's specific effects.

Residential Loans

In Sweden, favourable loans are largely responsible for the high thermal standards of buildings. Interest rates have been below the inflation rate during the initial years of the projects and reach market levels as late as ten to forty years after the investment. Therefore, these loans are a strong incentive for efficiency investment in new buildings and retrofit projects in residential buildings.

Transformation Sector

In the Netherlands, analysis of financial support (subsidies and risk-sharing loans, on average 15%) for DH projects provided until end-1984, shows about the same benefit/cost ratio as for similar programmes in Germany. Government guaranteed commercial loans were continued because an evaluation pointed out that risk-sharing is considered the most important incentive in government support for DH.

General Assessment of Effectiveness

The main conclusions of the effectiveness of financial incentive programmes are summarised in Table 9. More specifically:

— financial incentives have been generally effective in promoting energy conservation although the incremental effect has varied. Programmes with higher incremental effects usually had specific eligibility criteria, carefully balanced percentage of total investment provided by the measure, and targeted audiences (as in the Canadian AECIP or the Danish industry programmes);

Table 9

Summary of Financial Incentives Programmes

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed[1]	Implementation Environment	General Conclusions
Industrial Grants	- stimulation of discrete conservation investment	- most countries	- financial attractiveness and access - confidence - lack of information	- largely initiated between two price increases in 1970s - some terminated when energy prices started declining	- expansion and acceleration of investment - introduced new technologies - improved financial attractiveness - good benefit-cost ratio, even given recent price declines - wide range of incremental investment - created awareness - administratively complex - targeting on incremental projects possible
Tax Incentives	"	- North America, Japan, some European countries	- financial attractiveness - confidence	"	- easy implementation - created awareness - application process fairly easy for companies - of little use for non-tax-payers
Loans	"	- Japan, Germany, Austria	- access to capital - confidence	"	- in practice, small interference in market - mainly easing access to capital (companies in poor financial situation) - incrementality difficult to assess

1. Refer to market limitations described in Chapter V.
2. Six countries have programmes for institutional/public sector. Five countries have programmes for the residential sector.

Table 9

Summary of Financial Incentives Programmes *(Continued)*

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed[1]	Implementation Environment	General Conclusions
Residential/Commercial					
Grants	- stimulation of discrete conservation investment	- about half of Member countries	- financial attractiveness and access - lack of information - confidence - separation of expenditure and benefit	- largely initiated between two prices increases in 1970s - some terminated in early 1980s when energy prices started declining	- popular and visible - created awareness - provided information to consumers - improved financial attractiveness - helped develop conservation service industry - poor results in rental market - poorer benefit-cost ratio than industrial grant programmes - administratively complex
Tax Incentives	"	- Austria, Belgium, Denmark, Germany, Japan, Switzerland, United Kingdom, United States	"	- largely initiated between two price increases in 1970s	- lower government involvement - mainly used by higher income groups
Loans	"	- Denmark, Germany, Japan, Sweden, United States	"		
Energy Transformation Sector					
Grants	- stimulation of investment into CHP and for DH	- Denmark, Germany, Ireland, Italy, Netherlands, Sweden	- financial attractiveness		- subsidies effectively reduced investment risks - benefit-cost ratio similar to industrial programmes - rather high incrementality - often lack of utility co-operation
Tax Incentives		- Austria	"		
Loans		- Austria, Netherlands, New Zealand			

1. Refer to market limitations described in Chapter V.
2. Six countries have programmes for institutional/public sector. Five countries have programmes for the residential sector.

- the grant programmes analysed have had a positive benefit/cost ratio. The ratio has been highest for industrial programmes;
- while the evidence is rather weak, grant programmes have been more cost-effective than other financial incentives;
- financial incentives can be valuable in introducing new energy-efficient technologies depending on how strict the eligibility criteria are. This has been particularly true in the residential sector;
- grant programmes are the most complex and expensive financial incentives to implement;
- grant programmes in the residential sector have been very popular. The average energy savings of a retrofit grant are 12%. But renters have not responded well to these programmes;
- financial incentives need to be closely linked with information programmes, for marketing purposes and to publicise the best incremental investments;
- in the transformation sector there is evidence that risk-sharing, through guaranteed loans, is the most important incentive in encouraging district heating.

iii) Regulations and Standards

Regulations and standards are used to varying degrees in all IEA countries. Standards are efficiency levels established by governments for appliances, buildings or passenger cars. They can be voluntary but most have been mandatory. Regulations refer to controlling or directing conservation actions through government rules or restrictions. Some countries have regulations specifying maximum temperature levels in industrial plants or requiring labels on new automobiles. They have been used in the United States to mandate utilities to offer energy audits to the residential and commercial sectors (see section i). They are sometimes directed towards the energy consumer (e.g. individual billing of heating costs), but more often are directed towards energy service suppliers or industrial manufacturers. The use of government regulations or standards to achieve energy conservation varies considerably by sector and country.

In the industrial sector, there have been fewer standards or regulations because "the huge variety of technologies and organisations in factories, workshops, etc., makes it difficult to design regulations which will not require costly measures of verification." [1] The Japanese Government maintains the right to inspect an industrial site and also requires an energy conservation plan be submitted with an application form for a construction permit for new industrial and residential/commercial buildings larger than 2 000 square metres. In addition, the appointment of energy managers is required by law. In Portugal firms consuming over 1 000 toe per year must implement an energy management service, have their energy-use patterns examined every five years, and develop five-year plans for the rational use of energy which must be approved by the Directorate General for Energy. Italy also has a comparable mandatory programme. The United States requires all firms consuming more than 1 trillion Btu of energy (25 200 toe) per year to report their energy use to the Department of Energy. Norway requires industry to have specific energy conservation plans when establishing large new facilities and/or expansions which call for the allocation of firm electric power supply. A few countries require automated controls for heating systems and at least two countries set efficiency rates for boilers (Austria and Germany), mainly for environmental reasons.

Many regulations and standards have been directed towards residential/ commercial buildings, and most have been mandatory. They require minimum thermal efficiencies for new housing by prescribing either particular materials/techniques (prescriptive standards) or levels of performance (performance standards), heating system efficiencies, individual metering according to energy consumption in multi-occupancy buildings, boiler maintenance requirements and restrictions on air-conditioning. Governments sometimes also prescribe increased thermal efficiencies for existing housing stock when retrofitted. Standards for existing buildings may be the only effective way of reaching segments of this sector, such as multi-family rental housing. Both Germany and Sweden initiated model agreements for tenants and home owners. Due to the long life-span of new buildings compared to other energy-related equipment, strict building codes will lead to energy cost savings in the longer term and, if well designed, should require only minor additional investment in the construction phase.

Although many countries also have regulations for appliance labelling which are discussed in section i, few have specific mandatory energy efficiency standards for appliances. The European Commission pub-

1. Commission of the European Communities, *Comparison of Energy Savings Programmes of EC Member States,* COM(84)36 Final, February 1984, p.5

lished guidelines for its Members which include both performance standards and control of servicing of heating systems. Austria has linked tax incentives to minimum efficiency standards. There are few examples of labels showing the thermal characteristics of buildings. Denmark is the only country which requires a heat inspection report with the building's thermal quality when buildings are sold.

In the transportation sector, a number of IEA countries (primarily those with an automobile manufacturing industry) have fuel efficiency standards or targets for new passenger cars, although only the United States (and to some degree Canada, which can invoke mandatory requirements if necessary) has a mandatory programme. Three countries — Germany, the Netherlands and Austria — require mandatory car inspection for environmental and fuel efficiency maintenance on a regular basis. Almost all countries have speed limits on highways and some (e.g. the United States) have lowered them to save fuel. Germany has recommended speed limits for its motorways.

Fuel economy standards have been used to improve the efficiency of new passenger cars. Because of the relatively quick turnover of the car stock, in a few years new car efficiency improvements can have a major impact on fleet efficiency. The standards are directed at the manufacturers and importers to improve the new vehicles. Consumers are involved through parallel aspects of standards programmes — labelling, guides and other information sources.

Effectiveness of Regulations and Standards

Building Codes/Standards

Building codes are an effective means of introducing energy-efficient technologies in buildings. They ensure that minimum levels of efficiency are achieved in new buildings — a sector where the market is especially slow to act. They also permit the construction of more efficient buildings, if demanded by consumers or builders.

The procedure for developing and revising building codes is often laborious because of the multitude of special interest groups involved; also codes are often developed at one level of government and adopted at another and they include other aspects besides. The resulting time-lag has caused some standards to follow trends already started by energy prices, instead of taking the lead. For example, Swedish evaluations of building codes concludes that actual building practices met and sometimes even surpassed the increasingly stringent codes one to two years before they were enacted in 1977 and 1980. To some extent, this acceleration was due to efforts by the government which spurred improvements by distributing information to manufacturers, designers and contractors. In addition, the existence of standards has probably influenced product development. This is especially true for airtightness.

Developing standards is also complicated by the modelling required. But even the most sophisticated models have to assume standard conditions and thus generally cannot accurately predict what actual energy use levels will be using various design assumptions. Savings can be estimated but consumption depends on consumer behaviour such as opening windows and setting thermostats.

In the Danish evaluation, it was estimated that the higher energy standard for new buildings was responsible for approximately a 15-20% decrease in energy use per square metre and saved a total of about 10 petajoules per year between 1975 and 1981.

A Dutch study concluded that, from a benefit/cost point of view, standards in most European countries could be more stringent [1]. Due to the long lifetime of new buildings (fifty to a hundred years), discounted heating costs during the period, which have to be based on probable energy price increases in the medium term, will certainly outweigh the comparatively minor additional expenses for better insulation. Since insulation improvements are often cost-effective only when buildings are substantially modernised, there is a clear need for optimum insulation standards during construction.

According to an evaluation of conservation programmes in the European Community, the difference in the building codes in Europe narrowed between 1980 and 1982 [2]. Nevertheless, the Commission believes building standards can be strengthened, and it is preparing a model

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1. Meyer, L.A. "Energiebesparing in de sociale Woningbow", University of Groningen, Groningen, 1981.
2. Commission of the European Communities, *Comparison of Energy Saving Programmes of EC Member States, op. cit.*

"reference" code. The Commission believes that building codes for new buildings are very important because 20% of the buildings still standing in 2000 have not been built yet and insulation is two to four times less expensive during construction than during retrofit [1].

Appliance Standards

No specific studies have evaluated the effect of standards on residential appliance efficiency. The United States ruled in 1982 and 1983 that energy efficiency standards for eight appliances were not economically justified or effective. They did allow states to set their own standards and a number of states, including California, have set efficiency rates for major home appliances. A court decision in 1985 stated that standards should be set by Congress. The Department of Energy will stage new hearings and issue provisional rules. However, legislation is currently being considered which would establish specific national appliance standards while pre-empting existing and future state standards. If enacted, these standards would go into effect more quickly than standards established by the Department of Energy.

Automobile Fuel Efficiency Standards

The IEA reviewed the effectiveness of fuel efficiency standards in 1984. Only three IEA Member countries have attempted to quantify the fuel savings attributable to their programmes — Australia, Canada and the United States. None, however, has been able to clearly attribute improvements to prices or programmes. The United States implemented its mandatory programme in 1977 when energy prices were falling in real terms. Manufacturers were both sceptical they could achieve the targets and unhappy that the standards were based on fleet sales rather than individual car performance which is more predictable. But manufacturers did improve efficiency of their vehicles and they were better prepared when the second major oil price increase came in 1979-80. Once gasoline prices rose dramatically, manufacturers anticipated surpassing the standards and thus saw no need for them. In the early 1980s gasoline prices again declined and two of the major car producers in the United

1. Commission of the European Communities, *Towards a European Policy for the Rational Use of Energy in the Building Sector,* COM(84)614 Final, Brussels, 13th November 1984.

States were not able to reach the fleet average of 27.5 miles per gallon (mpg). The National Highway Traffic Safety Administration has reduced the 1986 standard from 27.5 mpg to 26 mpg in response. As shown in Table 4 in Chapter III, many of the other producers' programmes, however, did meet their target. As shown by the United States, fuel economy standards can be important. They initially were responsible for improved efficiency in new cars and it maintained rates during subsequent declines in gasoline prices. Even though the 1985 target had to be reduced, the improvement since 1978 is commendable.

The main findings of the review of the effectiveness of regulations and standards in Table 10 are:

— standards and regulations have been most useful in the residential/commercial and transportation sectors where there is more standardization of equipment and where there are special market segments such as rental housing;

— building codes/standards have been mainly limited to new buildings; due to the much larger stock of existing buildings and the ineffectiveness of market forces for major categories of existing buildings, standards should also be considered in this area;

— transportation vehicle standards have been effective in improving fuel efficiency of new vehicles, especially when combined with information programmes. There is no evidence if mandatory or voluntary programmes are more effective;

— regulations and standards ensure that minimum efficiency levels are met, but can discourage producers from exceeding these minimum requirements and thus achieving the full economic potential;

— they have been useful to provide long-term continuity through periods of energy price fluctuations;

— standards and regulations need to be enforced, and governments have backed these measures with small amounts of funds.

General Conclusions

A range of policy measures are used by governments to complement and strengthen market signals that stimulate conservation actions and address many of the market limitations described in Chapter V.

Table 10

Summary of Regulations and Standards

Policies/Programmes	Primary Goal	Degree of Use	Market Limitations Addressed[1]	Implementation Environment	General Conclusions
Building Codes	- upgrade efficiency of new building stock	- all IEA countries	- invisibility of consumption - lack of information - separation of expenditure and benefit	- energy efficiency aspect of existing building codes added after major price increases - have been maintained even in periods of declining energy prices	- very effective in overcoming market limitations - low cost means of upgrading thermal quality of new building stock - provide long-term signals - easy to adapt to regional/local conditions
Appliance Efficiency Standards	- upgrade efficiency of new appliances	- Japan, United States	- invisibility of consumption - lack of information - separation of expenditure and benefit	- initially implemented when energy prices increasing	- insufficient information to draw conclusion - most countries more interested in appliance labelling programmes than efficiency standards
Fuel Economy Standards for New Passenger Cars	- upgrade efficiency of new passenger cars	- nine countries - only United States has mandatory programme	- lack of information prices increasing for	- initially when energy and importers specific period - some kept after target period	- directed towards manufacturers - work in parallel with transportation information programmes - attribution of effects is difficult yet countries have maintained momentum to improve efficiency even when energy prices declining - both mandatory and voluntary programmes have achieved targets

1. Refer to market limitations described in Chapter V.

Different policy measures can address these limitations although in different ways. Their use depends on such factors as complexity and cost of implementation, government policy, legislative requirements and timing required. Often the combination of more than one policy measure or the offering of an array of programmes to suit different market segments can be even more effective. For example, residential energy audits are most effective when combined with financial incentives, and fuel efficiency standards are best when accompanied by guides, labels and brochures. Therefore, policy measures should not be considered in isolation but as part of an integrated approach.

The main conclusions from the analysis of policy measures used by governments are:

— most policy measures have been implemented to either address the lack of information and technical skills or the lack of access to financing or the economic attractiveness of conservation activities;

— financial incentives have shown to have positive benefit-cost ratios with the best results in the industrial and transformation sectors;

— there is a wide range of incremental effects due to a variety of factors including percentage of financial incentive, range of eligible items, implementation and programme design;

— more focussed programmes are more effective than general ones;

— awareness and motivation are not static and need to be reinforced periodically or through feedback mechanisms to give the consumer a better understanding of his energy use;

— standards and regulations have been most useful in the residential/ commercial and transportation sectors where there is more standardization of equipment and where there are special market segments such as rental accommodation;

— standards and regulations ensure minimum efficiency levels are met;

— effectiveness of programmes depends on good implementation, requiring human and financial resources, co-ordination within administrations and with other levels of government;

— in the industrial sector, a combination of programmes encourages businesses to develop good energy management. These programmes include energy audits, training, monitoring and targeting, technical materials and technology transfer programmes;

— there is still too little known about the effectiveness of programmes, and evaluations that have been undertaken have generally not been sufficiently comprehensive.

The specific conclusions are:

— thorough analysis should be made of the remaining opportunities for energy efficiency improvements, the obstacles to their achievement and which decision makers will need to act;

— upon identifying areas of economic potential which are unlikely to be achieved by the market, governments should assess the full range of policy instruments in order to determine the most appropriate and cost-effective programme mix for each situation;

— in designing and implementing programmes, every effort should be made to ensure their effectiveness and maximise the incremental conservation action that results;

— conservation programmes should be rigorously evaluated periodically to ensure they are meeting policy objectives and maximising effectiveness;

— information programmes should be the cornerstone of every conservation strategy: they can motivate and create awareness, explain conservation opportunities, improve technical skills, and publicise other government programmes;

— financial incentives should be used selectively to support the operation of the market by providing access to needed capital; motivating consumers to undertake conservation efforts; helping the introduction of new technologies; and helping to develop conservation services;

— regulations and standards can be valuable to keep the long-term momentum and to reach special market segments (e.g. the residential sector which is the least price responsive end-use sector, rented buildings and markets heavily influenced by style and advertising (e.g. automobiles)). They ensure minimum levels of effort, are useful during periods of energy price fluctuations and should be reviewed periodically;

— energy efficiency objectives should be carefully integrated with industrial, social, fiscal and other policies that affect energy use.

CHAPTER IX

Research, Development and Demonstration

Government support for the research, development and demonstration (RD&D) of more energy-efficient technologies has been a major element of the conservation efforts of many IEA countries since the mid-1970s. These efforts have resulted in the development or demonstration of a large number of new technologies and conservation techniques, some of which have already begun to have significant effects on end-use demand. Some countries, such as the United States and Japan, have emphasized long-range research aimed at achieving major advances in basic technologies, while other countries have focussed on demonstrating, evaluating and supporting the introduction of existing, under-utilised technologies.

The main contribution to promoting energy efficiency over the rest of the century is likely to be made by the commercialisation and diffusion of existing and new technologies rather than research and development. Demonstration — the trial of newly developed technologies or applications under normal working conditions on a large enough scale to determine with relative assurance the economic and technical feasibility of a full commercial application — is thus of particular importance as one of the major means of transferring the knowledge and experience learned about new and existing technologies. Further R&D is required to develop new technologies into the next century. Socio-economic research also has an important contribution to make to the formulation of energy conservation policies. The following chapter examines the government role in the support of such research efforts, the effectiveness of past government efforts and some possible future directions [1].

1. See Stern et al., *Energy Use: The Human Dimension,* National Research Council of the United States, 1985.

I. Technologies

A. *Focus of RD&D activities*

RD&D programmes over the last decade focussed on and continue to advance such technologies as heat pumps, heat exchangers, microwave industrial heaters, microelectronic controls, energy storage, municipal solid waste systems, DH and CHP. Utilisation of waste heat, new building materials, building design, modelling of heat loads, ceramic engines and control systems are further examples of the myriad of projects which governments and industry have undertaken.

A recent IEA study [1] identified end-use technologies where it is important to pursue further RD&D. They are:

Industrial Sector

— energy-efficient production systems;
— heat recovery systems (e.g. heat pumps);
— recycling of energy-intensive products.

Residential/Commercial Sector

— building design;
— heating and cooling systems (e.g. district heating, heat pumps);
— total energy management systems.

Transportation Sector

— more efficient vehicles (e.g. ceramic engines).

Energy Transformation Sector

— more efficient power plants (e.g. combined cycle, fuel cells);
— cogeneration systems (organic rankine cycle (ORC)).

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1. IEA, *Energy Technology Policy*, OECD, Paris, 1985. See Annex G for a review of the identified technologies.

Microelectronic sensor and control systems have an important role in many of these individual technologies. By applying these systems, energy consumption can be precisely adapted to actual requirements, thereby increasing energy efficiency. The same also holds for complete systems such as an electricity distribution system, where the deployment of these systems in conjunction with more effective storage systems could revolutionize electricity demand management.

B. The Roles of Government and Industry

The level and type of government activity in RD&D vary by industry and country. In the transportation sector, the automobile industry for the most part undertakes its own RD&D work relating to more efficient motors and vehicle design, although governments are involved to some extent in basic fuel efficiency research and play a major role in aviation RD&D. Some of this RD&D for automobiles has probably resulted from government targets for fuel-efficiency. Efficiency improvements are incorporated into new vehicles after internal demonstration work but without the educational demonstration stage for consumers.

In the industrial sector, companies often do their own R&D to improve their own efficiency. This is particularly important for certain energy-intensive industries such as cement and pulp and paper. In addition, manufacturers who make equipment (e.g. boilers) for use by other industrial consumers conduct R&D work to improve the efficiency of their products, sometimes followed by demonstrations to test products and educate the potential consumers. Small- and medium-sized firms generally do not have the funds or the expertise to undertake R&D.

The building industry performs much less R&D work, and faces major technology transfer problems when new technologies or processes are developed. Extensive demonstration efforts are necessary to reach the other decision makers in the building sector, including builders, architects, building owners and tenants.

Whether government funds are applied to R&D projects — conducted by government, universities or industry — or to demonstration projects — usually conducted by industry but often in collaboration with government — depends in large part on the philosophy of the government and the economic and industrial structure of the country. Certain countries such as the United States support and conduct R&D,

leaving industry to take over in following through with demonstration. In practice, however, R&D efforts in the United States are sometimes defined in a way which covers projects which in other countries would be regarded as demonstration. In specific technology areas, government funding for all RD&D can be greater than that of industry. In other cases, where industry has undertaken the basic R&D work on its own and is then faced with funding difficulties at the technology transfer stage, governments have concentrated their efforts on technology transfer. The United Kingdom, for example, although involved in R&D work, puts more emphasis on demonstrations which have significant replication potential through the Energy Efficiency Demonstration Scheme. Japan also has achieved notable success in technology transfer through extensive co-operation between government agencies and industry.

Governments also have a role to play in international conservation RD&D activities. International co-operation is generally more beneficial for expensive and universally applicable technology developments, but it can provide advantages for conservation RD&D, such as limiting duplication and allowing more to be done with total available resources; permitting the early adoption of technologies to specific national or regional circumstances; and permitting a wider range of approaches and optimal use of available scientific talent.

C. Funding for RD&D Programmes

Government spending on RD&D on conservation technologies has increased since 1977. While government energy RD&D budgets actually declined 7.6% between 1977 and 1985, conservation RD&D budgets increased 23.3%, although from a low base (see Table 11). In 1984 conservation represented 6.2% of total energy RD&D budgets compared to 4.7% in 1977. Although industry figures are difficult to obtain and IEA aggregate figures are therefore incomplete, indications are that expenditures for conservation RD&D in the private sector are substantially higher than government expenditures [1].

1. Nine countries (Australia, Austria, Italy, the Netherlands, Norway, Spain, Turkey, United Kingdom, United States) submitted estimates of industry energy conservation RD&D expenditures in 1984 totalling $3 052.13 million. Total government energy conservation RD&D expenditures for those nine countries in 1984 were $376.03 million.

Table 11

IEA Government RD&D Budgets for Energy Conservation[1]

($ millions)

Country	1977	%[2]	1979	%	1980	%	1981	%	1982	%	1983	%	1984	%	1985	%
Australia	5.3	(18.0)	3.9	(8.1)	5.8	(9.4)	6.8	(9.7)	N.A.	—	10.2	(12.5)	N.A.	—	N.A.	—
Austria	5.3	(27.9)	5.9	(27.4)	7.2	(33.0)	6.0	(29.6)	6.9	(31.2)	5.3	(25.4)	7.6	(33.3)	6.5	(31.0)
Belgium	5.5	(6.6)	3.6	(6.9)	5.4	(6.2)	6.0	(7.9)	4.5	(6.4)	6.0	(9.5)	7.1	(10.60	4.3	(7.0)
Canada	13.4	(5.5)	19.5	(6.9)	25.5	(9.1)	37.2	(11.3)	43.4	(12.7)	54.6	(14.0)	54.8	(12.4)	50.4	(13.4)
Denmark	1.9	(11.4)	2.1	(7.8)	3.4	(17.2)	3.9	(30.0)	3.4	(27.2)	3.8	(31.2)	3.2	(29.1)	2.7	(26.0)
Germany	13.9	(2.2)	32.4	(4.4)	38.2	(5.1)	43.5	(5.4)	28.7	(2.8)	22.1	(3.6)	12.9	(2.1)	14.2	(2.6)
Greece	.0	(0)	.0	(0)	.1	(0.3)	.1	(0.3)	.6	(10.0)	.5	(9.1)	.1	(1.4)	.2	(2.2)
Ireland	.3	(12.5)	.4	(8.0)	.9	(15.0)	2.3	(32.9)	2.1	(35.6)	1.6	(43.2)	.7	(46.7)	.8	(38.1)
Italy	13.4	(6.7)	13.5	(4.9)	15.6	(5.4)	11.6	(2.4)	14.9	(4.0)	21.6	(4.9)	25.9	(4.4)	19.3	(3.4)
Japan	55.9	(8.0)	62.1	(6.5)	31.6	(2.3)	18.2	(1.3)	10.7	(1.0)	11.7	(0.9)	11.9	(0.8)	12.3	(0.8)
Netherlands	11.2	(10.8)	13.6	(12.1)	17.0	(14.9)	17.3	(14.6)	13.8	(14.1)	19.0	(19.5)	16.6	(19.8)	19.2	(16.7)
New Zealand	.8	(21.0)	.8	(12.5)	1.3	(11.9)	1.3	(14.0)	1.2	(14.3)	.9	(11.4)	1.7	(18.1)	1.4	(14.0)
Norway	2.3	(8.2)	5.5	(14.0)	6.2	(17.2)	5.4	(17.5)	4.7	(17.2)	4.4	(19.4)	3.9	(18.0)	3.5	(16.1)
Portugal	N.A.	—	N.A.	—	.1	(2.7)	.2	(6.9)	.2	(6.9)	.3	(8.3)	1.7	(29.8)	1.5	(27.2)
Spain	2.5	(6.4)	2.3	(4.2)	2.2	(3.4)	3.3	(5.4)	8.1	(14.5)	25.2	(19.8)	38.0	(26.1)	34.4	(27.7)
Sweden	22.9	(36.7)	23.5	(22.7)	29.9	(30.2)	32.3	(23.5)	36.6	(33.2)	35.4	(35.9)	28.0	(30.6)	22.3	(27.1)
Switzerland	2.6	(8.6)	4.0	(8.5)	5.8	(11.5)	5.7	(12.1)	4.9	(11.0)	4.7	(10.2)	6.6	(14.6)	7.0	(14.5)
Turkey	N.A.	—	N.A.	—	.2	(7.4)	.2	(16.7)	.4	(21.1)	.9	(32.1)	0.6	(25.0)	0.7	(30.4)
United Kingdom	21.2	(6.4)	22.9	(5.7)	20.2	(5.0)	21.5	(5.0)	40.1	(10.3)	44.3	(10.6)	32.6	(8.4)	37.1	(10.2)
United States	140.1	(3.4)	185.3	(3.6)	380.9	(7.5)	266.8	(6.8)	162.5	(5.4)	226.7	(8.0)	169.7	(7.2)	173.6	(7.7)
TOTAL	318.7	(4.7)	397.3	(4.6)	597.3	(6.5)	489.6	(5.8)	387.8	(5.2)	499.3	(7.0)	423.7	(6.3)	411.5	(6.2)

1. In 1985 U.S. dollars.
2. Percentage of total government RD&D budgets.

Source: Country submissions.

These aggregate IEA figures are greatly affected by United States expenditures which since 1977 have represented as much as 63% of total IEA government RD&D budgets in 1980. In 1985 the United States represented 40% of the IEA total. Netting out the United States from the IEA total shows for the most part a steady increase in spending on conservation from 1977 to 1983, except for a dip in 1979, and a slight decrease since 1979. When the United States is included, RD&D conservation peaked at $597.3 million in 1980, dropped dramatically over the next two years, increased again in 1983 to $499.3 million and declined slowly since.

There is a wide range of perceptions among IEA countries regarding the need for government support for RD&D. As shown in Table 11, support to conservation RD&D as a percentage of total government support for energy RD&D ranged from 0.8% in Japan in 1985 to 31% in Australia and 38% in Ireland.

Government RD&D programmes vary according to the needs of the country, the industrial infrastructure, and the philosophy of the government. No matter what emphasis is decided on, RD&D programmes interact with and are part of other government programmes. They almost always make use of other tools such as financial incentives, information programmes and regulations and standards for both the basic R&D work, and the integration of new technologies into the market. Examples of some innovative energy conservation RD&D government programmes in IEA Member countries include:

— The Canadian Super Energy Efficiency Housing Programme is a demonstration programme which promotes energy-efficient construction techniques in the residential sector. The programme provides consumer education, builder training, product development and monitoring of homes designed to satisfy the "R-2000" energy consumption standard. The programme takes advantage of the builders' knowledge and skills by allowing the builders to design and construct the buildings as long as the energy consumption of the finished product does not exceed a specified amount.

— In Japan, the "Moonlight Project" is designed to develop and commercialise energy-efficient technologies. The programme synthesises efforts applying to all end-use sectors. The government funds large-scale R&D projects (on a cost-sharing basis if the companies are actually able to apply such technologies). Financial assistance has also been provided to one or two private companies on an equal cost-sharing basis to develop efficient household appliances. A number of basic energy conservation research projects are conducted in National Research Laboratories through the Moonlight Project.

— In Sweden, the part of the government's research programme which concerns "new energy systems in buildings", focusses primarily on heat storage and heat pumps. The work is conducted through the co-operation of manufacturing industry, contractors, consultants, building operators and administrators, local authorities, government bodies, research organisations and the Institute of Technology.

— The United Kingdom stimulates the development and uptake of energy-efficient technologies and designs in two ways. First, the Energy Efficiency Demonstration Scheme provides financial assistance to organisations which are able to demonstrate new ways in which energy can be used more efficiently. Independent monitoring of the performance of demonstrated technologies, coupled with a co-ordinated promotional programme, are two key elements of the United Kingdom's approach. Second, the United Kingdom makes available, on a selective basis, funds to assist R&D into energy-efficient technologies and designs. Promotion and dissemination of the results are regarded as an important feature of the programme.

— In the United States, the government sponsors various industrial R&D projects in specific areas such as efforts to reduce energy requirements in aluminium and steel processing, recovery of energy from industrial waste, improved process efficiency and others. R&D programmes in the United States also include advanced propulsion technologies, ceramic materials and alternative fuel utilisation for the transportation sector, advanced energy storage technologies and basic research in materials science, biocatalysis and tribology. The approach taken to transfer new developments to industry is based on proving the performance of new technologies through testing and evaluation in the industrial environment and informing industry of the results. This transfer of information on new technologies is accomplished through close co-operation between the government and trade associations and professional societies, as well as technical reports, workshops, seminars and conferences.

There have also been extensive international efforts in the energy conservation RD&D area:

— the European Community has both R&D and demonstration programmes. For R&D, the Community's role has been to encourage co-ordination, disseminate findings and support R&D of certain problem areas (thermal analysis and improvement of buildings, energy saving and heat recovery in industry, advanced energy-saving technologies in transport, advanced heat pumps, advanced batteries and fuel cells). The demonstration programme offers up to 40% of the eligible cost of the project as a grant which is to be paid back in part if the project is successful. The programme is for projects which create full-sized replicable installations which either use alternative energy sources, save energy or substitute hydrocarbons.

— There are also IEA collaborative projects in energy conservation RD&D, covering a wide range of technologies. Collaborative projects are undertaken on either a cost-sharing basis, a task-sharing basis, or sometimes a combination of both. Results of the projects are shared by all participants. Examples of cost-sharing projects include two information centres: the Air Infiltration Centre and the Heat Pump Centre. The tendency over the years, however, has been towards task-sharing projects such as countries conducting research work in common, or exchanging information on ongoing activities within each country. Consideration is now being given to establishing a separate IEA information centre that would concentrate on end-use technologies.

D. Assessment of government programmes

Assessing the effectiveness of government involvement in RD&D activities is as important as for other types of policy instruments. For both R&D and demonstration, assessments must examine the design, management and results of the programme itself in light of its goals. In addition, assessments of R&D programmes must analyse the type of technology work being done in terms of whether funded projects offer significant potential savings, and how much and whether the technologies are marketable. Demonstration programme assessments must also look beyond a micro analysis of the programme to assessing whether it is attracting useful technologies and whether it is increasing the market penetration of the new technology. The market limitations which can most effectively be overcome by effective RD&D programmes are lack of information and technical skills, and lack of confidence in new technologies. While the results of programme evaluations depend on each country and programme, the lessons learned can be valuable for other governments.

Selected country programme evaluations include:

Sweden — Heat Pump RD&D

— In Sweden, an evaluation by the Energy Research Commission (ERC) of government support on research for heat pump technologies found that the results led to a substantial development of the technology and that there has been good transfer of the know-how. Direct effects in terms of the near-market technical development were concluded to be small, although the assessment was made against a rather short perspective. Therefore, energy-savings assessments were considered to be very difficult. It was concluded that, for further work, co-operation with the manufacturing industries and energy producers and distributors should be strengthened.

Conservation Demonstrations in the United Kingdom

— The United Kingdom's Energy Efficiency Demonstration Scheme is periodically evaluated in terms of its established targets for the level of energy savings, government expenditure and industry expenditure. Assessment of how well these goals are being reached results in the readjustment of interim targets, of how the Scheme is carried out and in what areas. For example, the initial emphasis was on industry, but this has since been expanded to include both domestic and non-domestic buildings. Some R&D work, in addition to demonstration projects, was added while the programme was under way. The fact that the programme is so closely monitored provides valuable guidance for future government expenditure in this field and ensures that national energy policy objectives continue to be served.

Conservation R&D in the United States

— The United States has conducted an extensive analysis of energy conservation R&D activities in order to determine areas that need to be addressed by government. Separating the effects, in terms of energy savings, of government and private sector activities has not been attempted, nor has the role of government in specific R&D projects been evaluated separately. Effort has been made, however, to identify developments which were accelerated through Federal participation.

The study found that government and private sector cost-shared projects in industry have supported over 200 technologies, of which 23 are now complete and being commercialised by industry. Accumulated energy savings from those 23 technologies are estimated to be 116 trillion Btus. Government efforts have also resulted in improvements in the transportation sector due to ceramics and automotive battery improvements.

The study also identified twelve technology areas within the industrial sector which need to be developed to improve energy efficiency [1]; four areas within the transport sector [2]; and three technology areas within the residential/commercial sector [3].

Conservation Demonstrations in the EEC

— The European Community's Demonstration Programme has been working continuously since 1979 and will continue at least until 1989. By the end of 1986 and since the beginning of the programme, some 4 200 proposals have been introduced of which some 1 200 have been selected for financial support. The overall

1. Process electrolysis, carbothermic processing; catalysis research; comminution; materials processing; sensors and controls systems; separation/concentration of chemical components; coatings and adhesives; energy cascading; waste heat recovery; combustion efficiency; and industrial waste utilisation.
2. Batteries and propulsion systems for electric vehicle commercialisation; new and more efficient heat engines for automotive applications; heavy-duty diesel engine technology, including more fuel-efficient, fuel-flexible and cost-effective systems; ceramics, ceramic composites, and ceramic coating development.
3. Building subsystems, systems integration, building retrofit and standards and guidelines; building equipment; and community systems, including district heating and cooling, community energy planning, development and management.

budget for the eleven-year programme is approximately 850 million ECU [1], which means that this programme is the biggest of its kind in the world. All areas are covered:

- energy savings (industry, buildings, transport, energy industry);
- alternative energy sources (biomass and energy from waste, solar, wind, hydro, geothermal energy);
- substitution of hydrocarbons (solid fuels, electricity and heat);
- liquefaction and gasification of solid fuels.

Some 150 projects have been completed with a "contractual success" rate of over 50%. In some 40 cases, the success has been repeated through replication elsewhere in the Community.

The programme has been evaluated twice, once in 1982 and again in 1984-85 by an external group of experts. The overall conclusion from both evaluations was that the programme fulfilled a specific need in the area and showed very positive results.

II. Socio-Economic Research

The formulation of effective conservation policies — like the formulation of an effective marketing plan for a product — requires an understanding of the many non-technical factors which influence efficiency improvements and which can make policies (or marketing strategies) more effective. There are four main areas of research:

- Consumer behaviour research. This is important because the factors influencing energy-consuming behaviour are complex and little work has been undertaken. Most of the work has been done in the United States although there is evidence that this has tapered off [2]. Some utilities in the United States which are putting heavy emphasis on conservation are still doing research. Europe started research much later than North America and in the past year

1. In September 1986, 1 ECU = US$1.
2. See Stern et al., op. cit.

activity has started to wane. However, the Swedish State Power Board has just started a seven-year project to study how to use energy more efficiently. The reason for starting the project is that the remaining surplus of electricity generating capacity is small and that options for expansion are few. The project will also study consumer behaviour, the use of energy today and how consumers react to increasing prices and changes in the price structure of electricity.

— Micro-economic research for improving the evaluation of policy measures. As was evident in Chapter VIII, there are still many methodological problems in evaluating the effectiveness of policy instruments. Research has been undertaken to improve the quality of evaluation methodologies and to increase their use in the evaluation of conservation.

— Macro-economic research to determine broad trends, impacts and influential variables, such as the impact of conservation on employment or environment, the development of various energy scenarios or the attribution of aggregate energy efficiency improvements to energy prices or government policies.

— Techno-economic research to have a better understanding of how energy is used, to develop better assessment of conservation potential and to develop better statistical indicators of improvements in energy efficiency. For the last, the European Commission has a two-year research project under way.

It is essential that socio-economic research should be developed appropriately in order to provide a better understanding of the factors which influence consumer behaviour and of the effectiveness of policy measures. More government support for socio-economic research as appropriate is needed to achieve this result. The IEA could help this development by providing a clearing-house for the exchange of information on the results of socio-economic research in Member countries.

Research in all these areas is hampered by the inadequacy of data about energy use. Consideration needs to be given at both national and international levels to improvement of the quantity and quality of these data to the extent that government expenditure and staffing constraints permit.

III. Conclusions

RD&D on energy conservation is widely spread over governments and industry. Substantial progress has been made in the last ten years. More needs to be done, however, to demonstrate new technologies which are technically viable, to improve the assessment of government programmes and to develop social research relevant to the formulation of energy conservation policies and programmes. Specific conclusions to these ends are:

— those Member governments which do not support demonstration programmes or other appropriate methods of technology transfer should look again at their position in the light of the success of such programmes in other IEA countries and in the European Community;

— the design, management and results of RD&D programmes should be carefully and regularly assessed; in the case of demonstration and technology transfer programmes, evaluations should examine the effectiveness of the effort in overcoming market limitations to the adoption of new technologies;

— the lessons learned from assessments should be made available to other governments directly and through the appropriate international organisations;

— socio-economic research should be continued or expanded as appropriate to ensure better formulation and assessment of conservation policies and programmes;

— efforts should be made to improve the quantity and quality of data on energy consumption to improve international comparisons of energy efficiency;

— there is a need for closer collaboration within government (since RD&D are often in ministries that do not handle energy policy) and between government and industry to avoid unnecessary duplication and to optimise use of resources.

CHAPTER X

The Exemplary Role of Governments as Energy Consumers [1]

Governments use energy directly and have the opportunity to set an example of good conservation practices. In doing so they will encourage others to use energy more efficiently. But failing to do so, will suggest that energy conservation is unimportant.

Governments also have a responsibility to manage their resources well. Like industry and commerce, many governments have developed energy management programmes. They have come to recognise that energy costs, constituting a significant proportion of operating costs, can be controlled and provide many financial benefits.

Governments face most of the same obstacles that confront other energy consumers. For example, many governments rent accommodation and face the same landlord-tenant concerns described in Chapter V. In many ways, the task is more complicated than for many industries because of the autonomy of various government organisations and the lack of incentives for cutting costs. While many governments have one central group responsible for conservation policy, the responsibility for energy use is dispersed [2]. For example, in IEA countries, responsibility for

1. This chapter deals with energy use directly controlled by governments and not with the entire public sector.
2. For a description of government organisation, refer to Chapter VI.

conservation in government buildings commonly falls to Ministries of Public Buildings or Administrative Affairs, in the defence estate to Defence Ministries and in schools to Education Ministries.

Government units have varying levels of autonomy in implementing programmes to achieve their energy efficiency goals. There remains, nevertheless, a need for the central co-ordination of government-wide programmes. Common functions of the co-ordinating body are to provide advice, guidance and assistance to the various participating organisations, to undertake training programmes, to report on total public sector energy consumption and to initiate measures to improve energy management. Often the point of co-ordination is within the ministry responsible for energy. In Canada, the Federal Energy Management Programme is co-ordinated by the Department of Energy, Mines and Resources which must make an annual progress report to Parliament. Nevertheless, it is useful to have each government administrative unit responsible for implementing conservation programmes. In the United Kingdom, the Energy Efficiency Office, which takes the lead in Government for co-ordinating energy efficiency policy, includes action within the government estate within its campaign. The Prime Minister has instructed all government departments to appoint energy managers. In the Australian state of New South Wales, a centralised payment of gas and electricity accounts for some departments through a "group vote" system had operated for many years. The decision of the NSW government to introduce individual departmental votes for these cost items from July 1982 clearly assigned management responsibility and accountability for all energy use to the individual departments.

Some countries have comprehensive mandatory programmes. This is valuable in requiring the large energy users (public works, defence) to undertake conservation efforts. In Canada, the Internal Energy Conservation Programme was created by the Cabinet in 1976 with specific targets and requiring each government organisation (departments, agencies and Crown Corporations) to develop its own energy management plan. In Denmark all public buildings (municipal, regional, state) must as far as possible be brought up to a reasonable energy economic standard by the end of 1989. The United States also has a mandatory programme. Among its specific objectives are reducing energy consumption, using energy more efficiently, and transferring applicable energy management experience and technologies among federal agencies and the private sector. Many governments have mandatory temperature settings or speed limits for their vehicles.

Results of Energy Conservation Programmes in the Government

The governments of many IEA countries have introduced several measures to conserve energy in their public sectors. Some of the results include:

— The state Energy Management Programme in New South Wales is the oldest in Australia. It was established in 1979, and the first two years of its operation saw a 16% reduction in government energy consumption. The main features of the programme include maintaining the government's total energy consumption (excluding that required for electricity generation and public transport) at the 1978-79 level for five years; applying energy conservation concepts in the design and construction of all government buildings and projects; and purchasing lighter, more fuel-efficient vehicles.

— In Austria government activities initiated in the mid-1970s led to a decrease of 2.5% in total energy consumption in federal buildings between 1978 and 1983. This decrease occurred despite a 25% increase in the size of the federal building estate and was achieved by the appointment of officials responsible for energy efficiency in all ministries, a high level of capital investment in energy conservation equipment (starting around 1978, increasing up to around 1 billion schillings, between 1981 and 1983), better training of boiler staff and increased use of district heat systems.

— By 1980, the goal of the Canadian programme had already been surpassed and the programme was redesigned. The Federal Internal Retrofit Programme and the Federal Off-Oil Programme were added to the IECP to form the Federal Energy Management Programme (FEMP). The FEMP shifts emphasis and responsibility for energy savings target setting towards individual organisations. Total government direct energy consumption in 1982-83 was nearly 5% lower than in the previous year and more than 21% lower than in 1975-76, the year before the IECP began. Energy savings in government accommodation were even more pronounced — 9% over the previous year and more than 24% over 1975-76.

— In Germany, it was found that the Federal Ministries reduced their energy consumption by 25% between 1979 and 1983. Similar decreases were noted for state and local governments.

- In the Netherlands, 0.18 billion guilders[1] were invested in the period 1980-83 for efficiency measures in central government buildings. Energy savings are estimated as 75 million cubic metres gas per year, indicating rather low payback periods between three and five years.
- In the United Kingdom, there is a target of 70% reduction in the energy consumption level of government buildings between 1972-73 and 1988. The energy bill in the government estate is now £100 million lower than it would have been otherwise.

However, not all programmes have achieved their desired results. For example, in the United States total energy consumption in fiscal year 1984 was 1.6% below that in 1975 and the total expenditure was approximately $1.0 billion less than in 1983. However, there is a requirement to reduce the amount of energy used per square foot by 20% between the fiscal years 1975 and 1985. As of fiscal year 1984 a reduction of only 5.4% had been achieved. The Secretary of Energy has written to all federal agencies to encourage better results for 1985.

Conclusions

Governments need to set a positive example of good energy management to all consumers. In addition, officials need to publicise and explain conservation strategies. Specific conclusions are:

- socio-economic research should be continued or expanded as appropriate to ensure better formulation and assessment of conservation policies and programmes;
- efforts should be made to improve the quantity and quality of data on energy consumption;
- there is a need for closer collaboration within government (since RD&D are often in ministries that do not handle energy policy) and between government and industry to avoid unnecessary duplication and to optimise use of resources.

1. On the average in 1986, 1 guilder = $1.

Annex A

IEA Principles for Energy Policy

In 1977, IEA Energy Ministers adopted twelve Principles for Energy Policy to guide Member countries in planning and carrying out energy programmes:

1. Reduce oil imports by conservation, supply expansion and oil substitution;

2. Reduce conflicts between environmental concerns and energy requirements;

3. Allow domestic energy prices sufficient to encourage energy conservation and development of energy supplies;

4. Slow energy demand growth relative to economic growth by conservation and substitution;

5. Replace oil in electricity generation and industry;

6. Promote international trade in coal;

7. Concentrate natural gas on premium users and expand its availability;

8. Steadily expand nuclear generating capacity;

9. Emphasize research and development through international collaborative projects and more intensive national efforts;

10. Establish a favourable investment climate to develop energy resources, with priority for exploration;

11. Plan alternative programmes should conservation and supply goals not be fully attained;

12. Seek appropriate co-operation with non-Member countries and international organisations.

Annex B

Lines of Action for Energy Conservation and Fuel Switching

Adopted by the Governing Board at Ministerial Level
on 9th December 1980

GENERAL

1. Ensure that governments are, and are seen to be, energy efficient in the operation of their own buildings, transportation fleets and other activities, and that other fuels are substituted for oil in government operations wherever possible.

2. Encourage market confidence in new energy conserving equipment and processes, for example by demonstrating the use of such products and technologies and purchasing them for use within government facilities.

3. Give high priority to assessing the results achieved by existing programmes, as a basis for stronger and more effective action.

4. Develop training programmes for skilled labour to expand technical expertise in energy management, and make parallel efforts to stimulate energy management wherever practical, in line with the IEA Energy Management Initiative announced in October 1980.

APPROPRIATE ENERGY PRICING

5. Allow energy prices to reach a level which encourages energy conservation, movement away from oil, and the development of new sources of energy.

INDUSTRIAL SECTOR

6. Actively support industry efforts to increase energy efficiency and fuel substitution, by ensuring an overall economic climate that encourages investment and by working with industry to provide advice and, where necessary, fiscal, financial and legislative means to encourage rapid adoption of modern equipment and technologies. Target setting and monitoring of progress by industry itself or in co-operation with government can lead to a more rapid move towards efficient processes and substitution away from oil.

7. Investigate urgently the potential for the productive use of waste heat and encourage its use by providing incentives or removing institutional barriers. In particular, governments should encourage the development of combined heat and power facilities, by ensuring that satisfactory and reasonable commercial arrangements exist for linking such facilities to existing electricity grids or in the case of surplus heat, to link such facilities to heat distribution networks.

ROAD TRANSPORTATION

8. Carefully assess and, as appropriate, strengthen and extend through the 1980s current policies to improve automobile fuel efficiency. Countries without fuel economy standards should consider their introduction where necessary.

9. Ensure that automobile testing procedures reflect actual road use and continue efforts to examine the possibility of developing tests that will allow the introduction of standards for vans, trucks and energy-intensive recreational vehicles.

10. Review the level and structure of fuel taxes and purchase and road taxes for automobiles with a view to encouraging oil savings and improving fuel efficiency.

11. Ensure that automobile owners are well informed about the financial and energy savings from better maintenance and driving habits. The regulation of maintenance should be considered along with upgrading of automobile mechanics' knowledge of energy-efficient tuning procedures.

12. Introduce stronger measures to encourage and support the use of public transportation systems.

RESIDENTIAL AND COMMERCIAL BUILDINGS

13. Examine the rate of insulation of present homes and commercial buildings as well as the potential for improved efficiency of heating and cooling systems, and, where necessary, stimulate change by regulatory means or by providing incentives. In particular, the training of installers and builders should be upgraded.

14. Encourage solar heating and cooling technologies where they are economic.

15. Consider the introduction of mandatory codes for new buildings which cover all energy use.

16. Examine urgently the particular constraints inhibiting improved energy efficiency in rented accommodation, and develop solutions to these difficulties.

17. Support and encourage the substitution of non-oil fuel, used either directly (including district heating) or converted to electricity, in residential and commercial use wherever infrastructure exists or can be provided.

ELECTRICITY GENERATION AND TRANSMISSION

18. Reduce oil-fired generation as rapidly as economically and technically possible by substituting other fuels so that oil-fired capacity is used primarily to meet middle and peak loads. No new oil-fired plants should be authorised except in particular circumst-

ances where there are no practical alternatives. Particular efforts should be made to facilitate reconversion of oil burning plant to coal or other solid fuels, wherever possible.

19. Examine the potential for reducing transmission losses by upgrading electricity grids.

Annex C

Extract from Conclusions of the Meeting of the IEA Governing Board at Ministerial Level on 9th July 1985 pertaining to Energy Conservation

Ministers adopted the following Conclusions.

I. Conservation

Ministers noted that the IEA have under way a wide-ranging study designed to help governments assess which conservation programmes are likely to be most cost effective. While detailed policy proposals must await the completion of this study, on the basis of the work so far done, Ministers concluded that in order to further reduce the energy intensity of IEA economies, government conservation policies should be actively pursued and should focus on the following types of action which, depending on national circumstances, could assist in achieving greater energy efficiency:

(a) Ensuring that the energy pricing and tariff systems give the right signals to consumers.

(b) Ensuring that information programmes are well directed towards the removal of the obstacles to energy conservation.

(c) Identifying what financial barriers exist, helping to improve access to financial resources and encouraging where appropriate the use of innovative financing schemes by the parties concerned.

(d) Improving the skills of the conservation service industry.

(e) Developing more effective evaluations of their conservation programmes and a better understanding of the factors which influence consumer decisions.

(f) Standards and regulations.

(g) Well designed programmes of research, development and demonstration.

Annex D

Developments in Energy Demand and Energy Efficiency, 1973-1985; Supporting Data and Analyses

This Annex includes the additional data and analyses underlying the summary material included in Chapter III of the study. For an introduction to the basic trends and concepts examined in this Annex, refer to Chapter III. In order to avoid duplication, the Annex contains a number of references to tables or figures contained in the body of the report.

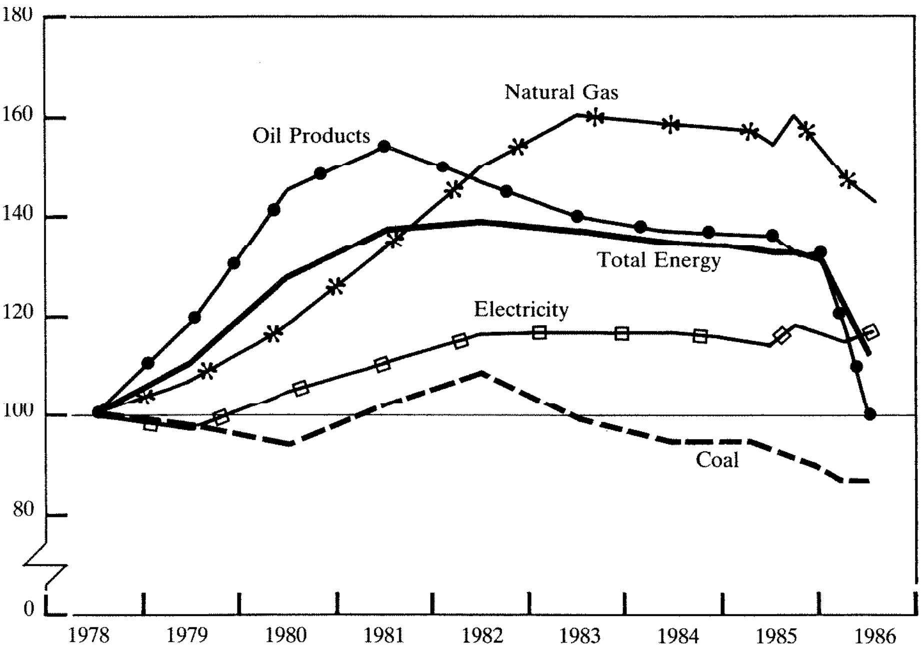
The main purpose of this Annex is to describe recent trends in energy efficiency and how they have affected overall energy demand. One statistical indicator of energy efficiency improvements is the ratio of the energy use to GDP of Member countries, called energy intensity. The energy intensity of IEA Member countries decreased by about 20% from 1973 to 1985. This decrease in energy intensity, however, reflects both efficiency improvements and structural changes in IEA Member countries and therefore is only a rough indicator of the rate of progress toward improved efficiency. For individual countries, structural changes and other factors can have major effects on energy intensity. As a result, while efficiency gains were made in all Member countries over the past ten years, some countries actually increased their energy intensity. Table 1 (see Chapter III) provides a more detailed breakdown of energy intensity levels and trends.

Response to Movements in Energy Prices

One explanation for the change in energy intensity, particularly after 1979, is the change in the relative prices of production factors (labour, capital and energy). As shown in Figure 2 (see Chapter III), energy

Figure D.1

IEA — Indices of Real Energy End-Use Prices
1978 = 100



Source: IEA Energy Prices and Taxation.

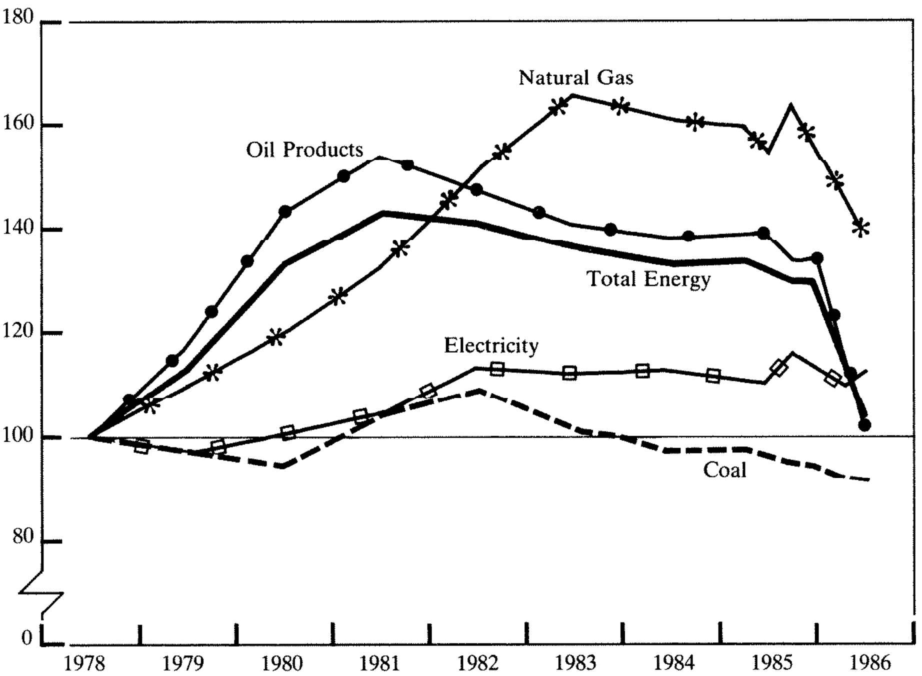
prices increased roughly in line with the prices of other production factors between 1973 and 1978 following the steep rise in the relative price of energy in the 1973-74 period. Absolute energy prices in the total OECD rose by 78% from 1973 to 1978, while the absolute prices of capital (measured by the deflator of fixed capital formation [1]) and labour (measured by unit labour cost) increased by 57% and 53% respectively

1. From a theoretical point of view, cost of capital should be defined in more rigorous ways reflecting the institutional factors (such as depreciation method, and tax rules) and interest rates in the capital market. The fixed investment deflator adopted here is only a rough proxy to the true "user cost of capital".

during the same period. However, after 1979, energy prices rose much faster than in the 1973-78 period in both absolute and relative terms. Energy prices rose by 80% in just four years from 1978 to 1982, while the cost of capital rose by only 36% and that of labour by even less.

Figure D.2

North America — Indices of Real Energy End-Use Prices
1978 = 100



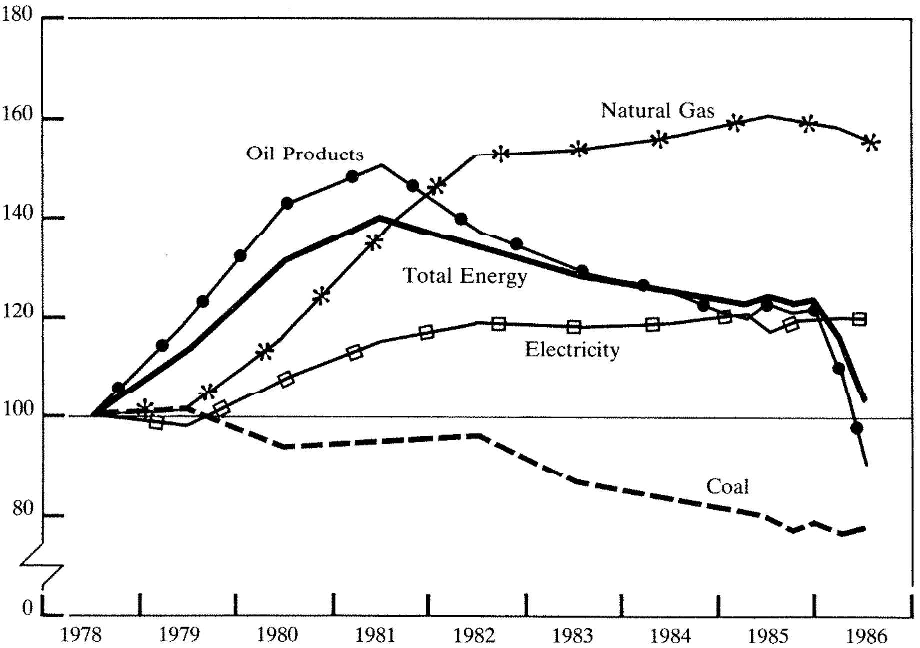
Source: IEA Energy Prices and Taxation.

Figures D.1-D.4 show changes in real prices for the major energy forms for the IEA as a whole and by region for the period 1978-1986. Note that average real end-use energy prices (based on price indices in national currencies) reached their peak in 1982 for IEA as a whole. They remained relatively stable until late 1985 and fell sharply during the first six months of 1986 to approximately the same level that existed in late 1979. Oil and gas prices have been most affected by the recent price decline, while coal has continued its gradual trend toward lower prices and electricity has been virtually unaffected.

Table 2 in Chapter III summarises the results of an IEA Secretariat analysis of the responsiveness of energy demand to increasing energy prices that have been experienced during several periods within the past thirty years. The analysis attempted to exclude the effects of income

Figure D.3

Europe — Indices of Real Energy End-Use Prices
1978 = 100

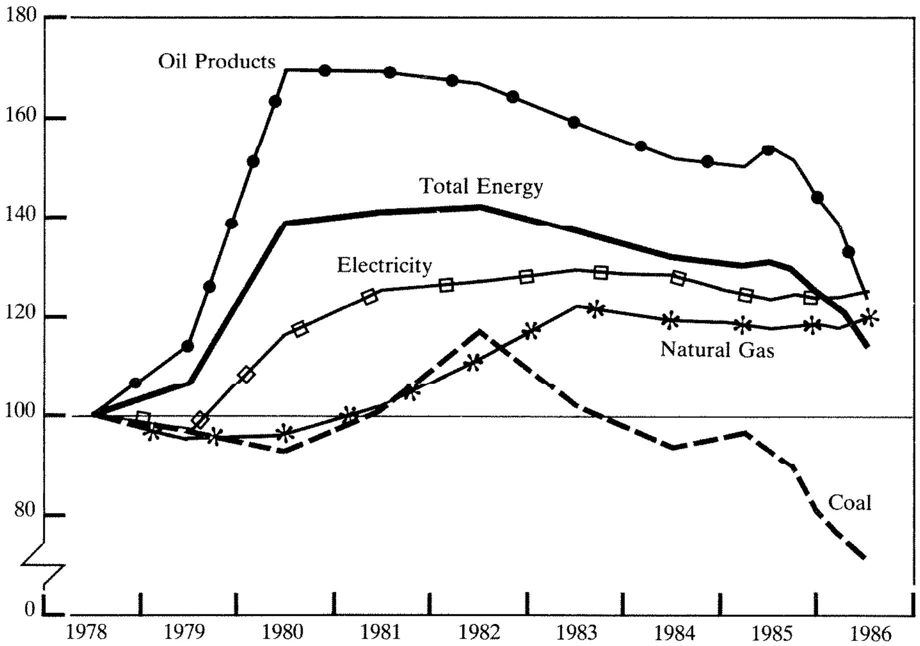


Source: IEA Energy Prices and Taxation.

growth and major structural changes that were not primarily or directly dependent on energy prices. The table indicates that energy demand has apparently responded strongly to rising retail energy prices, especially over the long term (up to ten years), in every sector and region. On average, a 10% increase in end-use energy prices results in about a 5% decrease in demand (an own price elasticity of 0.5) and, as other analyses have shown, most of this reduction is achieved through improved energy efficiency. A similar analysis concluded that energy demand was generally less responsive to declining energy prices; that is, demand generally increased *less* than 5% in response to price decreases of 10%. The analysis was based on data from periods of declining prices for specific fuels which occurred over the past thirty years.

Figure D.4

Pacific — Indices of Real Energy End-Use Prices
1978 = 100



Source: IEA Energy Prices and Taxation.

Table 2 (see Chapter III) also reveals some interesting differences among sectors and regions. While small variances (less than 0.1) are not statistically significant, there are a few regional or sectoral elasticities that appear sufficiently different to warrant comment:

— the average elasticity for industrial fuels appears to be below those for the transportation and residential/commercial sectors. This suggests that industry may be less price elastic than other sectors, even though industry generally appears to be sensitive to energy price changes and the observed reductions in energy intensity have been greatest in this sector. These apparent contradictions have several possible explanations. Industry's lower average price elasticity may be because industrial energy demand is more strongly determined by technological and structural changes that are not directly dependent on energy price movements. Other analyses have indicated that there are long-standing industrial trends towards improved energy efficiency (and reduced energy intensity) and that these trends have continued even during periods of declining energy prices. It is also possible that the many ways in which industry responds to price increases are not fully captured in the elasticity estimate. For example, in response to price increases industry may shift to new products, reduce production, or sponsor research that might lead to major efficiency improvements ten or twenty years later. It is likely that the estimated elasticities do not fully reflect all of these possible responses.

— For the residential/commercial sector, the price elasticity of fuels seems to be highest in the Pacific region, with an insignificant difference between North America and Europe. There might be several different explanations of the difference between the Pacific and the other regions. One possibility is the generally milder climate in the Pacific, which makes larger percentage reductions in climate-dependent energy demand (such as space heating and cooling) easier to achieve in response to price increases.

— For the transportation sector, it appears that Europe has been most responsive to rising energy prices, with North America a close second. It also appears that the European transportation sector is significantly more responsive than the other European end-use sectors. In contrast, the price elasticity of transportation fuels in the Pacific (which is dominated by Japanese demand) is clearly lower than in the other regions and lowest among its other end-use sectors. These various differences are less easily explained. They may reflect the differing effects of economic growth on the transportation sector and the major differences in transportation patterns among the three regions.

Table D.1 shows the ratio of percent changes in energy intensity in terms of GDP to percent changes in real energy prices. The table provides a different perspective on the relationship between energy prices and

Table D.1: **Real Energy Prices and Energy Intensity** (Cumulative percentage change)

	Changes in Real Energy Prices[1]			Changes in Energy Intensity[2]			Ratio of Intensity Changes to Price Changes		
	1973-78	1978-82	1973-82	1973-78	1978-82	1973-82	1973-78	1978-82	1973-82
Residential/ Commercial[3]									
United States	57.7	40.6	121.7	-10.7	-11.4	-20.8	-0.18	-0.28	-0.17
Japan	10.1	69.8	86.9	- 8.3	-19.2	-25.9	-0.82	-0.28	-0.30
Germany	14.0	23.5	40.9	- 5.7	- 4.0	- 9.4	-0.41	-0.17	-0.23
France	47.1	64.3	141.6	-17.5	-18.2	-32.5	-0.37	-0.28	-0.23
United Kingdom	36.7	28.2	75.4	- 3.4	- 2.2	- 5.5	-0.09	-0.08	-0.07
Italy	59.2	67.4	166.4	- 5.4	-12.8	-17.5	-0.09	-0.19	-0.11
Canada	4.6	78.9	87.2	- 8.8	- 9.0	-17.0	-1.90	-0.11	-0.20
Total OECD	43.6	46.2	109.9	-12.9	-14.1	-25.2	-0.30	-0.31	-0.23
Industry[4]									
United States	96.8	42.1	179.6	-17.4	-23.4	-36.8	-0.18	-0.56	-0.20
Japan	39.9	44.8	102.6	-27.4	-16.3	-39.2	-0.69	-0.36	-0.38
Germany	56.0	32.0	106.0	-24.2	-24.3	-43.0	-0.43	-0.78	-0.41
France	73.5	65.9	187.9	-12.7	-23.7	-33.4	-0.17	-0.36	-0.18
United Kingdom	92.6	36.3	162.5	- 1.6	- 7.9	- 9.3	-0.02	-0.22	-0.06
Italy	52.2	80.6	174.9	-20.6	-22.5	-38.5	-0.39	-0.28	-0.22
Canada	70.3	77.7	202.7	-22.4	-29.5	-45.3	-0.32	-0.38	-0.22
Total OECD	79.8	49.9	169.5	-21.1	-24.9	-40.7	-0.26	-0.50	-0.24
Transportation									
United States	9.9	32.8	45.9	- 0.01	-18.5	-18.6	0	-0.57	-0.41
Japan	0.9	24.3	25.5	3.0	- 7.0	- 4.1	3.22	-0.29	-0.16
Germany	3.0	34.5	38.5	- 1.4	- 2.3	- 4.2	-0.46	-0.08	-0.11
France	22.9	8.9	33.9	- 1.2	- 2.1	- 3.2	-0.05	-0.23	-0.10
United Kingdom	9.5	40.7	54.2	- 1.0	-16.1	-17.0	-0.11	-0.40	-0.31
Italy	37.6	8.4	49.2	0.5	1.3	1.8	0.01	0.15	0.04
Canada	-4.3	34.9	29.2	- 6.5	-23.5	-28.5	1.52	-0.68	-0.98
Total OECD	9.5	30.8	43.3	- 3.7	-18.3	-21.4	-0.39	-0.59	-0.49

1. Change in end-use prices.
2. Change in the index of final energy demand divided by the change in the index of real GDP.
3. Includes public and agricultural use.
4. Includes non-energy use.

Source: IEA, Energy Price Data and Energy Balances of OECD Countries.

intensity. It clearly indicates that industry has experienced the largest percentage increases in energy prices and achieved the largest reductions in energy intensity.

Table D.1 also indicates the comparatively small increases in end-use transportation prices since 1973 and radical differences in the rates of change in transportation energy intensity among the countries for which data are provided. The very substantial reduction in energy intensity in the United States, United Kingdom and Canada compares to virtually no change in Japan and Germany, among others. These trends are discussed in more detail in the transportation section below.

Analysis of End-Use Sectors

While the efficiency of energy use has increased substantially since 1973 in almost all sectors, the rate of change in efficiency, as well as in the other factors affecting energy demand differs greatly from one sector to another. Table D.2 provides energy demand data for all end-use sectors for selected years from 1973 to 1985. The following sections review the trends in energy demand and efficiency for each end-use sector, and the transformation sector.

Industry

Industry remains the most energy consuming end-use sector in the IEA even though between 1973 and 1985 industry's share of total final energy consumption (TFC) dropped from 41% to 38% while TFC decreased by 9% to 951 Mtoe [1] (see Table D.2). This decrease has primarily taken place since the second major oil price increase in 1979-80. The decline in consumption has largely been at the expense of oil which decreased 20% or 87 Mtoe for the IEA countries as a whole, the share of oil in industrial energy consumption dropping from 42% in 1973 to 37% in 1985. Only electricity use increased between 1973 and 1985 in absolute terms.

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1. Including non-energy use.

Table D.2

IEA Total Final Energy Consumption by Sector[1]

	1973		1979		1983		1985		Average Annual % Change		
	Mtoe	Share of Total (%)	Mtoe	Share of Total (%)	Mtoe	Share of Total (%)	Mtoe	Share of Total (%)	1973-79	1979-83	1983-85
TFC											
Total	2 502.9	100.0	2 692.0	100.0	2 388.4	100.0	2 507.9	100.0	1.2	-2.9	2.5
Oil	1 434.2	57.3	1 537.4	57.1	1 269.6	53.2	1 305.6	52.1	1.2	-4.7	1.4
Solid Fuels	300.5	12.0	285.6	10.6	265.2	11.1	289.2	11.5	- .8	-1.8	4.4
Gas	479.3	19.2	508.6	18.9	474.9	19.9	501.8	20.0	1.0	-1.7	2.8
Electricity	288.9	11.5	354.6	13.2	371.1	15.5	403.6	16.1	3.5	1.1	4.3
Industry[2]											
Total	1 045.8	100.0	1 061.4	100.0	860.0	100.0	950.6	100.0	.2	-5.1	5.1
Oil	434.4	41.5	461.5	43.5	311.6	36.2	347.2	36.5	1.0	-9.4	5.6
Solid Fuels	230.1	22.0	215.6	20.3	197.5	23.0	219.2	23.1	-1.1	-2.2	5.3
Gas	244.2	23.4	222.1	20.9	196.6	22.9	215.9	22.7	-1.6	-3.0	4.8
Electricity	137.1	13.1	161.5	15.2	154.0	17.9	167.9	17.7	2.8	-1.2	4.4
Transport											
Total	641.3	100.0	748.2	100.0	717.6	100.0	730.5	100.0	2.6	-1.0	.9
Oil	635.5	99.1	743.0	99.3	712.3	99.3	724.9	99.2	2.6	-1.0	.9
Resi/Comm.[3]											
Total	815.8	100.0	882.5	100.0	810.8	100.0	826.8	100.0	1.3	-2.1	1.0
Oil	364.2	44.6	332.8	37.7	245.7	30.3	233.5	28.2	-1.5	-7.3	-2.5
Solid Fuels	68.5	8.4	69.6	7.9	67.4	8.3	69.7	8.4	.3	- .8	1.7
Gas	234.9	28.8	286.1	32.4	277.9	34.3	285.5	34.5	3.3	- .7	1.4
Electricity	148.1	18.2	188.7	21.4	212.6	26.2	230.7	27.9	4.1	3.0	4.2

1. Shares may not add up to 100% because direct consumption of heat is not shown.
2. Includes non-energy use.
3. Includes public and agricultural use.

Source: Energy Balances of OECD Countries.

i) *Changes in Energy Intensities*

Industrial energy consumption declined on average by 0.8% per year between 1973 and 1985; and industrial output of IEA Member countries increased at an annual rate of about 2%. This resulted in an overall reduction of industrial energy intensity (the ratio of industrial energy use to value added) of about 28%. The development of industrial energy intensities for Member countries of the IEA is shown in Table D.3.

For all IEA industry, the decreases in energy intensity were markedly different between 1973-79 and 1979-84. Whereas overall energy intensity decreased at a rate of about 1.7% per year between 1973 and 1979, the annual decrease in the period 1979 to 1984 was about three times higher (about 5% per year). According to preliminary data, energy intensities increased in 1985. This can be attributed primarily to the differences in the rate of growth of energy prices during these two periods, but may also reflect necessary delays in the response of industry to the initial oil price increases of 1973-74. This accelerated trend can be found in most IEA Member countries, with a few exceptions. On a country-by-country basis, Japan had by far the steepest decline, followed by Luxembourg, Belgium, Denmark and Germany. It should be noted, however, that due to different starting levels in 1973 and variations of industrial structure, the possibilities for relative changes of energy intensities were quite different in the various countries. Countries which were still in the process of industrialisation (Greece, New Zealand and Portugal), as well as several other countries (Ireland, Netherlands and Norway) actually increased their intensities.

The trend of decreasing energy intensities did not start in 1973, but has been occurring in the industry of most IEA Member countries for more than thirty years. For manufacturing industry in all OECD Member countries it has been estimated that in the period 1960-73 energy intensity decreased each year at a rate of about two-thirds of the rate experienced between 1973-79. The decline in the 1960s was partly due to substitution of oil for coal.

Besides increasing energy efficiency, the major cause of decreasing industrial energy intensity is structural change in the types of industrial products. Since 1973, structural changes primarily involved shifts away from energy-intensive industries to less energy-intensive industries, but another major shift was from the industrial to the service sector. In

Table D.3: **Energy Intensity in Industry** (Energy Consumption[1]/Value Added[2] Ratio)

Country	Ratio[3] 1973	1979	1984	1985[4]	Average Annual % Change 1973-84	1973-79	1979-84	Average Annual % Change Based on National Currencies 1973-85[4]
Australia	0.51[6]	0.55	0.51	0.51	0.1	1.2	-1.4	—
Austria	0.24	0.22	0.21	0.21	-1.3	-1.1	-1.4	-1.3
Belgium	0.45	0.38	0.32	0.30	-3.1	-2.8	-3.5	-2.6
Canada[7]	0.74	0.68	0.70	0.70	-0.5	-1.5	0.8	-0.5
Denmark	0.21	0.22	0.15	0.16	-2.9	0.7	-7.0	-3.0
Germany	0.25	0.20	0.18	0.18	-3.0	-3.8	-2.0	-3.0
Greece	0.35	0.39	0.40	0.37	1.3	2.0	0.4	1.2
Ireland	0.31	0.32	0.34	0.35	0.9	0.7	1.2	1.1
Italy	0.32	0.27	0.24	0.23	-2.7	-2.7	-2.7	-2.7
Japan	0.35	0.30	0.21	0.16	-4.4	-2.3	-6.8	-4.7
Luxembourg	1.70	1.42	1.05	1.0	-4.2	-2.9	-5.8	-4.1
Netherlands	0.32	0.38	0.34	0.37	0.6	3.1	-2.3	0.9
New Zealand	0.32	0.35	0.40	0.40	2.0	1.3	2.8	2.3
Norway	0.52	0.50	0.55	0.48	0.5	-0.4	1.6	0.6
Portugal	0.34	0.38	0.38	0.45	1.1	1.8	0.3	1.6
Spain	0.31	0.28	0.23	0.27	-2.6	-1.9	-3.3	-2.4
Sweden	0.38	0.37	0.30	0.29	-2.1	-0.7	-3.7	-1.9
Switzerland	0.11	0.10	0.10	0.08	-0.7	-1.0	-0.3	-0.9
Turkey	0.41	0.42	0.37	0.43	-0.7	0.4	-2.0	-0.5
United Kingdom	0.33	0.30	0.24	0.24	-2.9	-1.6	-4.5	-3.0
United States	0.61	0.57	0.46	0.43	-2.4	-1.2	-3.9	-2.4
IEA Total	0.42	0.38	0.29	0.30	-3.2	-1.7	-5.0	—

1. Final energy consumption excluding non-energy use and feedstocks.
2. Value added of manufacturing, construction and mining/quarrying industry but excluding coal/oil/gas production; calculated based on industrial shares of GDP.
3. Expressed in toe per thousand 1980 United States Dollars.
4. Preliminary data; therefore change rates until 1985 not yet calculated.
5. Average annual intensity changes based on the industrial value added on a 1980 National Currency basis. This is another proxy for absolute energy intensity which is designed to eliminate the distortions resulting from exchange rate fluctuations compared to the U.S. dollar.
6. Because of a break in time series of energy consumption, feedstock levels for 1974 had to be used.
7. Canadian data under revision (including about 6.9 Mtoe consumption in 1973, which is not yet accounted for in the OECD data base).

Sources: Energy Balances of OECD Countries;
OECD - National Accounts.

addition, the product mix within industrial branches has shifted towards products with a higher value added ("intra-industrial"). Due to limited data quality, this factor's influence often cannot be separately identified.

The rate of structural change also accelerated after 1979, similarly to the rates of overall intensity changes. From 1973 to 1983, the iron and steel, textiles, wood and non-metallic minerals industries all grew more slowly than overall industry, whereas chemicals, pulp and paper, food, metal products, telecommunications and engineering all grew more rapidly. Even though chemicals, as well as pulp and paper, are energy-intensive industries, a net trend towards less energy-intensive industries took place due to the dominating decrease of iron and steel. As a result of the economic recession, this structural shift was more pronounced in the period from 1979-83 — a cyclical effect which has been partially offset with the economic upturn in 1984. When assessing individual country developments, another factor to be considered is that energy-intensive industries (e.g. aluminium) sometimes shifted their production to countries with large, low-cost energy resources (e.g. Canada, Australia), thereby affecting industrial energy intensity trends in those countries.

ii) *Efficiency Improvements*

Secretariat analysis for the six major European IEA countries indicates that energy efficiency improvements within single industries have been the most important contributor to the decline in total industry's energy consumption in the 1973-83 period. The rates of efficiency gains during the period 1979-83 were also comparatively higher than the previous six-year period 1973-79. These improvements are particularly important against the background of decreasing industrial investment between 1979 and 1982 which adversely affected industrial energy efficiency. The dominant factor behind the decline in overall industrial energy consumption was the acceleration of energy efficiency improvements, a consequence of much higher energy prices and other market-related factors, but probably also of government conservation programmes (see Chapter VIII). These results are in line with some studies on a national level. For example, a Swedish study [1] showed that, apart from lower production growth in the period 1974-83, efficiency improvements contributed to almost 60% of lower final energy consumption (structural effects to slightly more than 40%). For Germany, it was found for the

1. Source: National Energy Administration, Stockholm.

period 1979-83 that, apart from changes in the level of industrial activity, genuine efficiency gains were twice as high as effects of inter-sectoral structural changes [1]. These conclusions were recently reenforced by an independent study, the results of which are summarised in Table 3 (see Chapter III).

Table D.4 summarises the results that have been achieved in Japan according to an analysis done by the Ministry of International Trade and Industry (MITI) for the period 1979-85 in the manufacturing and mining industry. The table indicates that efficiency gains were the most important factor.

In the United States, industrial energy use (including conversion losses) in 1983 was down 456 Mtoe from 1960-1972 energy use trends; that is, if pre-1972 energy intensities had prevailed, industrial energy consumption would have been 456 Mtoe higher in 1983 than it actually was. Of this total decline, a 25% reduction in industrial output (relative to pre-1972 trends) accounted for about 250 Mtoe and a 31.6% reduction in energy use intensity (also relative to pre-1972 trends) accounted for 206 Mtoe. Improved equipment efficiency accounted for about 70% of the latter, while structural changes accounted for approximately 30%. It should be noted that due to the different treatment (inclusion of conversion losses, extrapolation of previous trend), the growth term is much larger than in Table D.4 and the analysis on Europe.

Improvements in industrial energy efficiency have been achieved by several means (which were depicted generally in Figure 1; see Chapter III):

— *Integrated conservation investments,* which were part of general technological progress in industrial processes and equipment, probably made the single largest contribution to improved energy efficiency. In such cases, improved energy efficiency is an integral part of general plant and equipment investments.

— *Operational* improvements ranging from sophisticated control systems, to better maintenance ("housekeeping") had a major effect on industrial efficiency during this period.

— *Discrete conservation investments* intended primarily to improve energy efficiency were another major contributor. Such invest-

1. Source: ISI - Fraunhofer Institute, Karlsruhe.

ments (in heat recovery equipment, etc.) or other modifications to existing facilities were especially evident after 1979.

A method widely used by industry to achieve efficiency gains during this period was the institution of integrated energy management programmes. A central feature of such programmes has usually been the designation of a senior manager with a broad range of energy-related responsibilities, including the operation and maintenance of energy-using systems, the identification and evaluation of major efficiency investments and decisions on fuel choice. There has been a general trend toward the establishment of such energy management programmes in large, energy-intensive industries over the past ten years. This trend has been accelerated in several countries through both voluntary programmes, such as the current U.K. efforts and mandatory requirements, such as the Japanese requirement that industries whose energy consumption is over a fixed threshold must appoint energy managers.

Two other factors have had important influences on industrial efficiency, especially in certain industries or during particular periods.

— Short-term changes in production levels, as a result of fluctuations in economic activity, have affected industrial efficiency. These effects differ, however, depending on the industry and facilities

Table D.4

Determinants of Japanese Industrial Energy Consumption in the Period 1979-85[1]

(Mtoe)

	79-80	80-81	81-82	82-83	83-84	84-85	Period 1979-85
Total change in energy consumption	-10.1	-13.8	-9.8	+ 5.3	+ 7.2	+ 0.5	-20.7
by factor:							
Change in production level	+ 0.2	+ 1.0	-2.6	+10.4	+14.9	+ 4.6	+28.5
Change in industrial structure	- 7.4	- 4.8	-2.1	- 1.7	- 4.1	- 3.5	-23.6
Change in energy efficiency coefficient (energy consumption/unit of output)	- 2.9	-10.0	-5.1	- 3.4	- 3.6	- 0.6	-25.6

1. All data are based on Japanese Fiscal Years, 1st April to 31st March.

Source: Ministry of International Trade and Industry, Tokyo. Because of the high quality of the Japanese data base, individual factors add up to total changes.

involved. Reduced production levels usually result in the closing of less efficient facilities. In some cases, however, low capacity utilisation can introduce inefficiencies not usually present. Similarly, very high capacity utilisation during an economic upswing can reduce efficiency because less efficient production capacity is utilised. Some recent data suggest that, on balance, rapid increases in overall economic activity tend to slow overall industrial energy efficiency gains, but that steady growth results in more rapid efficiency improvements.

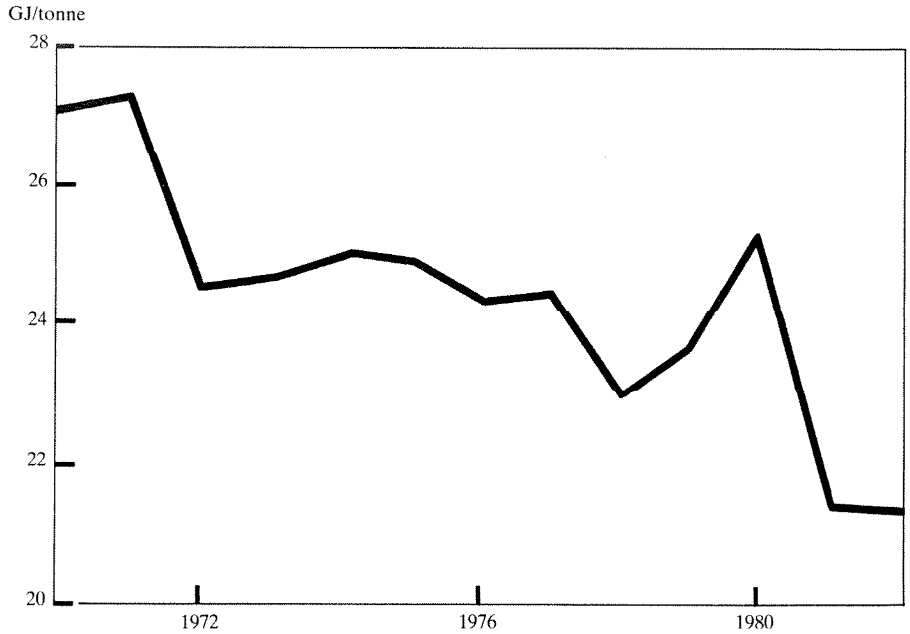
— Energy or fuel substitution has also affected industrial energy efficiency. Switching from oil or gas to coal, for example, usually reduces overall efficiency levels (often caused by increased deposits on heat transfer surfaces), but also reduces total energy costs. The trend toward greater industrial use of electricity has increased industrial energy efficiency in terms of TFC. Electricity has often permitted the adoption of radically different, economically more productive and sometimes more energy-efficient industrial processes — especially when energy costs are concerned. If, however, the primary energy required to generate the electricity is considered, overall efficiency may decrease.

For better indicators of the actual efficiency improvement realised in the industrial sector, data on individual industries or industrial products must be examined. The following figures list several different examples of industrial efficiency improvements. In every case, substantial progress was made since 1972-73 — a reflection of both long-term trends towards improved productivity, as well as more vigorous conservation efforts.

On a product-specific level, Japan for example improved energy efficiencies of selected energy-intensive industrial products in the period 1979/85 compared to 1973 as shown in Figure 3 (see Chapter III). In particular, Japanese steel producers adopted energy-efficient continuous casting processes in close to 90% of its plants, compared to about 40% in the United States and the Netherlands, about half in the United Kingdom and only close to 30% in Australia. One of the reasons for the lack of improvement in the Japanese aluminium industry may be the large production decreases that occurred in this industry over the past ten years. As a result of this decline there were no major investments in new production facilities. But despite the lack of improvement, the Japanese industry is still among the most efficient of IEA producers.

In the United Kingdom, specific energy consumption for the production of crude steel decreased between 1970 and 1981 as shown in Figure D.5.

Figure D.5



Source: Energy Use and Energy Efficiency in the U.K.Manufacturing Industry up to the Year 2000. Energy Efficiency Office, 1984, London.

Residential/Commercial Sector [1]

The residential/commercial sector is complex to analyse because it comprises several unrelated subsectors which have been grouped together for convenience — from home heating to farming. Figure D.6 shows the change in the energy use of the different subsectors since 1973. The residential subsector represented over half of the total consumption for the sector in 1984.

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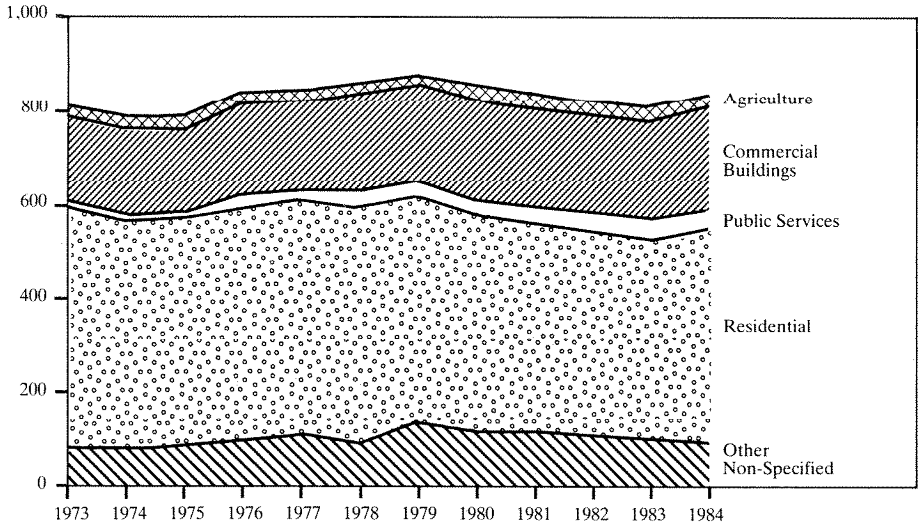
1. This sector includes residential, commercial, agriculture, public and "non-specified" subsectors.

As for all end-use sectors, there is no statistical indicator of total energy efficiency improvements. In addition, because of the structure of the sector there is no single indicator of energy intensity which adequately describes the changes for the entire sector. Population data are the most readily available although for some subsectors (e.g. agriculture) per capita energy consumption is not a suitable measure of energy intensity.

Figure D.6

IEA Residential/Commercial Sector Energy Consumption by Subsector from 1973 to 1984
(in Mtoe)



Source: Energy Balances of OECD Countries.

For the IEA as a whole, per capita energy use in the sector increased by 2.5% between 1973 and 1979, declined by about 12% between 1979 and 1984, and increased by 2.1% from 1984 to 1985. In Europe and the Pacific, energy intensity increased about 10% between 1973 and 1979. After 1979, European energy intensity decreased about 15% through 1983, then increased again during both 1984 and 1985. For the Pacific region, residential/commercial energy use per capita experienced both annual increases and decreases from 1979 to 1985, but on average there was no change. In North America, energy intensity fell during both periods although the fall was more pronounced from 1979 to 1985. These differences in the rate of change in intensity can be attributed largely to regional differences in the rate of growth of the penetration of major space conditioning equipment and appliances.

(a) *Residential Subsector*

In the residential subsector, energy use per capita decreased continuously in most IEA Member countries from 1973 to 1983, but increased slightly from 1983 to 1985 (Table D.5). Increased energy prices and government policies and programmes have influenced behavioural changes and consumer investments which have resulted in major energy efficiency improvements. Changing demographic patterns and lifestyles have also introduced major structural changes to the residential sector over the past twelve years. Increasing penetration of central heating and major energy-using appliances have boosted residential energy use. Similarly, the creation of smaller, but more numerous households, with more space per capita, has also increased energy demand.

A United States 1984 study estimated that behaviour modification accounted for around 45% of energy savings in the period 1973-77, while between 1977 and 1982 this proportion had fallen to 30% [1]. In the period 1973-77, only around 15% of total conservation savings were derived from investments to technical improvements in energy use, but for the period 1977-82 this figure had grown to 40%. This reinforces a more general conclusion that behavioural or operational changes are the first conservation actions to be taken in response to rising energy prices, but that such actions tend to have diminishing importance over the long term.

One study published in 1985 covering eight [2] IEA Member countries and France found significant structural changes in the residential subsector in the period 1972-82 [3], including an increase in the living area per household, an even larger decrease in the number of people per dwelling, a notable increase in the penetration of central heating in those countries of the eight with low levels (except Japan), and the continued growth in the stock of electrical appliances. The study calculated that these structural changes would, in isolation, have increased energy use per dwelling between 1972 and 1982 by about 10-15% in North America, Denmark and Sweden, 15-20% in Norway, the United Kingdom and Germany and more than 20% in Japan and Italy. In most countries,

1. U.S. Department of Energy, *A Retrospective Analysis of Energy Use and Conservation Trends: 1972-1982,* Washington, D.C., February 1984.
2. The eight are: Canada, Denmark, Germany, Italy, Japan, Norway, Sweden and the United States.
3. Schipper, Ketoff and Kahane, "Explaining Residential Energy Use by International Bottom-Up Comparisons", *Annual Review of Energy* 1985. 10:341-405.

Table D.5

IEA Final Energy Consumption, Residential Subsector[1]

(toe per capita)

	1973	1979	1983	1985	Average Annual % Change 1973-79	1979-83	1983-85[2]
Canada	1.08	1.10	0.96	1.00	0.2	- 3.3	2.4
United States	1.31	1.12	0.98	0.94	-2.6	- 3.3	-2.2
NORTH AMERICA	1.29	1.12	0.98	0.94	-2.4	- 3.3	-1.8
Australia	0.33	0.35	0.40	0.40	0.6	3.9	-1.2
Japan	0.16	0.23	0.24	0.25	6.4	0.4	2.4
New Zealand	0.30	0.34	0.36	0.45	2.2	1.3	11.5
PACIFIC	0.18	0.25	0.26	0.27	5.2	1.1	2.1
Austria	0.85	0.93	0.80	0.90	1.7	- 3.7	5.9
Belgium	1.14	1.04	0.79	0.91	-1.5	- 6.8	7.8
Denmark	1.41	1.21	0.82	1.09	-2.6	- 9.2	15.6
Germany	1.04	0.71	0.54	0.81	-6.1	6.8	22.4
Greece	0.17	0.22	0.21	0.23	4.0	- 0.7	4.4
Ireland	0.61	0.60	0.58	0.57	-0.3	- 0.7	-1.4
Italy	0.24	0.17	0.10	0.11	-5.4	-12.2	2.3
Luxembourg	1.35	1.30	1.02	1.22	-0.6	- 5.8	9.0
Netherlands	0.99	1.03	0.84	0.83	0.6	- 4.9	-0.6
Norway	0.74	0.80	0.78	0.89	1.2	- 0.6	7.2
Portugal	0.09	0.09	0.12	0.12	0.0	5.5	1.2
Spain	0.13	0.15	0.14	0.15	2.6	- 1.0	2.7
Sweden	1.51	1.27	0.89	1.13	-2.9	- 8.3	12.7
Switzerland	1.18	1.10	0.81	0.85	-1.1	- 7.4	2.4
Turkey	0.26	0.27	0.28	0.29	0.2	0.8	2.9
United Kingdom	0.60	0.67	0.63	0.68	1.8	- 1.5	3.6
IEA EUROPE	0.59	0.52	0.43	0.50	-2.3	- 4.8	8.6
IEA TOTAL	0.76	0.68	0.59	0.61	-1.9	- 3.4	2.2

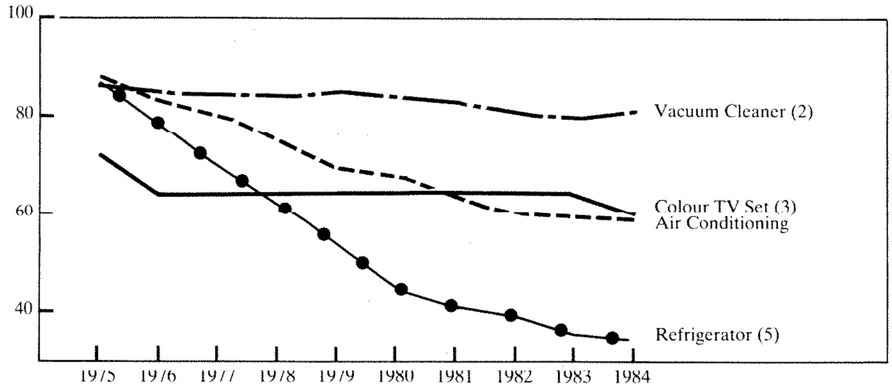
1. Changes in the definitions of the residential and commercial sectors made between 1973 and 1979 mean that the percentage reductions for the 1973-79 period are sometimes overstated.
2. 1985 data are preliminary. The large annual changes observed, especially from 1983 to 1985, may be partially the result of changes in weather conditions.

Source: Energy Balances of OECD Countries;
OECD — National Accounts.

Figure D.7

Efficiency Improvements of New Electric Household Appliances

a) Japan (Index: 1973 = 100) ¹

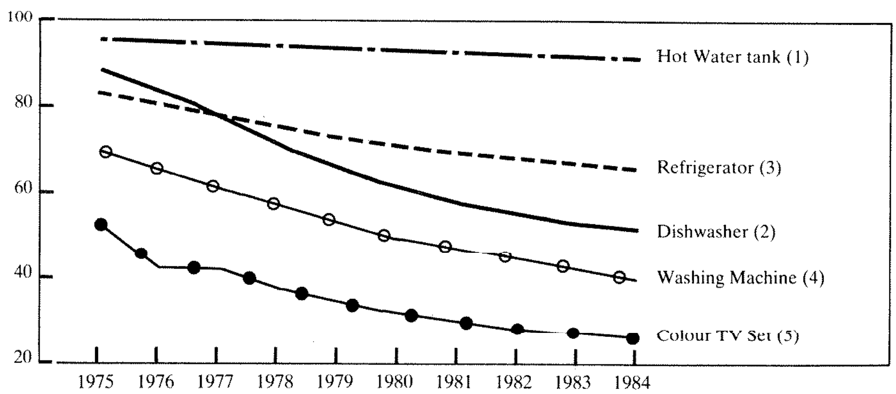


Specific Electric Power in 1973

(1) All figures by Japanese fiscal years which is 1st April to 31st March.
(2) 628 W.
(3) 148 W — 19.2 inch type.
(4) 847 W — 1 600 kcal/h class.
(5) 79.6 kWh/month — 170 litre type.

Source: "Energy Conservation in Japan", The Energy Conservation Center, Tokyo

b) Germany (Index: 1970 = 100)



Specific Electricity Consumption in 1970.

(1) 1.14 kWh/kWh of hot water.
(2) 2.7 kWh/cycle.
(3) 1.2 +/- 0.5 kWh/100 litre and day.
(4) 0.8 kWh/kg of clothes washed.
(5) Big screen

Source: Prof. Schäefer, Technical University of Munich, Germany however, energy use per dwelling did not grow this quickly because of large improvements in energy efficiency which offset the effects of the structural changes in housing characteristics.

As an example, Figure 4 (see Chapter III) shows efficiency improvements in specific useful energy for space heat in the period 1970-82.

Another example, Figure D.7 shows efficiency improvements of electric household appliances in Japan and Germany compared to the 1973 level.

(b) *Commercial, Agriculture and Public Subsectors*

Neither the IEA nor most of its Member countries keep comprehensive and consistent statistics on final energy demand for these subsectors. Analysis is complicated by their use as a statistical "catch-all", representing an aggregation of energy demand for a variety of dissimilar economic and social activities. The public subsector is rarely defined and can be difficult to distinguish from the commercial subsector, which includes a wide array of activities related to the provision of services [1].

The first comprehensive study of the service sector in seven IEA countries was not done until 1985 [2] largely because of the complexity and lack of end-use data. The study estimated that space heating accounts for 60-65% of total delivered energy consumption in commercial subsector buildings in central Europe and the United States. Only in the United States is air-conditioning significant (at 13%). Lighting accounts for an estimated 9% in Germany and 12% in the United Kingdom and the United States.

Again, there are no good statistical measures of energy efficiency or intensity in this sector. The study uses two types of indicators: per square metre and per employee. Each indicator has elements of both efficiency changes as well as some structural and income changes.

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1. Analysis of the sector is further complicated by the different categorisations used in various IEA countries. For example, Japan reports no energy consumption in the public subsector in 1983 but a very large consumption in the "other (non-specified)" subsector.
2. Lee Schipper, Steve Meyers and Andrea N. Ketoff, "Energy Use in the Service Sector. An International Perspective", *Energy Policy*. Volume 14, No. 3, June 1986, pp.201-218.

The per square metre indicator showed:

	Percentage Change	Period [1]
Denmark	-27	1972-82
Sweden	-17	1972-82
United States	-18	1970-80

(1) Those years were used because they had comparable weather.

Source: Schipper, Meyers, Ketoff, *Energy Use in the Service Sector: An International Perspective,* Lawrence Berkeley Laboratory (19443), June 1985.

See Chapter III for trends in the energy use per employee indicator.

Energy demand in the commercial subsector is being shaped by a number of factors — including the rate of growth of the overall building stock and of particular businesses within the commercial subsector and the energy intensity of each process that occurs in a building. The transfer of residential activity to the service sector, such as increased use of restaurants, hotels and care for the elderly is one cause of increased commercial subsector energy consumption (although there have also been shifts of commercial activities, such as laundry and entertainment, to residences).

Increased energy efficiency in this sector has taken many forms, from technological improvements to building design, materials and equipment to operational changes that improve building maintenance and energy use control.

Transportation Sector

Oil consumption accounts for close to 99% of energy consumption in this sector, and road transport is responsible for 80% of this oil use. Energy efficiency has been improving since 1973. While overall energy use rose between 1973 and 1979, it declined from 1979 to 1982. Since 1983, total transportation demand has gradually increased, but in 1985 it still was below 1979 levels. Although the technical fuel efficiency of passenger cars has improved, better economic conditions act as a stimulus to overall consumption, particularly in certain European countries and by commercial vehicles.

Passenger Cars and Commercial Vehicles

Table D.6 shows the oil consumption in 1973 and 1983 by country for the two major categories of transportation: passenger cars and commercial vehicles. Passenger cars accounted for almost 67% of consumption in the road transport subsector in 1973, and 61% in 1983, while consumption by commercial vehicles increased from 33% to 39%.

Changes in consumption are mainly determined by the number of vehicles in the fleet, the average distance travelled per car, and fuel efficiency. Secretariat analysis based on technical data, estimates and historical trends provides a broad indication of changes in road transport, the largest subsector. Of the 19.6% reduction in consumption per passenger and commercial vehicle observed between 1973 and 1983, 65% was due to efficiency improvements (45% was price induced efficiency changes, 10% other efficiency improvements, and 10% attributable to shifts from gasoline to diesel), and 35% to reduced average distance travelled per vehicle.

Table D.6
IEA Oil Consumption for Road Transport
(Mtoe)

	Passenger Cars			Commercial Vehicles		
	1973	1983	% Change	1973	1983	% Change
Germany	17.2	23.2	34.9	10.7	12.4	15.9
Italy	9.5	10.7	12.6	7.6	11.5	51.3
United Kingdom	15.3	18.2	19.0	8.7	9.1	4.6
Netherlands	3.1	4.4	41.9	2.1	2.9	38.0
Sweden	2.7	3.3	22.2	1.6	1.9	18.8
Spain	4.0	6.3	57.5	3.3	5.1	54.6
Other Central Europe[1]	6.7	8.4	25.4	4.2	5.0	19.0
Other Northern Europe[2]	2.5	2.8	12.0	1.4	1.6	14.3
Other Europe[3]	3.1	6.0	93.6	3.1	5.8	87.1
United States	233.3	221.7	-5.0	108.3	148.4	36.8
Canada	18.7	17.2	-8.0	8.2	9.1	11.0
Japan	18.8	26.2	39.4	9.7	12.0	23.7
Australia	7.8	9.5	21.8	2.7	5.1	88.9
New Zealand	1.4	1.3	-7.0	0.5	0.6	0.2
IEA Total	344.1	359.2	4.4	172.1	230.5	33.9

1. Central Europe: Austria, Switzerland, Belgium, Luxembourg.
2. Northern Europe: Denmark, Norway.
3. Other Europe: Portugal, Greece, Turkey, Ireland.

Source: Secretariat analysis and International Road Federation.

Demographic trends are the most significant determinant, along with gasoline and car prices and disposable income, of passenger car consumption. The average distance travelled per passenger car is dependent upon economic activity, gasoline prices, the number of cars per family, the age of the car, the degree of urbanisation, the level of public transport, and motoring habits.

The economic cycle has an important role in commercial subsector consumption: increasing industrial output increases the total demand for freight transport, which in turn increases demand for commercial road transport. Population density, location of cities, and government expenditure on transport influence energy use among buses and coaches. Unlike passenger cars, there has been an increase in the average distance travelled per commercial vehicle, probably as a result of increased economic activity, which has played a greater role than higher oil prices.

Table D.7

Annual Gasoline Consumption per Passenger Car in IEA Countries

(Litres per Car)

	1973	1979	1985	% Change in litres per Car[1] 1973-85	% Change in Number of Cars 1973-85
North America	3 806.0	3 571.9	2 987.4	-21.5	30.6
Pacific	1 994.4	1 726.0	1 457.7	-26.9	83.7
Europe	1 512.4	1 359.1	1 200.3	-20.6	56.3
IEA Total	2 866.7	2 594.2	2 151.8	-24.9	44.8

1. For statistical reasons this figure includes gasoline consumption of light commercial vehicles.

Sources: Energy Statistics, IEA; International Road Federation, World Road Statistics, Editions 1977 to 1986; Motor Vehicle Manufacturers' Association of the United States; World Motor Vehicle Data, 1983, 1984 and 1986 Editions.

Average vehicle fuel efficiency in the passenger car subsector has been improving since 1973, which is important since turnover of the car fleet is very rapid (about ten years). Table D.7 shows the changes in annual gasoline consumption per passenger car between 1973 and 1984. For the IEA as a whole, the biggest change occurred since 1979, mainly due to the progress in North America. Voluntary and mandatory standards in nine countries have played a role — substantial improvement has been noted in the United States, Germany, Japan and the United Kingdom in the adoption of technical efficiency improvements in new cars, such as improved engine efficiency and more aerodynamic design. Table 4 (see Chapter III) describes the improvements made in new car fuel economy since 1973. Fuel economy derives from weight, engine power and design and is therefore greatly affected by the size and power of individual cars. There is no single accepted method of defining the technical efficiency of automobiles, which ideally would be independent of car size and power. Overall fleet fuel economy is also dependent on the proportion of urban versus highway driving and consumer driving patterns. There have been improvements in all weight categories, and there are now smaller differences between countries within each category. For commercial vehicles, technological progress in vehicle engine design and aerodynamic rather than fuel prices may be the key to affecting energy demand. Fuel efficiency improvements have been slower because units were already more technically efficient than most passenger cars and they have longer lifetimes. Goods vehicles have shown more improvement than buses, and also the relative use of diesel versus petrol has been responsible for different results across IEA countries.

Maritime, Aviation and Railway Subsectors

The maritime, aviation and railway subsectors are all very dependent on petroleum products for energy. (Only in Europe are electric railways widespread.) Together they accounted for 17.4% of oil consumption in the sector in 1973, and only 17.1% in 1984. Higher fuel prices and other factors have encouraged efforts to improve efficiency in each of these subsectors over the past decade.

Factors contributing to improved efficiency levels in the maritime sector include: a gradual shift from steam turbine ships to motor diesel powered ships; improvements in the design of diesel engines and propellers; and slow steaming. Figure D.8 depicts the trend in maritime energy efficiency as measured by world bunker oil demand divided by laden ton-miles.

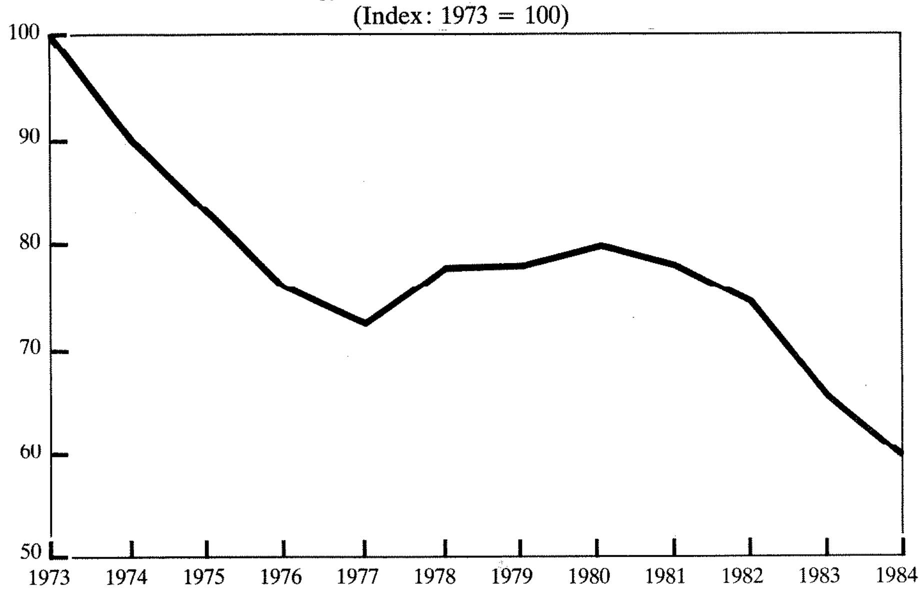
In recent years, new commercial jet aircraft have been introduced which are substantially more energy-efficient that existing commercial jets. Measures taken in the aviation sector to improve energy efficiency in addition to these technological advances include: removing paint to reduce the weight of planes, steeper angle of descent in landing and take-off to reduce air resistance, and lower cruise speeds and better taxiing procedures.

An energy efficiency measure used for the aviation sector is the ratio of fuel consumption to ton-kilometres for both passenger and freight traffic. Figure D.9 shows the trends in this factor since 1973.

Figure D.8

Energy Intensity in World Shipping [1]

(Index: 1973 = 100)



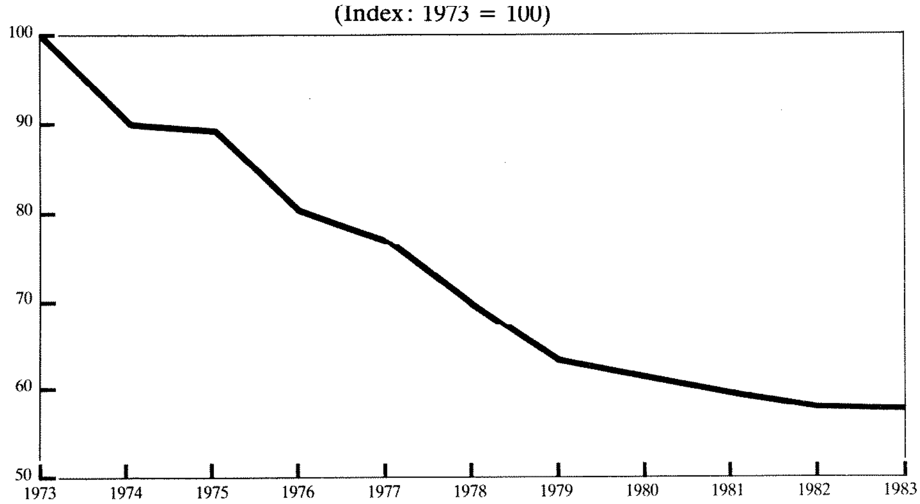
(1) Index based on world bunker oil demand divided by laden ton-miles.

Source: Fearnley's Limited, Norway;
World Energy Statistics Yearbook, United Nations.

Figure D.9

Energy Intensity in Aviation [1]

(Index: 1973 = 100)



(1) Index based on consumption of aviation fuel in OECD countries divided by world total of ton-kilometre flown.

Source: Energy Balances of OECD Countries;
International Civil Aviation Organization, Montreal.

The electrification of railways has been the primary measure used to improve the efficiency of railway transport. However, the ratio of energy consumption to passenger kilometres has not shown any consistent trend. The ratio fluctuates primarily as a result of changes in load factors (i.e. passenger/kilometre transported) and may go up or down depending on the country or period examined.

Figure D.10 shows specific energy consumption and respective efficiency improvements for different means of transport in Germany between 1978 and 1983.

Energy Transformation Sector

The transformation sector encompasses the conversion of primary fuel into more useful energy forms, as well as the distribution of energy to end-users. In the IEA energy balances, the energy demand of the transformation sector is the difference between the input of primary energy (TPER) and the secondary energy forms produced (TFC). It therefore represents exclusively the losses in the conversion processes and in the operations of extraction and distribution of energy. In 1985, this sector was larger than any of the individual end-use sectors. It can be divided into four components:

— losses in central station electricity/heat generation (equivalent to the energy content of the fuels and/or other energy sources used to generate electricity/heat minus the energy content of electricity/heat produced);

— consumption by power plants for their internal use including electricity consumed by pumped storage hydro plants;

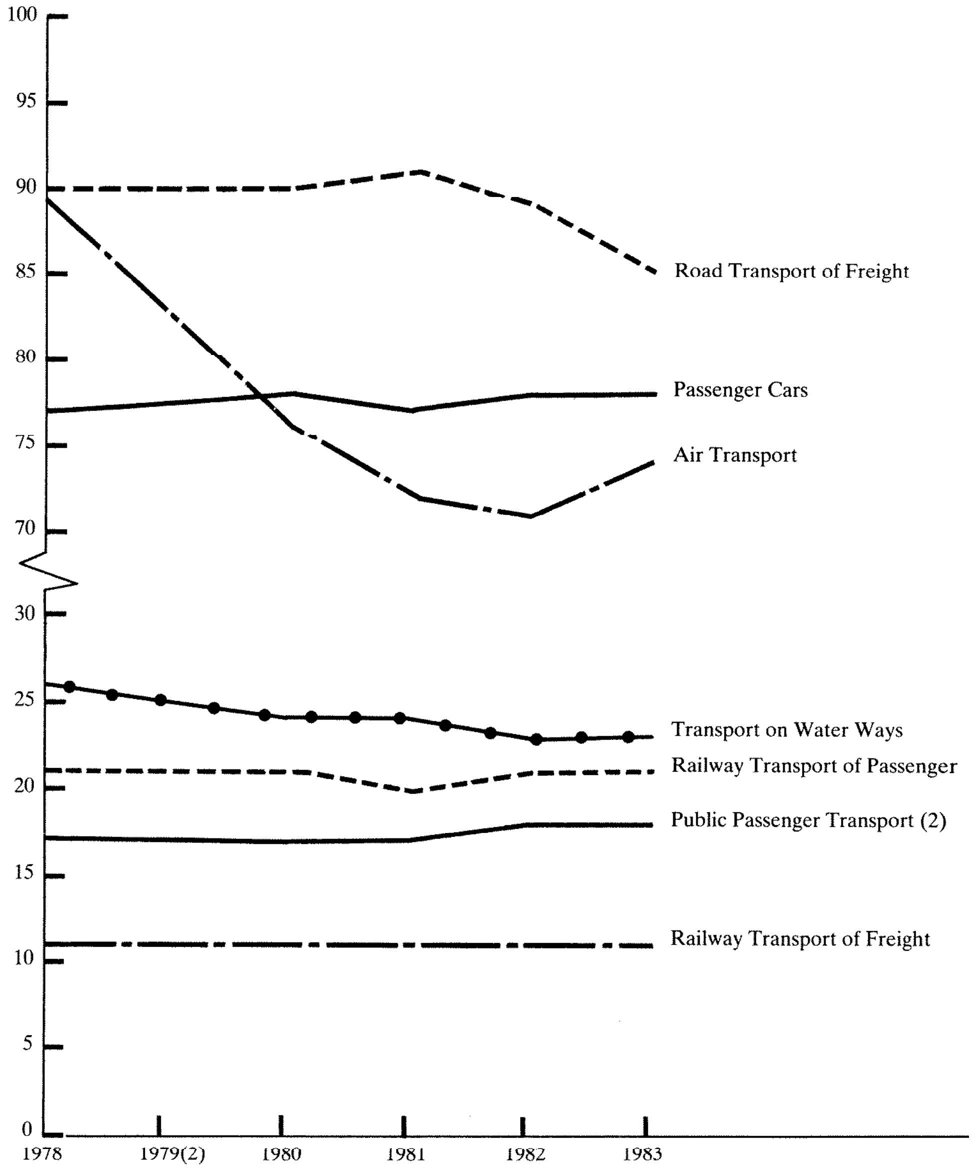
— fuel consumption and losses in petroleum refineries and by other energy sectors such as coal mines, oil and gas extraction;

— distribution losses (electricity grids; oil, gas and district heat pipelines).

The transformation sector is dominated by the electricity sector (close to 80%), with most of the rest accounted for by the energy use and losses in oil refineries. This sector merits attention due to its absolute size and growth rate. Between 1973 and 1985, the transformation sector grew by 19% to slightly above 1 000 Mtoe. While 1985 TFC in all of IEA was about the same as the 1973 level, TPER was 170 Mtoe higher than 1973 due mainly to growing demand for electricity (the generation of which usually results in greater energy losses than direct use of the primary

Figure D.10

Improvement of Specific Energy Consumption of Different Modes
of Transport in Germany between 1978/83
(grams hard coal equivalent per passenger-km or metric ton-km)



(1) No data available for 1979: trend thus extrapolated.
(2) Mainly road transport by buses, etc.

Sources: German Institute for Economic Research (DIW), Berlin.

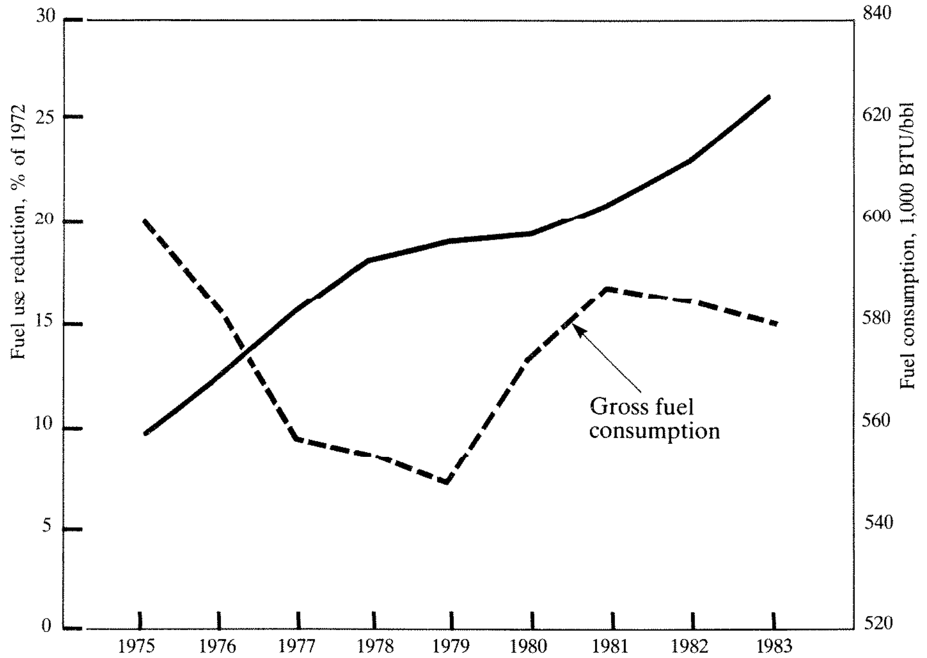
fuels). During that period, electricity's share of TFC increased from 12% to about 16% with total fuel inputs increasing from 930 Mtoe to about 1 250 Mtoe in 1985. The shift to electricity, because of its high end-use efficiency and convenience, has resulted in a shift of energy losses previously experienced in energy end-use to the energy transformation sector.

The total own consumption and losses of oil refineries accounted for 124 Mtoe (or about 7.7% of total refinery input) in 1973 and about 90 Mtoe in 1985 (about 6.4% of refinery input); a 17% reduction over this twelve year period. Refinery fuel use and losses decreased in comparison to overall oil input because of major efficiency improvements and the shutdown of both smaller and less efficient units. These factors outweighed the effects of lower overall utilisation rates of refineries (83% in 1984 compared to 90% in 1973) and the increased proportion of fuel consuming upgrading/cracking units, both of which decrease efficiency. The solid line of Figure D.11 indicates that the United States petroleum refining industry reduced overall energy consumption by 25.7% in 1983 compared to the 1972 level, corrected to account for changes in processing schemes, lead phase-out, reduced feed quality, etc. The dashed line of Figure D.11, which presents actual fuel consumption per barrel of refinery input uncorrected for any changes since 1972, shows that efficiency did, in fact, increase until 1979. It then decreased (probably due to increases in the production of lighter petroleum products compared to total output, decreases in crude oil qualities, and reductions in feed rates). During the 1979-1981 period, continued conservation efforts were not able to offset these effects, but the long trend toward improved efficiency resumed in 1982.

Absolute conversion losses in electricity generation were placed at about 590 Mtoe of TPER in 1973 and about 780 Mtoe in 1985. This increase in "losses" reflects the increasing demand for electricity and not a change in the efficiency of electricity generation. Figure 5 (see Chapter III) shows the development of average efficiency for steam-electric power plants in the United States since 1925. It clearly indicates that generating efficiency has not significantly changed since the 1960s. The transformation sector's own consumption and losses — except refineries — were 146 Mtoe in 1973 and about the same level in 1985. Electricity transmission and distribution losses decreased slightly to about 7% of total final electricity in 1985 (from about 8% in 1974). Own energy use in power plants increased to about 5.5% of total final electricity in 1985 (from 4.6% in 1974) due in particular to more coal-fired plants (coal grinding). Pumped storage plants consumed 0.5% of total final electricity in 1985 (0.4% in 1974). While pumped storage plants do use energy, they increase system-wide efficiency by replacing low efficiency (below 25%) gas turbine power plants normally used to meet peak demand.

Figure D.11

United States Refining Industry Fuel Consumption



Source: Energy Efficiency Improvement Report, API, United States.

To account for the energy losses in hydro and nuclear electricity production in terms of fuel equivalent (that is the theoretical amount of oil necessary to produce the same amount of electricity), some fixed assumptions about the efficiency of these processes are used in the TPER statistics of IEA and most Member countries. Given that hydro actually encounters only insignificant heat losses due to turbine friction and nuclear energy has limited alternative uses [1] the most important

1. In the case of nuclear, real losses of about 125 Mtoe are released into the environment in the form of waste heat. Even so, because of special siting and design concerns, there are few cases where the heat from nuclear plants is used (e.g. in an industrial plant in Switzerland).

opportunities for efficiency improvements are in fossil fuel-fired power stations (440 Mtoe in 1973, about 500 Mtoe in 1985). Most of the energy losses in electricity generation are released as low temperature heat from oil-, coal- and gas-fired thermal power stations. The size of this unused resource has grown because of increased electricity production and the slightly lower efficiency of coal plants compared to gas- or oil-fired electricity generation. Largely in response to the substitution of oil by coal-fired generation, the thermal efficiency of electricity generation decreased by less than 1 percentage point to about 36% in 1985.

One of the existing electricity generating technologies capable of increasing efficiency (by 30-40%) is combined heat and power (CHP), also called cogeneration. In industry, CHP played a major role in the past in most countries, e.g. in the United States where in 1920 about 60% of industrial electricity consumption was autoproduced. In many countries industrial CHP application declined as a result of deteriorating economics (decreasing ratio of electricity to fuel prices and process heat savings) but also structural and tariff reasons. Actual market penetration of these technologies is now very limited, except in a few countries. In 1985 in Europe, heat from CHP systems contributed only about 6 Mtoe to end-use heat demand in industry and the residential/commercial sector. This is about 5% of total final electricity consumption. When heat from district heating (DH) plants is included, about 10 Mtoe were produced. For total IEA, total heat supplied from CHP plants was about 8 Mtoe (about 2% of total electricity consumption). Since the early 1980s in the United States, the Public Utility Regulatory Policies Act (PURPA), which required utilities to offer to purchase excess electricity produced by CHP at marginal prices, and special tax incentives reversed the downward trend and led to a real boom in industrial CHP applications.

Market penetration of CHP/DH technologies is already very high in some northern countries, notably Sweden and Denmark. In Sweden, heat from CHP amounted to about 5% of TFC with DH providing nearly one-half of all the heat required for multi-family dwellings and about 40% of the requirements for non-housing premises in 1985. In Denmark, heat from CHP plants contributed about 17% to the total net heat consumption for space heating and hot tap water of about 4 Mtoe (an additional 26% from pure DH plants) in 1985. In Germany and Austria, DH contributed close to about 2.5% to total TFC in 1985.

Annex E

Selected Studies on Energy Conservation Potential; Data Sources and Supporting Analyses

This annex provides the sources of the data in Tables 5 and 6 contained in Chapter IV (referred to as Tables E.1 and E.2 in this annex) and a brief description of the development and purpose of the tables.

The data presented in Tables E.1 and E.2 do not represent a comprehensive or precise review of the potential for conservation in IEA Member countries. Such an assessment would require the gathering of detailed and current data on end-use technologies in all Member countries, which is far beyond the scope of this study. Although comprehensive assessments of conservation potential are extremely useful in the design of the specific conservation policies and programmes to be undertaken by Member governments, such a detailed assessment was not necessary to address the broader policy issues examined by this study. To fulfil the IEA requirements, a selection of recent technology and sectoral studies of conservation potential were sufficient.

Table E.1 provides an assessment of the economic potential for conservation by major end-use or technology categories. Column (a) indicates the percent of IEA's total primary energy requirements accounted for by the specific energy end-use or technology category for which data are provided. The column is intended to provide a rough indication of the magnitude of the potential savings indicated in columns (c) and (e). The estimates were derived from IEA data on energy end-use, as well as from a variety of other sources. Ranges are provided to indicate that these values do vary over time and by major region; however, they do not reflect the full range of the differences among IEA Member countries. Column (b) contains estimates of the average efficiency of the existing stock of the technology in question. The estimates are usually based on actual surveys of end-use efficiency conducted by Member governments or other organisations, but they sometimes have been derived from data on the efficiency of new products over time. Data on the average efficiency of existing physical stocks are often difficult to obtain but they are essential to a reliable assessment of conservation potential. Column (c) almost always provides data on the average efficiency of new products sold in the most recent period for which data are available. For the industrial sector, however, it contains data on the most efficient existing industrial facility in the category. It is assumed that the most efficient facility approximates the efficiency of the newest plants for the industry in question. The figure in parentheses in column (c) is the percentage reduction of the column (c) efficiency compared to the column (b) efficiency. The data on the Best Available Technology are intended to represent the savings that could be achieved through the application of the most energy-efficient technologies which are proven, commercially available and economically viable. Column (d) provides an estimate of efficiency and column (e) is the percentage reduction of column (d) compared to column (b). Column (f) contains an estimate of the average useful life of the technology and therefore is a rough indicator of the time span required to achieve the full potential savings (indicated in column (e)). Column (g) provides the reference numbers for the sources listed in the annex, as well as other relevant information. Finally, it sould be noted that the technology categories and the percentage savings indicated in columns (c) and (e) sometimes overlap. For example, the estimates of potential savings in all electric homes in the United States and Sweden include estimates of potential savings for electric appliances, although independently derived estimates for certain electric appliances are provided elsewhere. Also, efficiency improvements in electric motors, gas turbines or other cross-cutting technologies would result in energy savings in all sectors. The basic conclusion drawn from Table E.1 is that the average potential for savings (column (e)) is at least 25%.

Table E.2 lists the estimates made by independent studies of the potential energy savings that could result from cost-effective efficiency improvements. Column (a) indicates the end-use sector to which the estimate applies and column (b) the year of the study. Column (c) indicates the potential reduction in energy demand that could be achieved compared to the energy demand levels that would have resulted if no further efficiency improvements were made. For example, such estimates usually include the savings that will result from the gradual replacement of existing appliances and automobiles by the more energy-efficient products that are now being sold. Column (d) lists estimates of the energy demand reductions possible in comparison to the energy demand levels that are expected to result from current trends in product efficiencies and energy prices. For example, these estimates exclude the savings that are already expected because of the production of more energy-efficient appliances and automobiles and they usually exclude the savings that are anticipated to result from the further improvements in product efficiencies which are likely to result from market forces and current government policies. For studies that contain both types of potential estimates, column (d) would usually be lower than column (c) and the difference between the two would approximate the efficiency gains expected to result from market forces and current government policies alone. But this is not true for at least one study, which took into account the effects on potential savings of rising energy prices. All potential estimates are based on existing technologies, although in some cases the technology may not be widely available at present. Column (e) indicates the year in which the savings indicated might be achieved and column (g) provides reference numbers and other relevant notes. The two basic conclusions drawn from Table E.2 are that the average potentials for savings among all sectors and countries are: at least 25% compared to levels that would have been realised if no further efficiency improvements were made (column (c)); and at least 10% compared to levels that would exist in the year 2000 as a result of market forces and current government policies alone (column (d)).

On the whole the data provide convincing support for the general conclusion that a substantial potential for further energy efficiency improvements exists. While the studies examined do have some analytical weaknesses and use different economic and energy price assumptions, they all represent serious analytical efforts to estimate the further potential for energy efficiency improvements. There are, however, two major weaknesses of the data that should be addressed specifically. Because almost all of the studies were performed prior to 1986, they generally did not take into account the dramatic fall in oil prices that has occurred in 1986 nor do they reflect the efficiency improvements that were instituted after the time of each study's completion. The effects of these two weaknesses in the data, however, are considered to be generally quite small for a number of reasons:

- The actual effect on retail energy prices of the large drop in world oil prices has been comparatively small — about 15% on average.
- Most of the potential savings identified were based on conservation investments with comparatively high rates of return. Lower energy prices have reduced these rates of return but generally not affected the basic cost-effectiveness of such investments.
- The tables do not reflect the potential savings from new products and technologies that have been introduced since their completion or the cost reductions achieved in certain existing technologies, such as microprocessor controls.
- Lower interest rates and better economic conditions have improved the attractiveness of conservation investments in several countries.

Table E.1

Energy-Efficient Technologies and the Economic Potential for Conservation

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	Best Available Technology (e) % Savings	(f) Average Useful Life of Technology	(g) Notes
RESIDENTIAL	20-25%						
- U.S. (All electric)		1 501 (Watts per capita)		328	-78%	Over 30 years	(1)
- Sweden (All electric)		1 242 (Watts per capita)		266	-78%		(1)
Heating and Cooling	8-12%						
- Building shell thermal efficiency						Over 30 years	
- U.S. (winter)		160 (KJ per m² per degree day)	100 (-37%)	50	-70%		(1)
- Sweden (winter)		135 (KJ per m² per degree day)	65 (-52%)	35	-74%		(1)
Heating	8-12%						
- Oil/Gas - System Efficiency						10-20 years	
- U.S.		65-70% (% of TPER converted to useful heat)	75-80% (-13%)	84-94%	-23-26%		(2)
Cooling	1-2%						
- Central a/c -						10-20 years	
- U.S.		7 (Energy Efficiency Rating)	9 (-22%)	14	-50%		(3)(4)
Refrigerators/freezers	2%					10-15 years	
- U.S.		1 500 (kWh/year)	1 300 (-13%)	750	-50%		(3)(4)

Table E.1

Energy-Efficient Technologies and the Economic Potential for Conservation *(Continued)*

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	Best Available Technology (e) % Savings	(f) Average Useful Life of Technology	(g) Notes
- Germany		About 400 (kWh/year)	(-20%)		At least -20%		(5)
- Japan		35 (kWh/month)	28 (-20%)		At least -20%		(6)
Water Heating	3-5%					15 years	
- U.S.		4 000 (kWh/yr)	3 600	1 700	-57%		(3)(4)
COMMERCIAL	15-20%						
Heating and Cooling	10-12%					30+ years	
- U.S.		1.31 (GJ per m²/yr)	0.73 (-44%)	0.32	-75%		(1)
- Sweden		1.04	0.76 (-27%)	0.25-0.46	-55-75%		(1)
Large Office Buildings	5%						
- U.S.		270 (KBtu/ft²year)	200 (-26%)	100	-63%	30+ years	(7)
Lighting	3-5%					1-10 years	
- U.S.							
Ballast/Tubes		64 (lumens/Watt)	73 (-12%)	86	(-26%)		(3)(9)
Controls					(-20-30%)		
Total					-40-50%		
TRANSPORTATION	20-25%						
Automobiles	10-13%					10 years	(1)(10)40 mpg may be technically possible at cost of less than $1/ gallon saved.

Table E.1

Energy-Efficient Technologies and the Economic Potential for Conservation *(Continued)*

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	(e) % Savings	(f) Average Useful Life of Technology	(g) Notes
- U.S.		19.0 (miles per gallon)	26.1 (-34%)	31.5	-46%		
- Japan		[11] (km/1)	13 (-15%)				
Other road transport	7-10%						
Air Transport	2-3%	[25] (passenger miles/gallon)	30+ (-20%)	40+	-40%	15-30 years	(1)(11)(18)
- All							
Rail/Marine/Other	2-3%						
INDUSTRY	35-40%						
Chemicals	6-8%						
- U.K. (Inorganic)					-13%		(12)
Iron and Steel	5%						
- U.S./Japan/U.K./Neth.		22-24 (GJ/tonne)	17-18 (-20-25%)	N.A.	At least -20-25%	10-30 years	(13)(14)
Non-ferrous metals	3%						
- OECD (Aluminium)		15-17 (mWh/tonne)	13.5 (-10-20%)	N.A.	At least -10-20%	20-30 years	(8) Technology being developed could reduce consumption 30-40%
Paper	3%						
- U.K. (Paper & Board Making)					-30%		(12)
Stone, Clay and Glass	2%						
- U.S./France/Switz./U.K. (Bricks/Pottery)		2.5 (MJ/kg)	1.5-2.0 (-20-40%)	N.A.	At least -20-40%	10-30 years	(15) 0.5 MJ/kg theoretical minimum

Table E.1

Energy-Efficient Technologies and the Economic Potential for Conservation *(Continued)*

Energy End Use/ Technology	(a) % of IEA TPER	(b) Existing Stock Average Efficiency (Units)	(c) New Stock Average Efficiency (% Savings)	Best Available Technology (d) Efficiency	Best Available Technology (e) % Savings	(f) Average Useful Life of Technology	(g) Notes
- France/U.K./Switz./Germany (Cement)		3.6-3.8 (MJ/kg)	3.3 (-8-13%)	N.A.	At least -8-13%	10-30 years	(15) 1.5 & 3.0 MJ/kg theoretical minimums for dry and wet processes
Food	1%						
Space Heating, Cooling, Water, Heating, Lighting	2-3%						
ALL SECTORS							
Electric Motors	20%	75-90% (% converted to motive power)	80-92% (-2-7%)	85-93%	(-3-12%) (-10-20%) -15-30%	10-20 years	(8)(11) More efficient motors. (16)(17) Variable speed controls Total Potential Electric Motor Savings.
Central and On-Site Electricity Generation	35%						
- U.S. (Gas Turbines)	N.A.	30% (% converted to electricity)	35% (-15%)	39-41%	-25%		(18) Best combined cycle and steam injected gas turbines. Projected 1990 best: 44-48% efficient; total savings: 32-37%.

Table E.2

Sectoral Studies of Conservation Potential

Country	(a) End-Use Sector	(b) Year of Study	(c) Estimated Economic Potential for Demand Reductions %	(d) Remaining Potential After Projected Effects of Market Forces %	(e) Year in which Economic Potential could be Achieved	(f) Notes
United States	Residential/Commercial	1981	-50%		2000	(11)
United States/Texas	Residential/Commercial	1986	-50%		2000	(19) Electricity only
United States	Residential/Commercial	1985	-27%	-17%	2000	(20)
United States	Transportation	1985		-30%	2010	(20)
United States	Industry	1984	-35-40%		2000	(21)
		1985		-18%	2010	(20)
United States	All Sectors	1983		-22%	2000	(22)
Canada	Residential	1986	-33%	-21%	2000	(23)
	Commercial	1986	-22%	-24%	2000	(23)
	Industrial	1986	-15%	-9%	2000	(23)
	Transport	1986	-20%	-18%	2000	(23)
	All	1986	-22%	-17%	2000	(23)
Japan	All	1983	-15%		1990	
		1984	-more than 20%		1995	(6)
United Kingdom	Industry	1984	-21-29%		2000	(12)(24) United Kingdom study estimates that 21-25% efficiency gain is likely to occur 29% estimate based on "technical potential"
Netherlands	Industry	1985	-21%		2000	(25)
	Residential	1985	-21%			
	Commercial	1985	-38%			

Table E.2

Sectoral Studies of Conservation Potential *(Continued)*

Country	(a) End-Use Sector	(b) Year of Study	(c) Estimated Economic Potential for Demand Reductions %	(d) Remaining Potential After Projected Effects of Market Forces %	(e) Year in which Economic Potential could be Achieved	(f) Notes
Austria	Industry	1981	-10%			Heat pumps only
	Residential	1984	-25%			
Norway	Industry	1984		-12%		(26)
	Residential/Commercial	1984		-10%	2010	
Sweden	Residential	1985	-50%		N.A.	(27)
	Commercial	1985	-40%		N.A.	(27)
	Industry	1983		-20-50%	1990	(28)
European Community	Residential/Commercial	1984	-30%		1995	(29)
	Small-/Medium-sized Industry		-10-20%		N.A.	(30)
	Industry	1986	-25%		2000	(31)
Western Europe (EUR-9)	All Sectors	1983		-19%	2000	(22)
	Industry	1985	-30%		2000	(32)

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Annex F

Methodological Issues in Programme Evaluation

> "Programme evaluation is one means of providing relevant, timely and objective findings — information, evidence and conclusions — and recommendations on the performance of government programmes, thereby improving the information base on which decisions are taken. In this view, programme evaluation, as part of this decision-making and management process, should not be seen as an exercise in scientific research aimed at producing definitive 'scientific' conclusions about programmes and their results. Rather it should be seen as input to the complex, interactive process that is government decision-making, with the aim of producing *objective but not necessarily conclusive* evidence on the results of programmes. While credible analysis is always required in programme analysis, a strict research model ... is often inappropriate because of timing constraints and an inability to adequately take into account the multiple information needs of the client and users of the evaluation." [1]

Energy conservation programmes have proven to be difficult to evaluate for effectiveness. There are many reasons for this such as: inadequate data collection, poor programme design, lack of measurable objectives,

1. Treasury Board of Canada, *Guide on the Program Evaluation Function*, Ottawa, 1981, p.4.

the decision to evaluate often not taken until after the programme has been operating, evaluations are costly, time-consuming and complex and evaluations are often not done by an objective party.

There is no single ideal evaluation design since different policy measures require different approaches. Over the years, however, much knowledge has been gained in understanding evaluations. The bibliography includes many references explaining various aspects of evaluation techniques.

There are basic methodological issues which are common to all evaluations. This annex describes some of the major issues and how selected evaluations attempted to resolve them.

Incrementality

Incrementality is defined as the difference between what happened and what would have happened in the absence of a programme. It is common to also use the related expression "free-riders". A free-rider would be the participant in a programme who would have undertaken the activity even in the absence of the programme.

Incremental analysis can consider both the effects on conservation activity and on expenditure; however, both are not always done. It is usually the analysis of the effect on expenditure that is done.

Incremental analysis is an essential component in determining the effectiveness of a programme. Unfortunately, it is not always assessed in evaluations undertaken. Often, the estimates that are available, have not been done in a thorough and rigorous manner.

The following excerpt from the Canadian evaluation of its Ener$ave audit programme describes how they used the concept:

"The two-group design ... is based on a specific concept of incrementality. It identifies the significant factors of the decision process through models applied to the "normal", untreated, or control group. The factors are framed as a decision model. Activities are modelled as the consequences of a wide range of independent, or prior, conditions. The model is a predictive one, to be interpreted as saying:

- these are the important characteristics which are related to predicting activity

— the relationship of these characteristics to activities is defined by the model through the use of multivariate analysis.

"Assuming that the decision structure of the two groups is the same, this model will yield an unbiased estimate of what the program group would have done without the program. The differences, if any, between the predicted, *ceteris paribus,* levels of activity and the actual levels can therefore be attributed to that different characteristic, the treatment of one group with Ener$ave. The basic formula is:

Incrementality = (Actual Activity) - (Predicted Activity)

"The two groups do not need to have identical values on the model characteristics. The use of statistical matching, i.e. the multivariate model, will compensate for the differences. There are two prerequisites: data for both groups exist on all salient characteristics, and an assumption that the same decision structure applies. In terms of statistical reliability (as opposed to unbiasedness or validity), the model's range of variables should be similar for the two groups. Otherwise, the standard error of the predictions will be extremely large.

"This methodology should be clearly distinguished from that used to develop the cross-sectional profile ... . The profile identified the differences between the two groups on a wide range of characteristics; it was a single model whose dependent variable was a binary switch indicating participation in Ener$ave. The incrementality models are quite different. For one thing, they predict conservation activity and expenditures, not Ener$ave participation. But more importantly, they use statistical matching to apply models developed for the control group to the Ener$ave users, to produce predictions of what Ener$avers would have done had they used exactly the same decision structure as non-users. That aspect is not produced by the profile model, but is then used as the input to the incrementality estimate where it is subtracted from actual behaviour to determine the effect of Ener$ave (as the only difference between the relevant decision models of the two groups). The profile model shows differences in characteristics; the incrementality models control those differences to model the decision structure.

"An example may be useful. Let's say the average non-Ener$aver spends $500 on his attic while Ener$avers spend $600. The profile will show that Ener$avers spend more on their attics. But these people have some different characteristics. Perhaps Ener$avers are more likely to have moved into old homes that need more attic insulation. Perhaps Ener$avers are generally more enthusiastic about fixing up houses. The incrementality models ask: "What would similar people who didn't use Ener$ave have spent?" For the sake of argument, let's say people with those characteristics would have spent $700. Since Ener$avers spent $600 where similar non-Ener$avers spent $700, incrementality is $600 - $700 or (-)$100. In this example, Ener$ave users would have spent less than a *comparable,* or statistically matched, group of non-Ener$avers."

Attribution

Many evaluations have found it impossible to separate the effects of individual policies from the effect of other influences, such as energy prices, and structural changes in the economy. There are, however, many who feel that research designs can be developed to "control for or rule out alternative explanations for observed energy savings. Because alternative explanations such as increased fuel prices may account for some of the change in consumption, failure to take them into account will result in savings being incorrectly attributed to the programme. This situation is further complicated by the fact that few mechanisms presently exist for gathering information on energy consumption, and all factors that may influence energy use, in a direct, manageable and inexpensive manner" [1].

In a Swedish study of the effects of the energy economy programme, to determine attribution:

1. They removed a number of changes which *cannot* have been affected by the policy instruments.
2. They also tried to note other factors which may have affected the changes.
3. The econometric studies allowed a third kind of analysis to describe the effects. In these analyses, an imagined undirected development is described, based on assumptions about various economic parameters, primarily elasticity of price and incomes.
4. The resulting differences — negative or positive — between actual and hypothetical developments can thus be ascribed to government policy.

(1) Jon Soderstrom, "Measuring Energy Savings", *Energy Policy,* March 1984, p.104.

In work undertaken at the Oak Ridge National Laboratory on measuring the energy savings of U.S. Department of Energy conservation programmes, the following comment was made regarding the State Energy Conservation Programme (SECP) and its estimated saving due to thermal efficiency standards (which accounted for about 66% of the estimated savings):

> "...The standard algorithm for estimating savings is a function of the annual square footage of new building construction multiplied by an estimate of energy saved per square foot, times the number of years the thermal efficiency code has been in effect. Separate estimates are made for each of nine building types and summed for a total savings estimate."
>
> "Recent work suggests that this algorithm may attribute too much of the estimated savings to the SECP. Critical examination of each component of this algorithm reveals a number of flaws which could contribute to an overestimate of savings. For example, building construction rates were based on 1973 data, producing estimated rates considerably higher than are actually occurring. Further, this algorithm ignores the influence of factors other than the code. These other factors include code-compliance rates, the effect of local codes, construction lag time, and changes in the price of energy. Thus, there is some doubt about how much energy savings should be attributed to the SECP, and the actual savings could be less than reported in the evaluation" [1].

The evaluation of the impact of the Belgian information campaign also appreciated the complexity of separating the effects [2]. Because the impact study was not started at the same time as the actual information campaign, it was difficult to establish a proper control and thus impossible to accurately distinguish between the effects of the campaign and other effects. They undertook an approach of sampling two groups of households that used gas, one group of which had used the government's information brochures. These groups were surveyed and then the data was analysed using multidimensional regression analysis to evaluate the relative importance of each cause.

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1. Ibid, p.105.
2. Institut Interuniversitaire de Sondage d'Opinion Publique, *Mesure de l'impact de la campagne d'information en faveur des économies d'énergie,* Brussels.

Cost-Effectiveness

Most evaluations have made some attempts to determine cost-effectiveness. For some it has simply been to take the difference between the gross energy savings and the government (and sometimes only departmental) costs without controlling for incrementality. Although there are many methods, it is useful here to describe the methodology used for the evaluation of the Canadian Home Insulation Programme:

> "The evaluation attempted, through sophisticated modelling, to estimate both the incremental number of insulation activities and the dollar value of incremental spending on insulation among CHIP users that could be attributed to CHIP. These incrementality estimates were then used in a cost-benefit analysis. Over the 20-year life of the insulation, the present value of energy savings of 28.1 PJ per year (from all CHIP activities) is $2 100 million at a 7% discount rate. Subtracting $833 million (estimated total spending on CHIP) leaves $1 267 million as net economic benefit [1]. As an estimated 75% of CHIP-related investment was incremental, it follows that $950 million is the incremental net economic benefit. (At a 10% discount rate, the incremental net benefit would be $652 million.)"
>
> "These calculations assume that the incrementality was permanent, as the benefits from the incremental actions were measured for the full 20 years. However, the methods used in the evaluation were able only to determine what proportion of activities was incremental during 1977-82; they could not distinguish activities that might have occurred later and were simply accelerated by CHIP. To the extent that some CHIP users would have eventually acted without CHIP, the analysis overestimates the benefits."
>
> "A sensitivity analysis was performed to demonstrate the impact of various assumptions about accelerations (see Table)."
>
> "Even if CHIP only accelerated the insulation activity by four years, the benefits are still worthwhile. Probably closer to reality is the assumption that half the incrementality was permanent and half was accelerated by four years. This gives a net benefit from the

1. These figures are assumed to be 1980 dollars, as the mid-point of CHIP activity; they are based on reference cost price estimates of the various heating fuels.

programme for 1977-82 of almost $600 million (for comparison, the net cost to the government was $409 million). This analysis excludes any indirect benefits, for example, increased activity by *non*-CHIP participants as a result of publicity about the programme and increased awareness of energy conservation possibilities."

Table. Cost-Benefits under different acceleration assumptions. (Discount rate of 7% is used and where acceleration is noted, assumes this would be by four years on average.)

Assumption	Total Incremental	Total Benefits	Net Benefits	Net Benefits/ $1 Grant
1. Incremental CHIP activity is all acceleration	150	380	230	0.56
2. Incremental CHIP activity is 50% acceleration and 50% additional	390	980	590	1.44
3. Incremental CHIP activity	625	1 575	950	2.32

"The high benefit-cost ratio is based both on the relatively high incrementality of the programme and on the high cost-effectiveness of the individual actions taken. From the point of view of the individual home owner and average CHIP participant, an expenditure of $643 ($173 + grant) achieved a saving of about 14% (21 GJ per year) from 1.9 CHIP-eligible insulation activities, plus an additional 2.5% from air-tightening. This is $44 per GJ of annual reduction in energy use, well under the threshold levels for cost-effectiveness cited elsewhere in this report; it is equivalent to a levelized price of energy of $2.93 per GJ at a 7% discount rate (equivalent to about 1¢ per kWh). Individual activities were thus highly cost-effective, on average."

Annex G

Excerpts from IEA Energy Technology Policy Study on Conservation Technologies (pp.74—81)

Table G.1 provides an overview of the main areas of energy-efficiency technology, indicating their potential application and current status, and suggesting measures for encouraging policy decisions to accelerate change. It should be noted that microelectronic sensor and control systems have an important role in many of these individual technologies, as well as in complete systems such as an electricity distribution system, where their deployment in conjunction with more effective storage systems could revolutionise electricity demand management. The total systems approach should be emphasized; the energy efficiency and economic performance of the total system should be considered before specific end-use measures are determined. Another important idea might be to improve communication between and among sectors and consumers, as there are many cases where deployment in the market is delayed by lack of information.

Examples of technologies considered important to pursue are the following:

— *Transportation sector:* Use of liquid fuels will be inescapable as far into the future as can be foreseen, and the development of energy-efficient automobiles will play an important role in determining requirements. More efficient (e.g. ceramic) engines, which promise to halve fuel consumption, may significantly alter the gasoline supply/demand situation. Electric cars are a possibility whose advent could limit the demand for liquid fuels, but present planning should not anticipate their early success, which is

Table G.1

Overview of the Main Energy-Efficient Technologies

	Energy Savings Potential	Timescale for Significant Commercial Applications	International Variations	Impediments to Commercial Applications	Principal Policy Options
Internal Combustion Engines	Large, entirely oil-savings	10-15 years, allowing for introduction of new designs and rotation of car stock	United States, Japan, Germany, Italy, United Kingdom and Sweden, the main IEA automobile manufacturers	Car industry highly competitive. Main impediments would be if petrol prices fell sharply and were expected to stay low in medium term	Government standards for higher miles per gallon (probably combined with environmental standards); direct intervention to stimulate search for radically new automobile designs
Electric Battery Vehicles	Entirely oil-savings	Economic now for some delivery vehicles. 15-25 years for light vans and shorter distance car journey	"	Efficiency of battery which limits payload distance between charges. High costs per vehicle due to small market. Increasing efficiency of petrol and diesel vehicles	Continuing effort to improve battery efficiency. Public sector procurement for organisations with large fleets of light vans
Heat Pumps	Oil and electricity saving, but attractive only in certain countries and regions	Technology available today. 10-15 years where competitive with alternative fuels	Most competitive where - requirements for heating and cooling - air is space-heating medium (ground water, where available is more competitive) - gas and district heat not available	High initial cost Alternative heating fuels	Provision of subsidy for heat pump investment. Support for heat pump R&D especially to reduce capital cost

Table G.1

Overview of the Main Energy-Efficient Technologies *(Continued)*

	Energy Savings Potential	Timescale for Significant Commercial Applications	International Variations	Impediments to Commercial Applications	Principal Policy Options
Electronic Controls	Large, all sectors; all types of fuel. May improve competitiveness of electricity	Economic now	Smaller and less advanced IEA countries lack strong electronics industries	Lack of consumer awareness and cashflow constraints on investment	Information and advisory services. Assistance for demonstration schemes. Low-interest loans
Process Heat	Oil, gas and coal in industry	Waste heat recovery often economic now	Applicable especially where concentration of heavy industries	Often difficult to sell recovered waste heat (matching loads required close by). Lack of consumer awareness and cashflow constraint	"
Water Heat	Oil, gas and coal mainly in industrial and commercial boilers	Improved boiler designs and controls currently economic		Slow rotation of capital stock, but improved controls and insulation can be fitted to existing boilers and systems	Information and Advisory services. Assistance for demonstration schemes. Low-interest loans
Combined Heat and Power/ District Heating	Primary energy for electricity generation, oil for domestic heating	Economic now in some situations	Viability depends on (a) lack of competition from natural gas, and (b) favourable political and administrative structures	Surpluses and shortages tend to coincide with those on electricity grids. Obtaining a "fair price" from electric utilities. Availability of sites and connections with grid.	Reserve existing power station sites in favourable locations for potential future CHP use. Ensure utilities do not discriminate through unfair pricing for buying and selling. Assistance for demonstration schemes. Low-interest loans.

Table G.1
Overview of the Main Energy-Efficient Technologies *(Continued)*

	Energy Savings Potential	Timescale for Significant Commercial Applications	International Variations	Impediments to Commercial Applications	Principal Policy Options
Urban Waste	Local and minor, except in large conurbations	"		Organisation of refuse collection and of electricity supply industry	"
Building Design	Mainly domestic and commercial buildings	After 2000	Climatic variations and local building materials and design traditions affect what is feasible and economic	Slow rotation of building stock	Higher standards for design and construction and insulation

contingent upon the development of high-charge-density, multiple-charge/recharge, lightweight batteries. Research into battery storage is therefore imperative for widespread use of electric cars to be possible by the turn of the century.

— *Industrial sector:* Energy-efficient production systems, especially in energy-intensive industries such as steel, aluminium and other basic materials, will be decisive factors in determining demand in this sector. Total energy management systems in factories, including the recycling of waste heat, are being developed by the more competition-minded enterprises, but widespread use of these techniques could have a major overall impact. Technologies permitting the recycling of energy-intensive products could be important to pursue.

— *Residential and commercial sectors:* Reductions in energy demand must be achieved either by retrofitting existing buildings or, more efficiently, by building new stock. The technologies to be concentrated on include insulation, heating or cooling systems such as district heating, and/or heat pumps. The development of total energy management systems is essential to efficient energy use in large commercial and institutional buildings. Measurement technologies, among which micro-electronics will have a crucial role, will be a major direction for RD&D.

Energy conversion is an area which requires continued emphasis. In conventional power plants with steam turbines, about two-thirds of the input energy is lost in conversion. Investment in RD&D to increase conversion efficiency is essential, and deployment of more efficient electricity generating technology, even by small percentages, might have great impact on the entire system. For example, use of combined cycles (the combination of gas turbines and steam turbines) provides higher efficiency in producing electricity, with input sources such as low-calorific gasified coal, high-temperature gas-cooled reactors and/or pressurised fluidised bed combustors. Similarly, co-generation systems need to be further developed to utilise high-grade energy for electricity production and low-grade heat for industrial or district heating applications.

Magneto-hydrodynamics (MHD) is one of the technologies being developed for the direct conversion of high-temperature gas-flow energy. Its engineering feasibility has not yet been fully demonstrated and any future commercial application would have to be considered long term. Fuel cells also offer other possibilities for converting energy directly to electricity without requiring the intermediate formation of heat. Experiments have shown that they are highly efficient when compared with conventional technology. The major R&D obstacles seem to be the difficulties of scale-up and low cost effectiveness, but they have the advantage over MHD in that the technological basis is better established.

Principal Findings

- Potential for energy saving technology application is still considered large although priority areas will vary from country to country.
- Raising energy efficiency can be less costly than equivalent expansion of energy production and is an area where environmental benefits may reinforce energy benefits.
- Diffusion of technology already developed is of overriding importance.
- Measurement and control technologies are likely to make a significant contribution to further technical achievements in energy saving.
- Better understanding of end use is essential for determining where R&D is most needed, as well as the development of analytical technologies.
- Total systems approach should be adopted to assist the choice of R&D and other non-technical measures.
- Non-technical promotional initiatives such as fiscal policies, standards and information dissemination are likely to be as important as RD&D itself.
- Efficient direct energy conversion systems require continued RD&D.

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