CONTENTS ENVELOPE 5021

TENEMENT: Not Related.

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Energy Efficiency

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SUMMARY

- Whereas conventional oil is expected to plateau within the next twenty-five years, unconventional oil and other, non-oil alternatives will increasingly have to supply the incremental demand. Against these alternatives, energy conservation appears an "alternative" in its own right, being "indigenous", "safe" and "clean".

- The potential for improved energy efficiency is significant: existing technology - being economic against today's energy prices - could reduce energy consumption by some 30% in W. Europe.

- The capital investment per unit of energy saved of conservation measures looks very high versus those of new supplies. However, proper discounting of this capital investment over a reasonable economic life time shows that many important conservation options have a lower unit cost than today's world energy prices.

- One of the main reasons that energy conservation has not so far made a larger impact lies in the short pay back time that most private consumers demand from a cost saving measure.

- The possibility of lengthening the consumer's time horizon offers opportunities for both governments and business to develop the "invisible resource" of energy conservation to a greater extent.

I. INTRODUCTION

As a finite resource, conventional crude oil, which currently provides over half of the world's primary energy supply, cannot indefinitely meet growing demand. Current estimates for recoverable reserves imply that conventional oil production will "plateau" within the next 25 years. The estimated maximum production level may be some 20-40% higher than the present level, and could be maintained for perhaps 20-30 years before beginning to fall off. This implies, however, that incremental energy demand will increasingly have to be met from alternative sources in the not-too-distant future.

This in itself, is no direct reason for concern, since history is full of substitution of one resource by another as the price differential moved in favour of a new supply source.

However, alternative energy sources share some important characteristics - each to a greater or lesser extent - when compared with conventional oil:

- higher investment costs
- longer lead times to develop
- greater environmental impact in terms of visibility, waste disposal and perceived safety risks - hence problems of siting
- uncertainty as to when the anticipated need for them might actually materialise
- growing uncertainty as to the climate for private investments.

Against this background an increase in the efficiency of energy use would make good common sense.

Thus, "Energy Conservation" is increasingly being seen as an "alternative" in its own right, which could prove attractive against many new supply options, with the added bonus of being "indigenous", "safe" and "clean".

The body of this report will first consider the following questions:

- how can one save energy?
- is energy conservation worth considering?
- is it "economic"?

The answer to the last two questions appears to be positive. The next point thus follows logically:

- why, then, is energy conservation so slow in taking off?

An analysis of this question then points to some interesting opportunities for both business and governments to develop the benefits of this "invisible energy source" to a greater extent than is currently apparently being done.

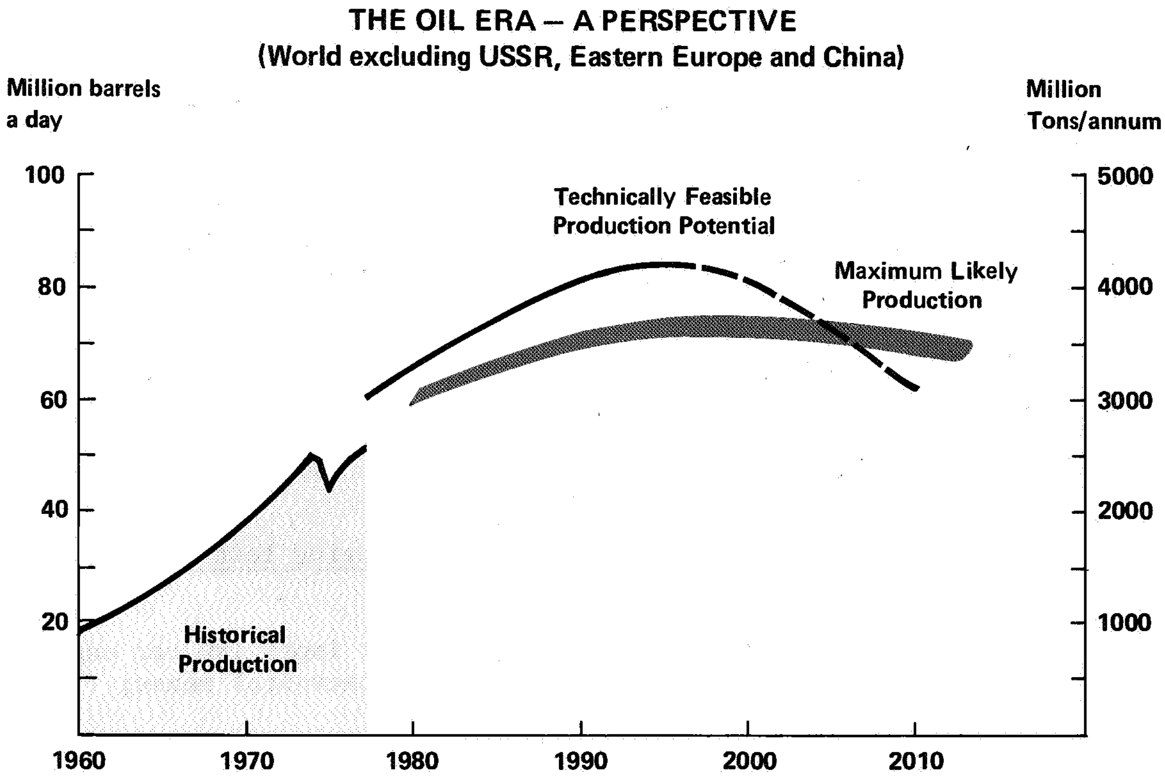

Fig. 1
Estimates of the total amount of ultimately recoverable conventional oil indicate that production will have to plateau within the next 25 years. The maximum acceptable production by country, reflecting resource constraints and producer strategies, will probably be lower than the "maximum technical potential". Oil demand will have to stay within this limit, leaving other options to provide the increment.

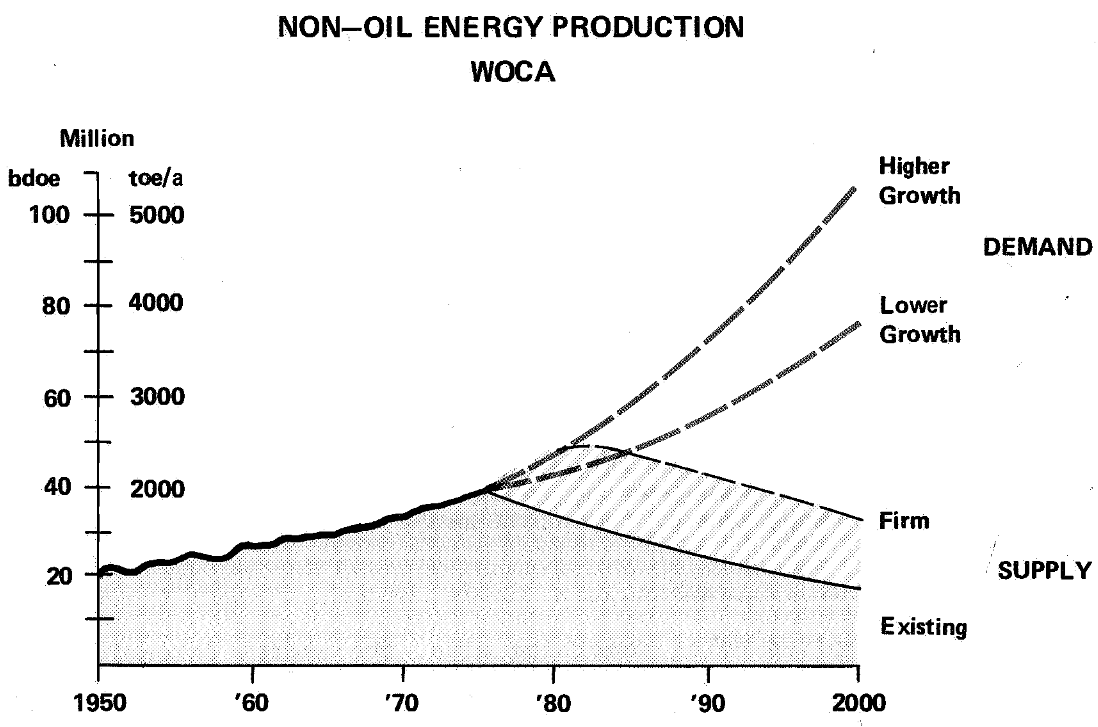

Fig. 2
Because of the excepted plateauing of conventional crude oil, other, non-oil energy forms will have increasingly to provide the increment. Much of this "alternative supply" is substantially more expensive than conventional oil and many effective conservation measures are competitive against the perceived cost of these alternatives.

II WAYS OF CONSERVING ENERGY

Simply stated, there are three ways of conserving energy:

(1) by not doing things*

For example: not going on holiday by car, or not heating one's house.

(2) by doing things but reducing the quality

For example: going on holiday in a smaller car, at a lower speed, with two families sharing one car; heating one's house to a lower temperature.

(3) by doing things as before (or better), but using less energy through improved efficiency

The so-called "technical fix" - for example: improving car engine performance, reducing friction and drag by technical means; insulating one's house.

This distinction allows some important observations:

- (1) and (2) do not require capital investment, and can therefore be implemented quickly in case of national emergency. However, they depend on voluntary austerity or compulsive measures regulating and directly affecting people's daily lives. Neither can be expected to be widely acceptable over a long period of time in which disposable income continues to grow. Major changes in lifestyle are long term affairs, which are very difficult to induce or to steer.

- (3) has a lasting effect but requires capital investment, not only by those who are accustomed to making and evaluating investments (the industrial, commercial and public sectors), but also by the ordinary citizen who has his own set of priorities and criteria.

To many people, energy conservation is associated with (1) and (2) and consequently is not really wanted. The word "conservation" often suggests austerity, belt tightening and reduction in quality of goods and services. Thus, while publicly professing that conservation is "good", most people tend to leave the conserving to others. It is important, therefore, to recognize the potential of (3), specifically where this option - once implemented and integrated into the production process - does not have to rely on continuous austerity and exhortation. It is therefore on this third option: improving the efficiency of energy use by technical means, that this report will mainly focus.

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* this generally implies doing something else, the energy intensity of which is not necessarily lower. Also a national strategy of "making chips rather than ships" will not necessarily conserve energy worldwide.

Since virtually every activity in an industrialised society requires energy, theoretically many options exist for improving energy efficiency. In practice the choices are rather more limited, but still a very large number of conservation measures are already available "off the shelf". It is important to recognise that energy efficiency has generally been improving for many years, and "energy conservation" means in fact just "more efficiency improvements". A very important general rule is that the form of energy chosen should be properly matched with the task required. Also, that any measure should never be considered in isolation but always in the broader context of primary energy, and also against the other factors: labour, capital and raw materials. These various aspects, together with a discussion of the definition of "efficiency", are covered in Appendix A. A discussion of some of the more important conservation options is given in Appendix D, of which the "Quick Guide to Energy Conservation" on page 21 gives a concise summary.

III THE POTENTIAL OF ENERGY CONSERVATION

The next question to be answered is: "Is improved energy efficiency sufficiently significant to be worth mentioning?" In order to give some idea of its potential, Fig. 3 shows a hypothetical case: the amount of total primary energy that would have been consumed in Western Europe in 1975 if all energy consuming stock were of a standard of efficiency justified by the post 1974 energy prices,* as compared with the actual consumption. The difference in volume is in the order of 5 Groningen gas fields or 11 Brent oil fields saved.

This example illustrates four important points:

(a) - the technical potential of improved efficiency is significant as compared with new supply options.

(b) - most of today's stock of energy consuming equipment is certainly not of an efficiency standard justified against today's prices, and this existing infrastructure will not vanish overnight. Thus although some retrofitting is economically attractive and hence justifiable, the bulk of improved efficiency must be expected from new, more efficient equipment. Since it is generally uneconomic to scrap existing equipment simply for the sake of energy conservation, the future rate of growth and hence turnover of equipment will have a very profound influence on the actual potential of improved efficiency that can be realised.**

(c) - potential and prospects must be analysed by sector of energy use, since purpose of use, economic criteria and technical potential differ markedly between the various end uses. (See Appendix C.)

(d) - the effect of energy conservation measures is difficult to measure and even more difficult to demonstrate in actual practice.

Detailed discussions on the definition of potential, the difference between maximum technical and economic potential, and estimates by sector, are contained in the Appendices A to E.

For the purpose of our argument, Fig. 3 may suffice to illustrate that the potential of improved energy efficiency does indeed warrant it to be taken seriously.

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* Using known technology as discussed in Appendix D and being economic against the "reasonable economic lifetime" as defined in Chapter IV. This estimate was composed from a sectoral analysis covering the four main European energy consuming countries.

** All measures listed in Appendix D under the heading "attractive" have a high pay-back in energy terms: that is, the energy content of a measure is very small compared with the amount of energy that it saves during its economic lifetime. In contrast, the energy content of the energy-using equipment itself (car, house and so on) is generally not negligible compared with the energy it uses. Replacing equipment just for the sake of improving energy efficiency is therefore almost always unattractive.

A HYPOTHETICAL ILLUSTRATION OF THE POTENTIAL OF IMPROVED ENERGY EFFICIENCY

Western Europe 1975
Primary Energy (Excl. Non-Energy Uses)

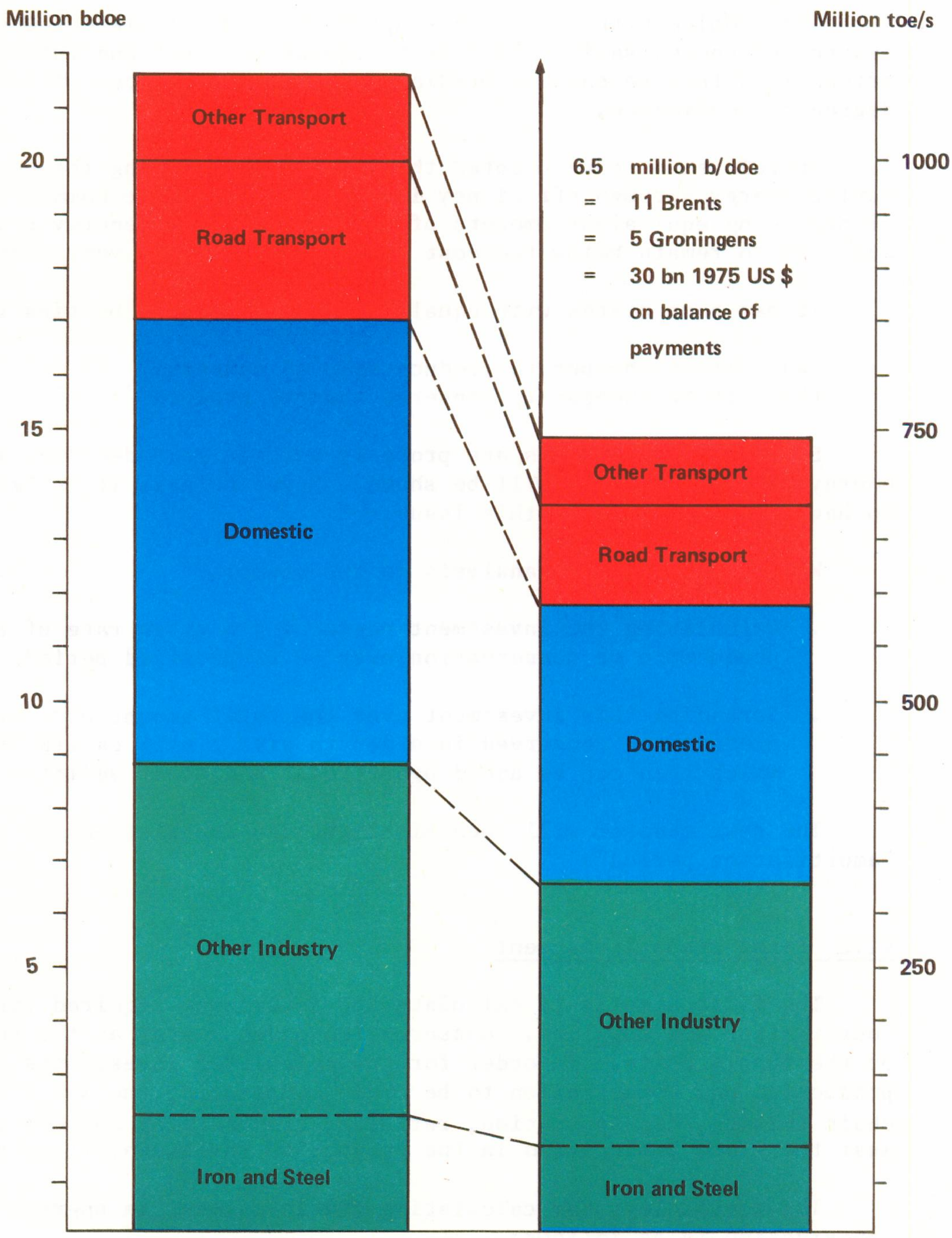

Fig. 3
Illustration of the potential of Energy Conservation in Western Europe in 1975. On the left is shown the actual primary energy consumption (excluding chemical feedstocks and other non-energy uses) by main end-use. Transformation losses (such as electricity generation) have been allocated to the various end uses. On the right is shown the estimated demand if all energy consuming equipment were of an efficiency standard economically justified against today's energy prices.

IV THE ECONOMICS OF ENERGY CONSERVATION AS COMPARED WITH SUPPLY

IV.1 The need for comparison

The next question to be answered is: "How 'economic' is energy conservation?".

The problem with the obvious approach - to calculate the economic returns of energy saving investments against current and future energy prices - is that no-one can predict future energy prices with any degree of confidence.

Therefore, we have adopted the method of comparing the cost of saving energy through efficiency improvements with the commercial cost of producing equivalent amounts of new energy, since energy prices are unlikely to remain below the cost of alternatives for very long.

It has been stated with equal fervour by various parties that:

(a) "it is cheaper to produce than to conserve"
(b) "it is cheaper to conserve than to produce"

Simple cost economics are probably not the main deciding force in energy conservation, as will be shown. Nevertheless, it is important to have a closer look at this issue.

We will develop our analysis in two steps:

- Calculating the investment needed for a given rate of energy production or conservation over an unspecified period of time;

- Spreading this investment over the total amount of energy produced or conserved in order to give a unit capital cost, to which then can be added operational and other additional costs.

The next chapter will then highlight the implications of the "amortisation period".

VI.2 First step: Investment

The first step is to calculate the investment required for energy conservation and supplies. Conservation saves energy at the very end of the supply chain. In order for the calculated investments for production and conservation to be truly comparable, the whole supply chain (mining, transportation, refining, transforming and distribution) must therefore be included in the production investment figures.

The methodology for calculating the investment in energy conservation is as follows:

- estimate the rate of energy consumption of average unit under consideration (e.g. detached house);

- estimate the cost of the conservation measure (e.g. filling cavity walls);

- estimate the reduction in the rate of energy consumption

The investment per unit of rate of energy saving is now given by the cost of the conservation measure divided by the reduction in the rate of energy consumption

For example, the average Western European car in 1975 cost $4000, and travelled 9,000 miles (15,000 kilometres)a year at an average of 21 miles per US gallon (9.5 kilometres per litre). It therefore consumed about 430 gallons (1600 litres) a year of gasoline, equivalent to about 9 barrels of crude oil (1.2 tons of oil)*

Efficiency improvements currently thought possible are in the engine (15 per cent), transmission (5 per cent), better lubrication (5 per cent) and improved design (15 per cent). It is estimated that an extra investment of $300-$400** could produce savings of roughly 25 per cent: in other words, each car could manage the same annual performance on 2.3 barrels (.3 toe) less.

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* the units of energy in this report are the barrel of oil equivalent (boe) and ton of oil equivalent (toe)

1 boe = .135 metric tons of oil equivalent (toe)
= .212 metric tons of hard coal equivalent
= 1.46 10^9 cal
≈ 5.8 10^6 BTU
= 6.12 10^9 joules

the unit for energy production and consumption are consequently "barrel per day oil equivalent" (bdoe) and "ton of oil equivalent per annum" (toepa).

1 bdoe = 50 metric tons of oil equivalent/annum (toepa)
= 76 metric tons of hard coal equivalent/annum
= 5.3 10^{11} calories/annum
= 2.1 10^9 British Thermal Units/annum
= 2.2 10^{12} joules/annum

Within the accuracy of our cost figures one can equate a ton of oil equivalent (toe) with 10^7 kcal, so that the scale for toe in all figures can be used as 10^7 kcal scale directly.

** global cost figures are calculated from examples in many different national currencies. Keeping such cost figures up to date in current money is a laborious effort of doubtful value for such a qualitative overview as this. Hence, although most of the analysis was carried out in 1977/1978, all cost figures in this report are expressed in 1975 US $.

Thus, 160 cars could save 365 barrels a year, which is 1 barrel a day. The investment for saving 25% would therefore be somewhere between $48,000 and $64,000 per barrel a day ($950 to $1300 per toepa) compared with a production, shipping, refining and distribution investment for a conventional daily barrel of oil of some $7000 ($120 per toepa).

The calculation of investments required for energy conservation has a number of complications, some of which are mentioned in Appendix E.

Generally, additional measures of the same kind become increasingly less cost effective if added on top of previous measures (for instance increasing the thickness of insulation rapidly reaches the point of diminishing returns). Properly speaking, costs of conservation measures should be shown against the incremental energy they save. However, for a general overview such as the underlying report, this would complicate matters too much, and ranges have simply been indicated which would provide significant but realistic reductions of energy consumption. (For instance, insulating an existing building has been assumed to save 15-25% whilst a completely insulated new building is assumed to save 35-45%.) It should further be borne in mind that estimates of future energy supplies which are not yet available as full scale commercial units have a tendency to increase substantially as they near their first commercial application (for instance, cost estimates for coal liquefaction and gasification doubled between 1974 and 1976). Similarly, cost ranges calculated for conservation measures are no more than indicators, and should not be taken too absolutely. Regional differences can be quite considerable and any actual project evaluation must take full account of local circumstances. Nevertheless, with these factors taken into account, ranges of investment were calculated for some important conservation measures.

The examples quoted are mainly taken from the domestic sector, for the sake of clearness. Similar examples could (and should) be quoted for the Industrial sector (which is as important a sector as the Domestic, see Fig. 3),but this would needlessly complicate our figures

The results of our estimates are summarised in Fig. 4. In the domestic sector, we find that the investments required to save one barrel a day of oil equivalent range from $7,000 ($140 per toepa) for improved gas cookers and central heating systems, to $60,000-90,000 ($1,200-1,400 per toepa) for double glazing. To improve private cars by 25%, an investment of $48,000-64,000 per bdoe ($950-$1,300 per toepa) is needed (as derived in the earlier example). For heat recovery in industry, a range of $5,000-35,000 per bdoe ($100-$700 per toepa) indicates the wide range of possibilities.

Comparing these investment figures with those estimated for new energy supplies (most of which are well under $30,000 per bdoe ($600 per toepa) - including the full production, refining and distribution chain) we see the basis for the claim that "it is cheaper to supply

INVESTMENT

Comparison of Investment in Energy Conservation with that of Energy Production from new sources

CONSERVATION AT USER'S END

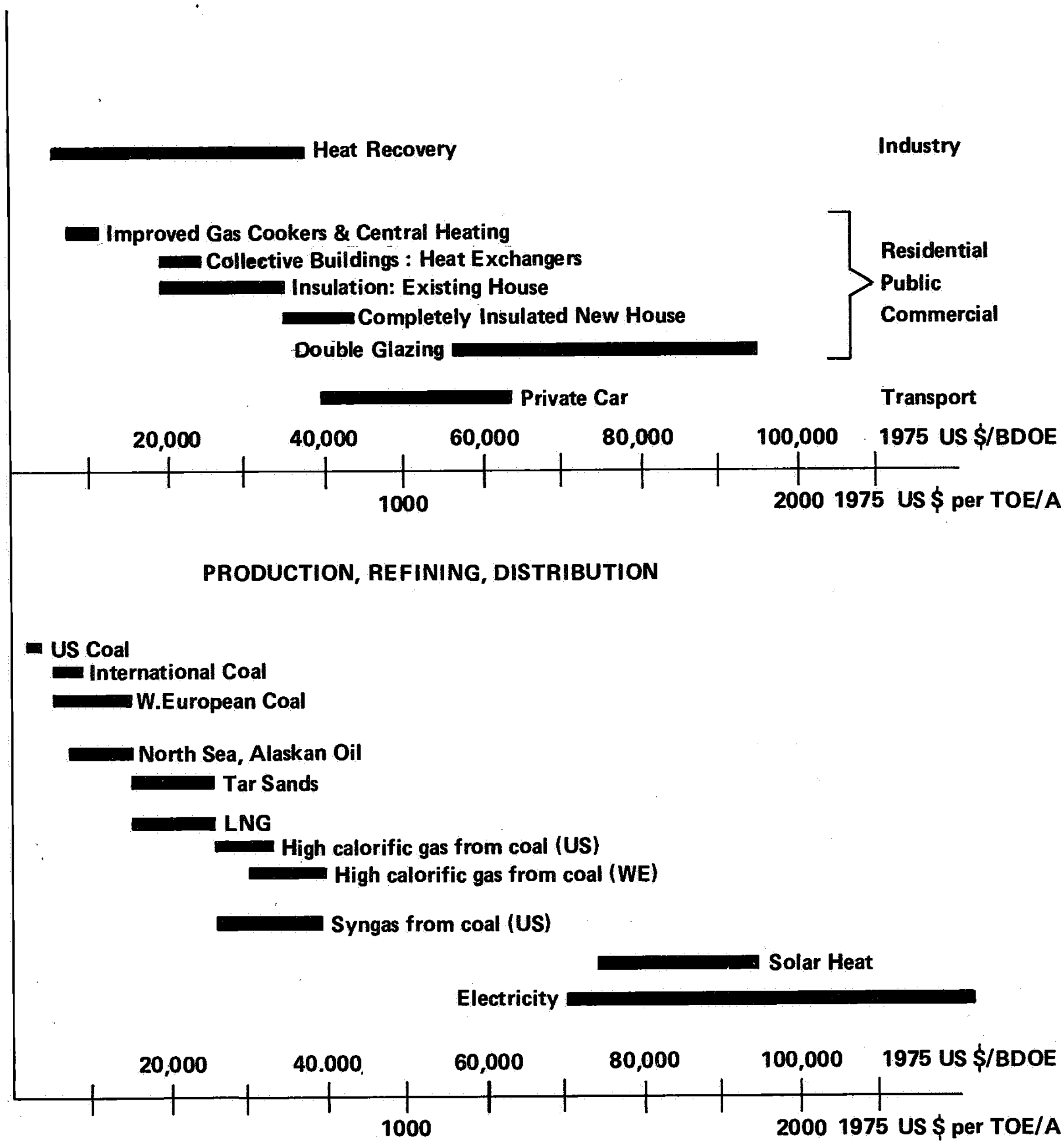

Fig. 4
Comparison of investment in Conservation and in Supply (including production, refining and distribution). In investment terms, Conservation seems unattractive as against most supply options. (Comparison on a net heat basis, disregarding the difference in quality of energy).

than to conserve". Indeed, high-technology North Sea oil appears to compete favourably on an investment basis with practically all the conservation measures shown. If we stopped our analysis at this point, the conclusion would be that energy conservation is not an economic proposition.

IV.3 Second step: unit costs

From the above it would appear that conservation does not look very "economic" due to its high capital intensity as compared with new supplies. However, capital investment is only part of the cost of supplies: it is the total cost of each option per unit of energy produced or saved that should be compared.

Investment in a conservation measure can be expressed as a comparable unit cost per unit of energy saved by dividing the initial capital cost by all the energy saved over the period under consideration, taking into account that the initial investment must either by borrowed against interest or make a return on capital. It can make some difference which form of finance is adopted, but for the sake of simplicity we will assume that all conservation measures are financed by a loan to be repaid at an interest rate in real constant money at a constant annuity.* (The difficulty of inflation is of secondary consideration, and works generally to the advantage of energy conservation as the annuity becomes an ever smaller part of income.) We have taken a 5% interest rate in constant money (that is: actual interest rate = inflation rate + 5%)** and have assumed no tax rebate.

The next crucial question is: over what length of time are the investment plus interest to be charged? Protagonists of energy conservation might insist, for instance, that the cost of home insulation should be spread over the full physical lifetime of the insulation, which could be more than 80 years. However, this is not a realistic proposition. The maximum term for a mortgage is of the order of 30 years. In industry, a process might perhaps last 30 years, but project evaluations are generally done over a period of 15 years only. Therefore, in those cases where the physical lifetime of the assets is longer than a reasonable amortisation period, we should take the latter economic lifetime - i.e. 25 years in domestic and 15 years in industry - rather than the physical lifetime.

Applying this methodology to convert a capital investment into a unit cost, we find that the relatively high unit capital investments derived earlier for conservation measures come down to much more reasonable cost figures. These range from some $2 per boe saved (15$/toe) for gas appliances to $17 per boe (115$/toe) for double glazing (see Fig.5).

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* This works out like a mortgage: one pays a constant annual sum over the period agreed, while the proportion between interest and repayment changes gradually over time, until the whole sum has been paid off.

** This is close to the observed long-term interest rates in OECD countries.

UNIT COST

Comparison of unit cost of Energy Conservation with that of Energy Production from new sources (Current W. Europe oil product prices shown for comparison)

CONSERVATION AT USER'S END

Amortisation over Economic Lifetime

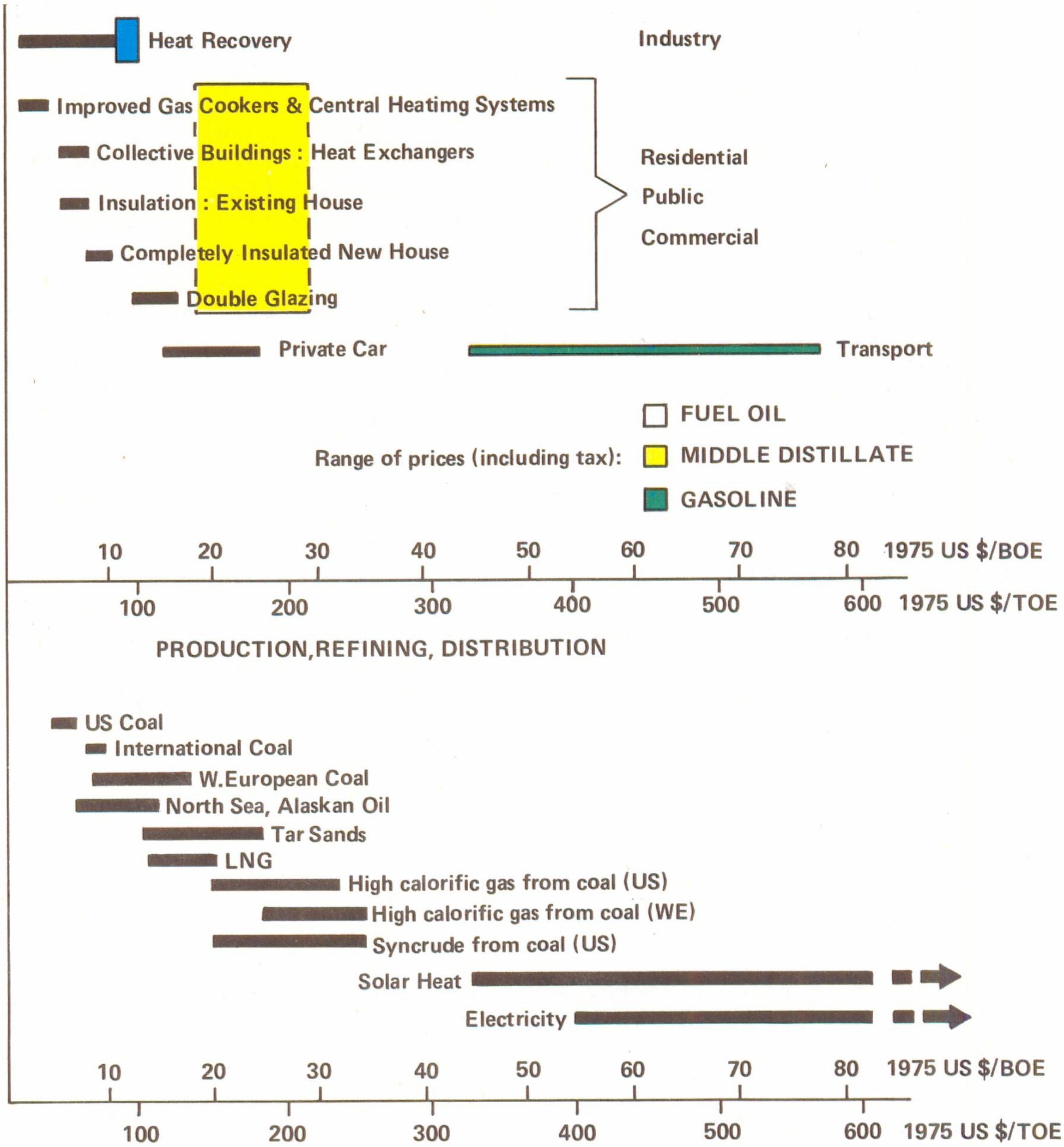

Fig. 5
Comparison of the unit cost of Energy Conservation versus Supply. The investment for conservation is amortised over a reasonable economic lifetime at 5% interest in real terms at a constant annuity, and divided by the total amount of energy saved, in order to arrive at a unit cost. The Supplies include capital and operating costs for production, refining and distribution. All unit costs are on a heat equivalent basis and do not indicate the premium value of all various fuels. Seen this way conservation looks very attractive. In order to illustrate the relative attraction of Energy Conservation, the bans illustrate the prices actually paid for energy delivered in the various West European markets. "Markets" selected are: Fuel oil for industry (blue), Gasoil for Domestic (yellow) and Gasoline for Transport (green).

It may perhaps seem somewhat surprising that the comparatively higher unit investment of conservation comes down to a lower unit cost. The main reason for this is that the energy conservation measures quoted in the example are all of a pure investment type: once the investment has been made there are hardly any further costs (apart from interest). In contrast, investment in plant, machinery and equipment is only part of the total expenses for energy supplies: also to be included are: operating costs (including salaries), provision for risk and corporation tax. In addition, there is a further production tax ("host government take", "petroleum revenue tax") and, particularly for the lighter oil products, often a further substantial extra element of sales tax. The resulting selling price is therefore substantially higher than the discounted unit cost of the investment.*

If we now compare for example the cost of e.g. insulating existing houses (of the order of \$5-8 per boe, i.e. \$37-60 per toe **, with the delivered cost of North Sea or Alaskan oil (from \$8-15 per boe, i.e. \$60-\$110 per toe)***, then energy conservation is clearly very competitive.

This can be further illustrated by setting the calculated unit <u>cost</u> of conservation measures against the energy <u>prices</u> paid in the various market sectors. We have selected the fuel oil price for industry, the gasoil price for domestic users and the gasoline price for transport, current in Western Europe in 1978 (in 1975 prices)****. The comparison shows that the cost of conservation measures - ranging from improved cookers to double glazing - is well below the energy prices actually paid in the market. (We can also say that the payout time of the conservation measures shown is shorter than their economic lifetime, see Fig 6)

The above analysis illustrates that, if properly assessed, many energy conservation measures are economic against today's world energy prices. This would be even more pronounced if compared with projected prices based on the costs of most alternative energy sources.

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* If the interest paid on energy saving equipment, on the other hand, were to be tax deductible then its unit cost would of course be lower still.

** investment amortised over 25 years

*** investment amortised over life of resource + operational cost and corporation tax.

**** this should not suggest that oil is the only energy used. These prices have just been selected as convenient "markers".

V WHY IS ENERGY CONSERVATION SO SLOW IN SHOWING UP?

In a changing economy the effects of a successful implementation of energy conservation is difficult to prove and isolate. From the available statistics it can be gleaned that some measure of conservation has indeed been realised in the industrialised countries since 1973 (See Appendix F), but the results are less than spectacular.

One reason for this has been mentioned before, namely the drag of the existing infrastructure. Secondly, there will always be some inevitable delay. A typical reaction in industry could have been:

Will energy prices stay high?	1-2 years
Analysis, estimate of future regulation standards, choice of options	1-3 years
Ordering and construction	1-3 years
TOTAL	3-8 years

Thus, much could be in the pipeline that has yet to show up in the statistics.

Nevertheless, considering the significant economic attraction of many available options, as illustrated in the previous chapter, one could be disappointed at the apparent lack of results and one can rightly ask:

"If energy conservation is so cost effective, why then is it so slow in taking off?"

There are, of course, some obvious barriers: lock-in by the existing infrastructure, human inertia, vested interest, general inflation masking (or actually outdoing) the price increases of energy,* and many institutional barriers.

However, the foregoing economic analysis enables us to get closer to the root of the problem: the individual consumer's attitude. The statement from the previous chapter that conservation is economically attractive does not necessarily imply that the consumer will take positive action.

The individual consumer (who has to make the investment) is unlikely to be fully aware of the realities of energy pricing and to possess complete information about the available options; capital is

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* in some cases (such as electricity in France) energy was actually cheaper in 1978 than in 1972, in real constant money.

always scarce and even where he has the necessary capital available, he will probably be unwilling to put it into a project of up to 15 to 25 years evaluation. Another problem is that conservation is by definition negative: after the measure has been taken the energy saved is "invisible", as opposed to the tangible barrels of oil produced by an oil field. Thus the contribution of conservation is very difficult to envisage in a clear cut way. Lastly, even with perfect information, capital available and willingness to spread it over a reasonable number of years, most people require some-one else to implement the measure for them: things must be easy to get done.

Perhaps the major reason for the consumer's inertia lies in the short pay-back time demanded by most consumers.

In calculating our costs over the "reasonable economic lifetime", we have implicitly supposed that the consumer indeed allows such a long amortisation of his capital investment. For most people, however, the time horizon in which an investment must pay-back is very much shorter. In industry, the maximum pay-back time allowed for cost-saving measures seems currently to be about 2 years only (before tax.)*

Capital investment in energy conservation is for the private consumer normally embodied in other kinds of capital (house, car etc.). Once it has been made it can only be traded together with the larger asset in which it has been embedded. Such measures only increase the second hand market value of an asset if they coincide with the taste of the next buyer. (Generally speaking, spending on the decoration/ improvement of a house immediately prior to selling is not recommended, as one cannot know the tastes and preferences of the eventual purchaser). Thus, unless energy conservation measures are generally recognised as economically worthwhile, people will tend to insist on very short pay-back periods for conservation measures, when they are willing to accept a much longer pay-off period for the asset itself (e.g. 30 years for a house). The average expectancy for use of a car is typically 3 years per owner; this is too short for amortising the extra cost of a more efficient car on a cost basis (although it is just about attractive against prices in W-Europe). In the domestic sector, we estimate that 2-4 years is the maximum period most home owners will allow for pay-back of an investment.** Fig. 6 shows that the actual pay-back time of various energy conservation measures is shorter than the economic life time, but that the pay-back time demanded by the consumer is even shorter.

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* See Appendix C.2 "Industry"

** Residential conservation investment could, of course, have a special attraction for higher income groups, since it allows an untaxed return on investment. It would be even more attractive where the home improvement interest were tax-deductable.

COMPARISON OF ECONOMIC LIFETIME, ACTUAL PAYOUT TIME AND TYPICAL CONSUMER'S SUBJECTIVE PAYOUT REQUIREMENT

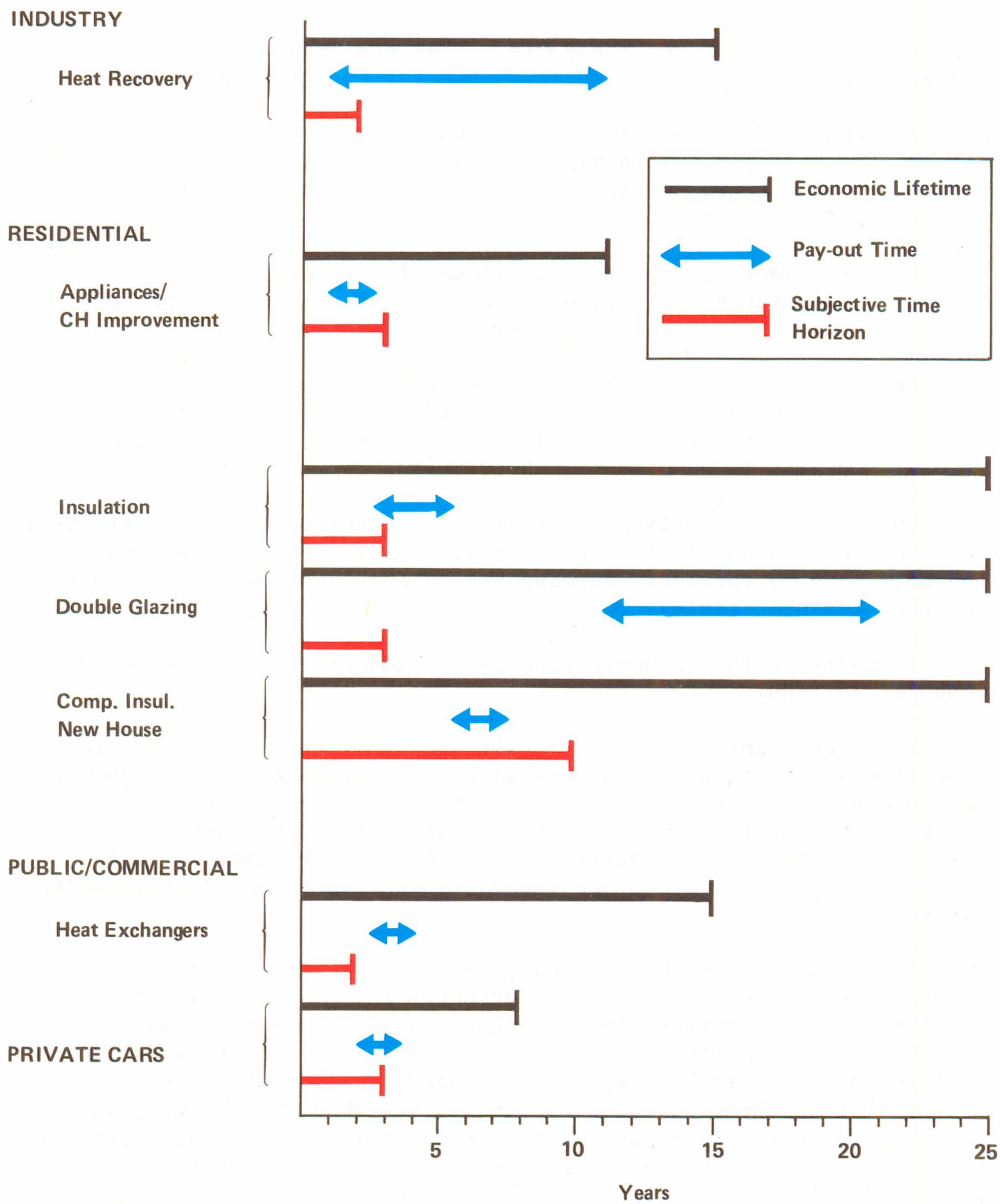

Fig. 6
The subjective time horizon for most consumers is shorter than the actual payout time. Both, however, are much shorter than the economic lifetime of the asset.

The consequence is, that if we now insist on getting the initial investment back within the shorter time horizons intimated, then the implied cost per boe (toe) is, of course, much higher (see Fig 7). (We can also say, that most payout times are longer than most people would allow).

Not surprisingly, on these timescales the economics of conservation appear less attractive than for energy supply.

The enormous impact of a short "amortisation" period is illustrated in Fig 8. This figure shows the relative order of importance of the two parameters used in converting a capital investment into a unit cost.

(a) the amortisation period allowed for recouping capital investment and interest overridingly determines the implied unit cost if less than 5-10 years

(b) the effective cost of capital (i.e. actual interest rate minus tax rebate or required return on capital plus corporation tax) is most important if the discount period is greater than 5-10 years

This picture clearly demonstrates the order of priority: first to lengthen the consumer's time horizon to more than 5 years at least, and only then to consider reducing the cost of capital (e.g. by making interest tax deductible).

Summarising the economic aspects of conservation we can now draw some conclusions.

From the examples quoted, it will be clear that investment per bdoe (toepa) on its own is not an adequate measure for the economics of conservation. The investments can be converted into unit costs using conventional economic criteria, but - although economically correct - these do not constitute an unequivocal yardstick. The consumer's economics encompass generally much more than just reducing his energy bill.

For example, double glazing - the least attractive option in terms of cost effectiveness - is currently the most popular, because it offers other benefits (less draught, less condensation, more comfort, sound proofing and visible status). In fact it is difficult to find any historical example of a major invention that was justifiable on the basis of comparable costs when it took off; instead, there was generally some attraction of special premium considerations (e.g. the steamship could maintain a guaranteed service) or because of perceived future benefits.

From the above we may draw two important conclusions:

(a) some energy conservation options that do not look economically attractive - even if properly evaluated over a reasonable

UNIT COST

Comparison of unit cost implied by consumer's subjective payout requirement (from Fig 6– shown in red) with costs of energy conservation and production as shown in Fig 5.

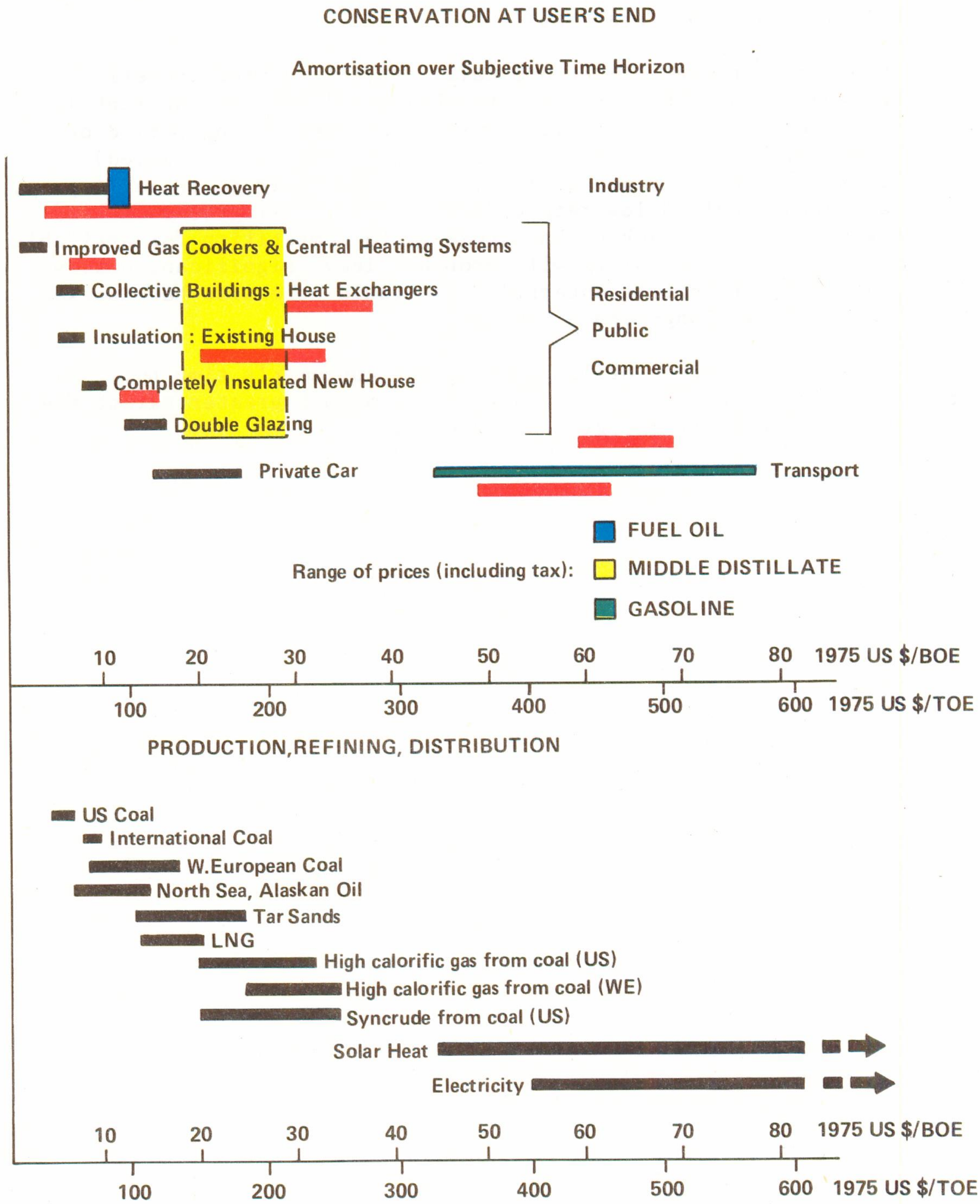

Fig. 7
One of the main stumbling blocks for the introduction of Energy Conservation is the difference between the subjective time horizon of the private consumer and the pay out of an investment. If the investment is to be amortised over the perceived subjective time horizon (see Fig. 6) then the implied unit cost (red lines) is much greater and for most measures is unattractive. It is interesting to note that double glazing – economically the least attractive option on cost benefit grounds – is most popular, because it offers other advantages (reduced draught, greater comfort, soundproofing and status).

economic lifetime - may nevertheless have a future. Considerations other than just reducing the energy bill can overridingly determine consumer behaviour. A supply source that is renewable or indigenous, (or even just new and exciting) might command a premium which - however difficult to quantify - could override simple cost considerations.

(b) Many options that are economically attractive when properly evaluated face the very real psychological barrier inherent in the need to spread a capital investment over a long period of time (divided by an invisible commodity - the energy saved). Thus, many options may fall well short of their potential impact, and attain only a low rate of penetration. Owing to a lack of awareness, to a lack of knowledge or to competition for available capital, many consumers will probably leave significant energy saving opportunities untapped, that could otherwise have worked in their own long-term advantage.

It is the prospect of lengthening the consumer's time horizon that provides an opportunity to develop to a much greater extent the "invisible" source of energy conservation.

THE RELATIVE SIGNIFICANCE OF AMORTISATION PERIOD AND EFFECTIVE COST OF CAPITAL

Unit cost of an investment of $10,000/bdoe ($200/toe pa)

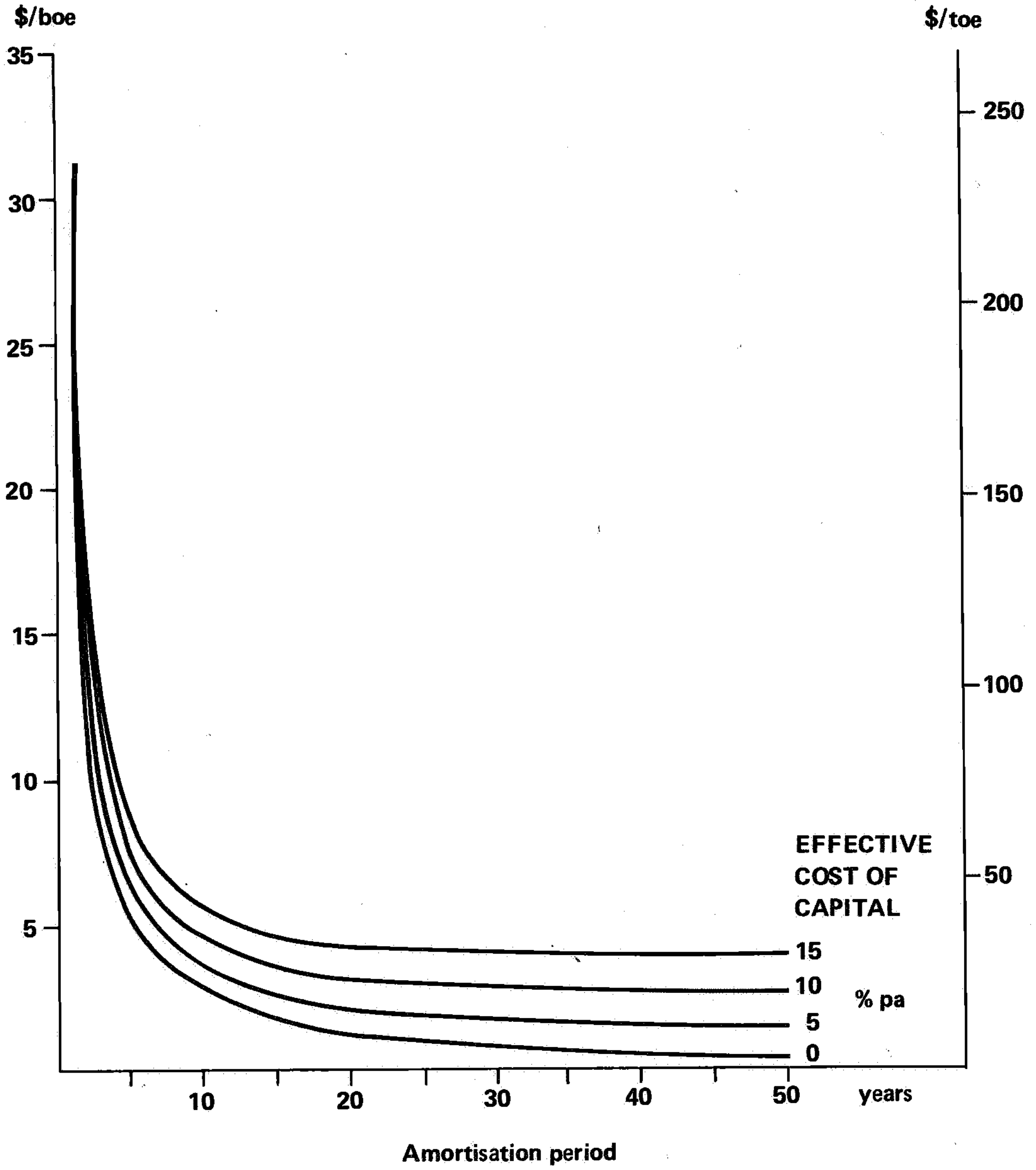

Fig. 8
The implied unit cost of an investment is determined by the effective cost of capital (interest or return on capital after tax) and the period over which the capital outlay is recouped (amortisation period).

For long amortisation periods (say more than 10 years) the cost of capital is the main determinant.

For very short periods, however (say less than 5 years) the period itself overridingly determines the implied unit cost.

VI THE IMPLICATIONS OF CONSUMER BEHAVIOUR

Energy use is dispersed throughout our society, and any analysis of decisions impacting on energy use should take into account its all pervasive nature by highlighting first of all the individual consumer's point of view.

However, a nation's economy is the result of all the individual micro-economic decisions summed together, and the consequences of such a sum should also be placed in the macro context of the entire economy.

One macro consideration specifically does focus attention - particularly that of governments - on the need to conserve energy: most countries import energy, so that the 1973/1974 price increase has severely affected the balance of payments of many countries and has brought home the dangers of insecurity of supply. Even where imports constitute a small part of total Gross National Product (GNP) they can have a disproportionate effect on the national economy if a country is not directly geared to exporting (as is shown, for instance by the current weakness of the US dollar, an important reason for which is the current trade deficit, partly caused by imported oil). Even for countries that have currently a strong export position (such as W-Germany and Japan) there lies a clear attraction in the possibilities of reducing the direct proportion between economic growth and energy consumption. This has motivated many governments to try and reduce the growth in energy imports by increasing energy efficiency.

The effect on consumers was much less pronounced. For the private consumer (in W-Europe), direct energy costs (including tax) as a percentage of total cost, even after the price increase, are still a relatively modest part of total costs: some 7% in industry (depending on type - 25% for the most energy intensive), some 7% of household costs, and some 30% in private road transport. The impact of the price increase on the consumer's awareness has, therefore, been rather modest. Where the increased burden on the balance of payments may be reckoned in billions of dollars annually, this would represent per head of the population no more than, say, one hundred dollars. This, combined with the individual consumer's usual preoccupation with the very short term (as expressed in the short time horizon highlighted in the previous chapter), the private consumer's reaction and action probably will stop well short of what would be "sound economics" in the longer term, or what would be desirable in the interest of the national economy.

However, although the "national" benefits of energy conservation, such as slower resource depletion, reduced environmental impact of energy use, employment opportunities and reducing the burden of the balance of payments can rightly be expounded as strong arguments in favour of active conservation, these arguments will weigh little with the prime actor and decision taker: the decentralised consumer. It is for this reason that this report focuses so much on the individual energy user rather than the nation.

If accelerated improvement of energy efficiency is really to take off, then it must be made easy for the consumer to implement. Whereas currently many energy suppliers are competing to sell energy in one form or another, an organized "conservation" sales industry hardly exists.

From the foregoing there are some important conclusions to be drawn, which hint at opportunities for both government and business to develop this attractive "invisible" resource to a greater extent than is currently obtaining:

(a) - the difference between the short time horizon usually applied to cost-saving measures by most private consumers (including Industry and Commerce) and the "reasonable" amortisation period applied to most commercial projects needs bridging;

(b) - a competitive "conservation service" industry by seeking out its customers and offering a comprehensive diagnosis, implementation and financing package - tailored to the individual's needs - , would greatly enhance the consumer's ability to turn the significant potential of improved energy efficiency into fact.

VII SOME POINTERS FOR REMEDIAL ACTION

The foregoing suggests ways in which both governments and the private sector can encourage and develop energy conservation, in order to prepare consumers for the inevitable rise in average energy costs in the not too distant future. (The legislator who actively keeps prices down for social reasons should be aware that he is discouraging both the development of new energy supplies and any significant improvement in the efficiency with which existing supplies are used).

This essay, being primarily analytical, cannot attempt to go into detailed recommendations. Nevertheless, some important broad observations can be made.

Perhaps the most important is that the path of "natural latent advantage" is generally more successful in the long run than that of "denial". Legislation that aims to reduce the quality and availability of goods and services denies the consumer comfort and choice, and would be difficult to maintain when real disposable income continues to grow. (Equally, laws that are passed but not enforced weaken the credibility of the whole legal system, the basic framework of a democratic society).

Improvements in energy efficiency will have to be effected not only by those who are used to making explicit economic evaluations, but also by the mass of the populace, and in a "one man one vote system" the legislator has to step warily. Centralised regulation can easily result in heavy handed counter-productivity. The difficult but rewarding challenge in this field is to find ways of helping the consumer to help himself. The wise legislator will seek to shape the law as a catalyst for the consumer's own advantage; for instance by encouraging a service industry that can help the private consumer over the hump of making the required investments. Denying water to a camel merely results in an angry camel; give it a push over the sand dune so that it can see the distant oasis, and it will start running towards it. In this way, for instance by providing the consumer with understandable and objective information, governments can help to make the individual's economics coincide better with the national economics.

However, the temptation of detailed regulation should be resisted. The history of Regulation is full of well meant legislation, that either produced unexpected unwelcome side effects; or even became counter-productive to its primary aim; or was drawn into formulating ever more detailed rules which only drew forth ever more clever evasions.

Thus, legislation in the field of energy conservation should always take into account that conservation is not an aim in its own, that energy is only one factor in the socio-economic total, and that the encouragement of latently existing advantages is always more effective than trying to stem a still rising tide of demand.

It is essential that energy conservation be recognised as a business opportunity for it to become really effective. The private sector can and should develop a competitive professional conservation service industry (offering packages of diagnosis, evaluation, installation and financing) that, working through the decentralised drive of the profit motive, can seek out its customers much more positively and effectively than centralised regulation and exhortation could do.

By developing ways to enable the customer to see more clearly the benefits for himself, both governments and the private sector can help to overcome the main reasons for consumer inaction:

- lack of concern, information and expertise
- shortage of capital
- shortfall of time horizon
- inertia

Thus, the following action items would seem most appropriate to accellerate the appreciation and implementation of improved energy efficiency:

- <u>education and information</u> in which price plays an important signalling role.

- <u>improving the feedback of energy costs on energy consumption: energy labelling</u>

  e.g. proper sales information on energy specific consumption; individual metering in collectively heated apartments.*

- <u>formulating and agreeing standards for new important classes of energy consuming equipment (cars, appliances and buildings)</u>

  This type of action seems to be well under way in the USA and France. In Japan, the car manufacturing industry has profited by imposing performance standards on their models in anticipation of legislation in the U.S.A. A comprehensive programme is also underway in the US to test appliances and to set up meaningful standards. Where building contractors tend to be conservative and are understandably reluctant to increase the cost of their product, the timely introduction of building codes, setting higher minimum standards for insulation, draught proofing, heating equipment and controls seems definitely indicated. The exchange of international

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* Individual metering can also be improved - meters are usually tucked away somewhere invisible, and the cost feedback occurs only four times a year when the bill arrives. Direct visible feedback (the sight of a meter ticking away money) has shown itself to be very effective in reducing waste and discouraging nonchalant use.

experiences could show what can be done and how to achieve (and not to achieve) it.

- facilitating the acquirement of loan capital for energy-saving investments through, for instance, leasing, hire purchase or making energy-saving home improvements mortgageable.

- encouraging the development of energy conservation as a business opportunity and setting professional standards for conservation specialists

  The development of a competitive energy conservation service industry would greatly reduce the need for legislators to enforce conservation. The profit motive would then naturally achieve with technical fixes what the legislator would otherwise have to enforce (probably by quality reducing restrictions).

In this way the public and private sector could seek to enhance the individual's ability to act so that his private micro economics can adapt to the consequences of the inevitably higher energy prices in the immediate future.

VIII CONCLUSIONS

- The need for energy conservation is recognised more readily by governments than by individual consumers - who decide how much and how efficiently energy is used. As micro behaviour determines macro effect, it is in the interest of governments to make greater conservation an attractive proposition for the individual consumer.

- Attitudes and perceived self-interest motivate behaviour. Effective conservation need not involve reduced or lower quality of performance; but in most cases it does require a capital investment to achieve greater efficiency.

- The discounted unit cost per unit of energy saved of many important conservation measures is less than current unit energy prices, provided a reasonable period is allowed over which to amortise the initial capital investment.

- Private individuals, who account directly for about half of the energy used, have different criteria than do suppliers - notably a shorter time horizon over which they expect to recover their investment.

- Other factors - such as comfort, fashion and status - can override economic considerations in determining behaviour. Therefore, some conservation measures that are not currently competitive in purely economic terms may nevertheless have a promising future.

- In the longer term, price will dictate energy use, but existing infrastructure imposes a significant time lag. Complementary legislation can encourage the consumer to make investments that are to his own advantage, thereby helping the individual's economics to coincide with the national economics more effectively than through compulsion.

- The potential is high. For example, some 30% of the energy now consumed in Western Europe could be saved by technical improvements (possible with existing technology, and economically justifiable against current energy prices).

- Energy conservation must be developed as a business opportunity, with skilled specialists demonstrating the benefits and cost-competitiveness of energy-saving equipment and services to the consuming decision-makers in all sectors. The profit motive would thus reinforce exhortations and legislation. Result: more conservation and reduced energy imports, plus productive earnings and new jobs.

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WOCA PRIMARY ENERGY DEMAND

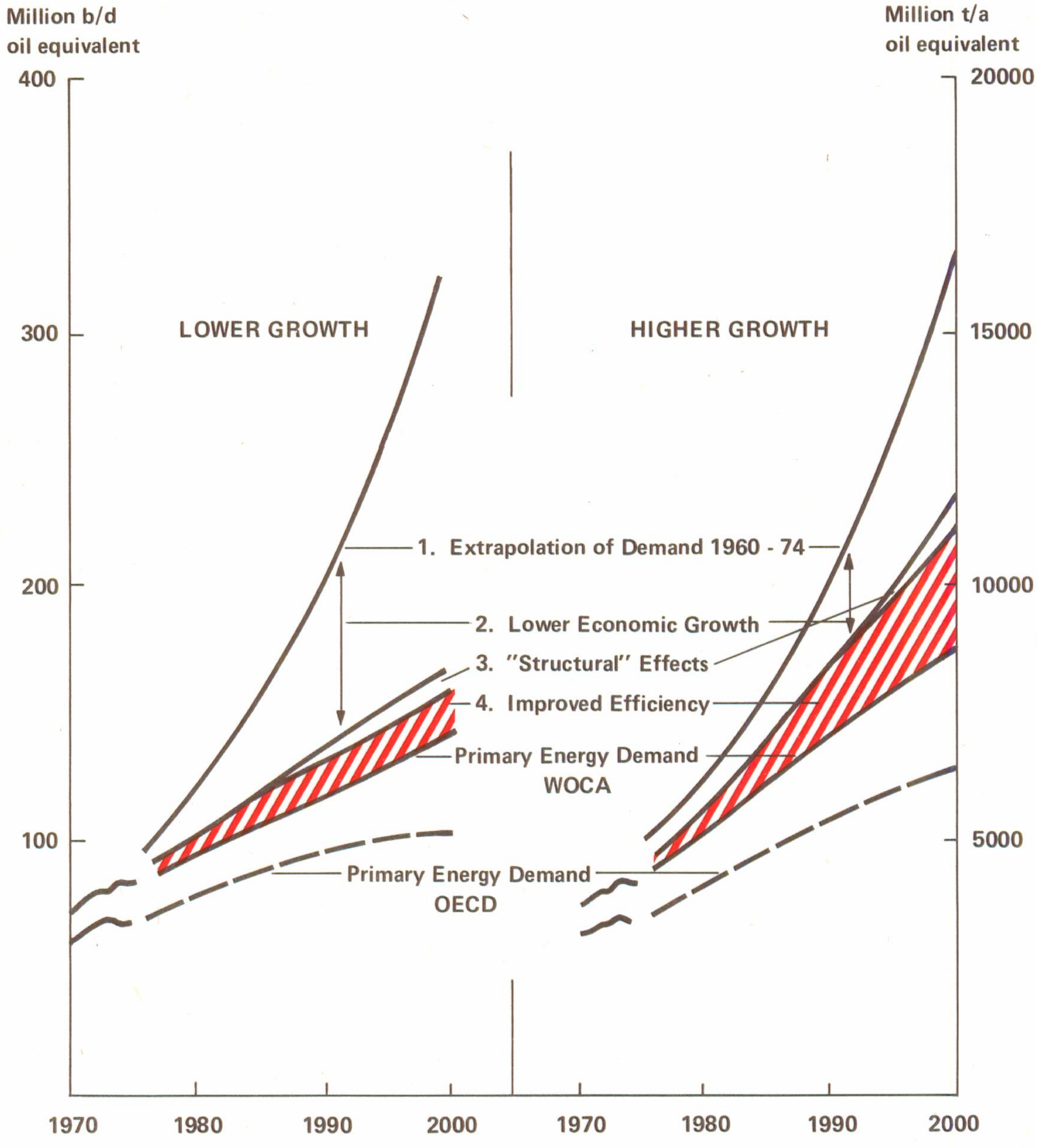

Fig. 9
Two current projections of future energy consumption, both significantly lower than the 1960–74 trend would have implied. These scenarios, here summarised for the world outside the communist areas, were composed by quantifying 13 end-use segments for 10 geographical regions within the supply constraints foreseen. The chart illustrates three main reasons why energy consumption is expected to grow more slowly than in the sixties:

- lower economic growth (for a variety of reasons)
- structural effects (such as saturation in private cars and space heating)
- improved energy efficiencies

The latter is much greater (in absolute and relative terms) under the Highest Growth case than under the Lower, due mainly to faster turnover of capital stock which allows a greater impact of new more efficient technology. Under both scenarios, the non–OECD area more than doubles its share in total energy consumed.

A QUICK GUIDE TO ENERGY CONSERVATION

A rough ranking of effectiveness (not necessarily taking into account cost effectiveness) is indicated by: + (effective), and o (probably not effective) and - (counter-effective) signs, in order to give an idea of the relative importance of various options (including both "improved efficiency" and "lower quality" measures). This ranking contains a large element of subjective judgement and should not be taken as an absolute yardstick. A short discussion of these measures is given in Appendix D.

ROAD TRANSPORT

+++ smaller cars
+++ engine improvement
++ weight reduction
++ drag reduction
++ use of micro-processors to improve driving habits
+ speed limits
+ car pooling, mini-buses
++ to o improved routing; closed town centre; de-bottlenecking
++ to - scheduled public mass transit systems

INDUSTRY

+++ integrated design of new processes
++ correct choice of the type of energy used, combined with good combustion technology
++ waste heat recovery, used for preheating and space heating
++ insulation
++ replacing steam by direct firing techniques
++ co-generation of heat and power
++ heat management and improved maintenance
+ improvements of buildings (see Commercial0
+ to - recycling of used materials

RESIDENTIAL

+++ integrated design of new houses, building codes
++ insulation (loft/roof, walls, floor; in this order)
++ draught proofing (counter-productive if ventilation reduced too much)
++ boiler improvements: boiler insulation; ducts insulation; flue heat recuperator for gas boilers; low heat capacity boilers; flame modulation; electric ignition rather than pilot light
++ automatic control, sensing outside temperature and optimising on/off time of boiler and temperature of CH water.
++ heat pump
++ to + double glazing
+++ to o regulatory limits of indoor temperature and hot water temperature
+ improved efficiencies of appliances and lighting
+ individual room thermostats for maximum utilisation of incident solar heat (counter-productive if window left open)
+ wind screening by trees
+ solar hot water (solar space heating, including seasonal storage, currently economically unattractive in many temperate zones).

+ hot water waste heat recovery
+ to o exhortations/regulations for switching off unused lights and closing curtains.
++ to - district heating (transmission losses and load management problems offset boiler efficiency; however, greater flexibility in fuels). District heating from power stations' waste heat only attractive if it operates in heating following mode, yielding electricity as a by-product. The national electricity grid then has to balance the swings between supply and demand, which is less attractive in non-hydro countries.

COMMERCIAL/PUBLIC

+++ integrated design of new buildings
++ double glazing (glass surface far greater than in residential)
++ draught sealing, controlled ventilation
++ heat pump (see Residential)
++ heat management
++ improved efficiency in lighting
++ waste heat recovery, using out-flowing air to preheat in-flowing fresh air
++ controls sensoring outside temperature; switch off during nights and weekends
++ individual room thermostats
+ solar
+++ to - regulatory limits for temperature in winter and summer
++ to - insulation. Large office blocks often need cooling above 10°C outside temperature due to their high density of (daytime) occupation, high lighting load and favourable volume/surface ratio. Hence insulation could increase the required cooling and could cost more in cooling energy than the corresponding heating gain would yield.

GENERAL

+++ replacing electrical resistance space heating by direct fuel heating (in non-hydro countries) or by heat pumps
+++ energy labelling: clear display of performance characteristics
+++ minimising distortion of the price signals
++ education and understandable information
++ to o exhortations

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Much of the information and insight contained in this report was gained by personal interviews both within and outside the Shell Group. The following short list contains some outside publications (in English) that we found particularly illuminating. It is by no means exhaustive, either with regard to the total amount of material consulted or with respect to the subject matter covered, but is rather intended to give additional detail on some of the more important issues.

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APPENDIX A

TECHNICAL EFFICIENCY

A.1 The Overall Potential for Saving Energy

Our society is dependent on energy for many of its activities. At one level this requirement is readily observed as the direct consumption of fuels in Transport, Industry, and the Domestic sectors. But, since all products and most services we consume require energy in their production, we also consume energy in many indirect ways. Clearly the manner in which we use fuels directly influences total energy consumption, but similarly our selection of products and services (high versus low energy intensity) and the pattern of our life style (e.g. the need for transport and for particular forms of housing) also strongly influences overall consumption.

This pervasive nature of our energy use naturally means that, in theory, energy could be conserved in many ways. From primary energy sources to end use we can roughly distinguish the following levels:

(a) efficiency of extraction, transportation, processing and transformation.

(b) mix of fuel types and energy forms consumed directly by the end use sectors Transport, Industry and Domestic.

(c) the efficiency of end use, i.e. the way the available fuels and/or types of energy are converted into the tasks required.

(d) the mix of goods, services and activities which make up our society.

Efficiencies (a) and (c) could be improved and mixes (b) and (d) could be changed to achieve a "minimum energy" solution. Instructive as such a theoretical "optimisation" exercise might be, in practice, the degrees of freedom are very restricted.

Although the mix of goods, services and activities (d) is undoubtedly influenced by energy prices, it can hardly be "optimised", and regulatory attempts to dictate details of daily lives can quickly call forth an angered reaction.

The mix of "marketed" or "delivered" fuels will be a result of availability, price and relative convenience to provide the proper form of energy (heat, power or electricity). This mix of fuels (b) can have a profound influence on the overall primary energy consumption, as the efficiency with which the main forms of energy: heat, power and electricity can be obtained from the primary fuels differs markedly. To a large extent, however, this mix is dictated by availability of fuels and the mix of tasks required.

The supply efficiency (a) is almost exclusively a matter of concern to the energy industries, who, being cost conscious by nature, in principle should be expected to optimise efficiencies against the other factors - labour, raw materials and capital - against current and expected energy prices. The fuel mix (b) overlaps with the end use efficiency (c), and one of the most important conservation measures is indeed the proper match of available fuels, through the possible forms of energy, to the required results. In this report we concentrate mainly on end use efficiency improvements that reduce the amount of primary fuels irrespective of their type. It is important, however, to realise that in doing so we zoom in on only one of 3 x 4 dimensions ((1), (2) and (3) of Chapter II and the above (a), (b), (c) and (d)), and that end use efficiency improvements should always be assessed for their effect on primary fuels consumed.

In this context it should also be mentioned that in our terms conservation means the reduction of total energy per usage considered and should thus be distinguished from simple substitution e.g. oil conservation by substitution with coal.

A.2 The Technical Definition of Efficiency

In order to describe the scope and potential of technical efficiency improvement one should have at least a rough quantitative technical definition. Perhaps surprisingly, this does not appear to be easy.

Energy manifests itself in different forms, the most important of which for our purposes are:

- heat
- mechanical power
- electricity

The "first law" of thermodynamics states that in no process energy is ever lost. In that sense any process is an "energy conserver". However, it is generally not possible to transform the various forms of energy into each other on a one to one basis. Whereas it is possible to convert mechanical power or electricity fully into heat, the reverse is not true: heat can only yield a mixture of power (mechanical or electrical) plus heat of a lower temperature. The higher the temperature difference between input heat and waste heat, the higher the possible percentage of power output. This is embodied in the "second law" and is the basis of the terminology "quality" or "grade" of energy: high temperature heat has a higher "quality" or "grade", since it can produce more power, speed up chemical and physical processes such as catalytic cracking and drying, and so on.

Since the various tasks in society require different forms of energy, it is of the greatest importance to have the proper match of specific task and specific energy form.

Let us illustrate this with an example: the use of an electrical resistance heater to maintain a desired indoor temperature in winter. An electrical resistance converts all electricity into heat without loss, and has therefore an "efficiency" of 100%. This may seem a very efficient utilisation of energy, but in fact it is a less than optimal way to maintain a relatively small temperature difference between the inside and outside of a house (however convenient it may be to the user). Heat contained in primary fuels is liberated at a very high temperature in a power station, then converted into, say, 35% electricity, while 65% is rejected as waste heat to the environment. With a further loss of say, 10% of electricity transmitted and distributed, the overall "efficiency" of the system: primary fuel-power station - transmission/distribution - resistance heater is in fact only 31.5%.

If we compare this with a gas heater, which on average over a whole year loses about 30-40% of the combustion heat through the chimney and by other shortcomings such as the switching on/cooling off operation, then - including a 5% loss in gas transmission/distribution - the overall system efficiency is 57-67%, twice as high as the electrical route.

However, this is not the whole story. The gas flame, providing a high grade energy, could drive a device called a "heat pump" to extract low temperature heat from the outside and upgrade it to the required room temperature, in the same way a cooling unit extracts heat from a refrigerator and rejects it into the room. Gas fired ("absorption type") heat pumps exist which yield 1.2 to 1.5 times as much (low grade) heat output as the (high grade) calorific equivalent of the combustion process. Thus, by the use of such a device (and by further improvements of the heat load following) the overall "efficiency" of the gas heating system could be close to or even more than 100%*. So, compared with what would be possible, the electrical resistance heat supply system has an efficiency of less than 25%!

This is still not the end of the story; the "useful space heat" obtained is in fact used to balance heat losses through the skin of the house and through ventilation. Reducing these losses would also reduce the amount of fuel required and increase thereby further the overall efficiency. The ultimate in "efficiency" in this example could be: a heavily insulated house, with controlled air flow and pre-heating of the incoming air with outflowing air, heated by a heat pump. This example shows how "efficiency" quoted for devices that form only part of a total supply chain, can be very misleading. Where furthermore the average efficiencies, degree of insulation etc. of currently existing energy consuming equipment is largely unknown, the best one can do, in general, is to estimate the relative improvement compared with the situation in a chosen base year.

Another practical example (partly covering the same ground) may be useful for further clarifying the implications of "improved energy efficiency".

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* This may sound like creating energy, but it implies only that better use has been made of the low temperature heat outside. The definition of "efficiency" for this case is here at fault.

An old gas storage water heater may convert less than 50% of the input therms on a gross calorific value (G.C.V.) ** basis of gas into heat in the hot water drawn off during a year of operation in a certain household. The use of a modern design of instantaneous gas water heater could be more appropriate to the needs of this particular household and convert 70% (G.C.V. basis) or more of the input therms of gas into hot water. The total savings effected can certainly be thought of as conservation if the old storage heater is near the end of its life.

If the storage heater were only one year old then an accurate assessment of energy conservation should include the deduction of the energy wasted by early scrapping of the storage water heater. An assessment of the effect of the change on the balance of payments of the country concerned should also consider the import cost of the water heater or the materials required to make it. These are usually unimportant refinements when the change is restricted to the utilisation equipment, but become of greater importance when the form of energy supply is changed in order to improve energy conservation or improve balance of payments. Before going on to this aspect it is necessary to reiterate the dangers of comparing utilisation efficiencies of appliances using different forms of energy supply. For instance, the old gas storage water heater could have been replaced by an electrical instantaneous water heater of 98% utilisation efficiency, but this would have caused an increase in overall energy consumption and a worsening of the balance of payments position if the marginal units of electricity have to be generated from imported fuels. (If the user wishes to know how much electricity or gas each appliance will use in a year, and hence how much each choice will cost him, then of course the appliance utilisation efficiency is useful. Note, however, that the 'bench test efficiency' or 'continuous operation efficiency' often quoted in energy cost comparisons can be misleading, as the annual utilisation efficiency for some types of appliance with widely varying patterns of offtake can be significantly lower). To investigate the potential for overall energy savings in a country which generates marginal electricity requirements from fuels, the energy loss that occurs when producing electricity in thermal power stations must be taken into account. Large modern central power stations can only be expected to convert 36% (G.C.V.) of the input energy to electricity. Due to the inevitable use of some older less efficient plants and the subsequent transmission and distribution losses the overall average efficiency of power generation and distribution to our residential consumer is likely to be between 30 and 35% (G.C.V.). The overall technical efficiency of energy utilisation of the electric instantaneous water heater is then 30% x 98% = 29% (G.C.V.) to 35% x 98% = 34% (G.C.V.). This has to be compared with 95% x 80% = 76% for the gas instantaneous heater if natural gas is distributed with 5% loss and energy consumption for compression.

** Gross calorific value refers to the amount of heat liberated by perfect combustion, including the heat contained in water vapour formed during the combustion process.

The example emphasises again the need to define the question one is trying to answer very clearly before starting the analysis. To develop the point further, if the gas distributed were made from coal then the gas making efficiency (say 60% for future SNG processes) would have to be taken into account, which reduces the gas instantaneous water heater overall efficiency to 76% x 60% = 46% (G.C.V.). So conversion of coal to gas rather than electricity is an overall more efficient use of energy (for this particular case of instantaneous water heating), but how should coal gas and natural gas be compared? Of course, it depends on the question that is to be answered. Natural gas distribution will use less energy than the manufacturing and distribution of gasified coal but this is not usually the problem. It is more likely to be 'which system would minimise foreign expenditure'.

To answer this question it is necessary to take into account the cost of expenditures other than those on fuel imports, as a switch from an imported form of energy to an indigenous one could possibly cause a worsening of the overall balance of payments due to the need to import capital equipment or materials to make it. Manufacture of generating plant, transmission and distribution equipment and energy utilisation equipment is itself a consumer of energy, and a consumer of other resources that need to be conserved.

Provided the objective of the analysis is clear then it is possible to indicate the likely result of any change, or even suggest the optimum solution to the problem. The main difficulty when discussing 'energy conservation' stems from the fact that many people can not take a wide enough view, and hence tend to ignore the wider implications of following a too simplistic aim.

A.3 A Pragmatic Definition

From the above it will be clear that the definition of absolute "efficiencies" for end uses can hardly be meaningfully derived. How then do we measure "improvement in efficiency"? In many cases, one has a yard-stick which is readily applicable - e.g. miles per gallon (or litre per kilometre, or joule per metre), BTU per ton crude steel, and so on. However, in most cases such yardsticks are more difficult to define. If one wants to measure a country's economy as a whole, then obviously no single output unit would suffice.

Nevertheless, in order to give some indication of the possible impact of and scope for improved energy efficiency, we have adopted the following pragmatic definition of "energy conservation", or "energy savings" for any particular end-use:

> "the reduction in energy per unit of activity, as compared with the average practice in a chosen base year".

THE DEFINITION OF % SAVINGS
ENERGY PER UNIT OF ACTIVITY, BASE YEAR = 100

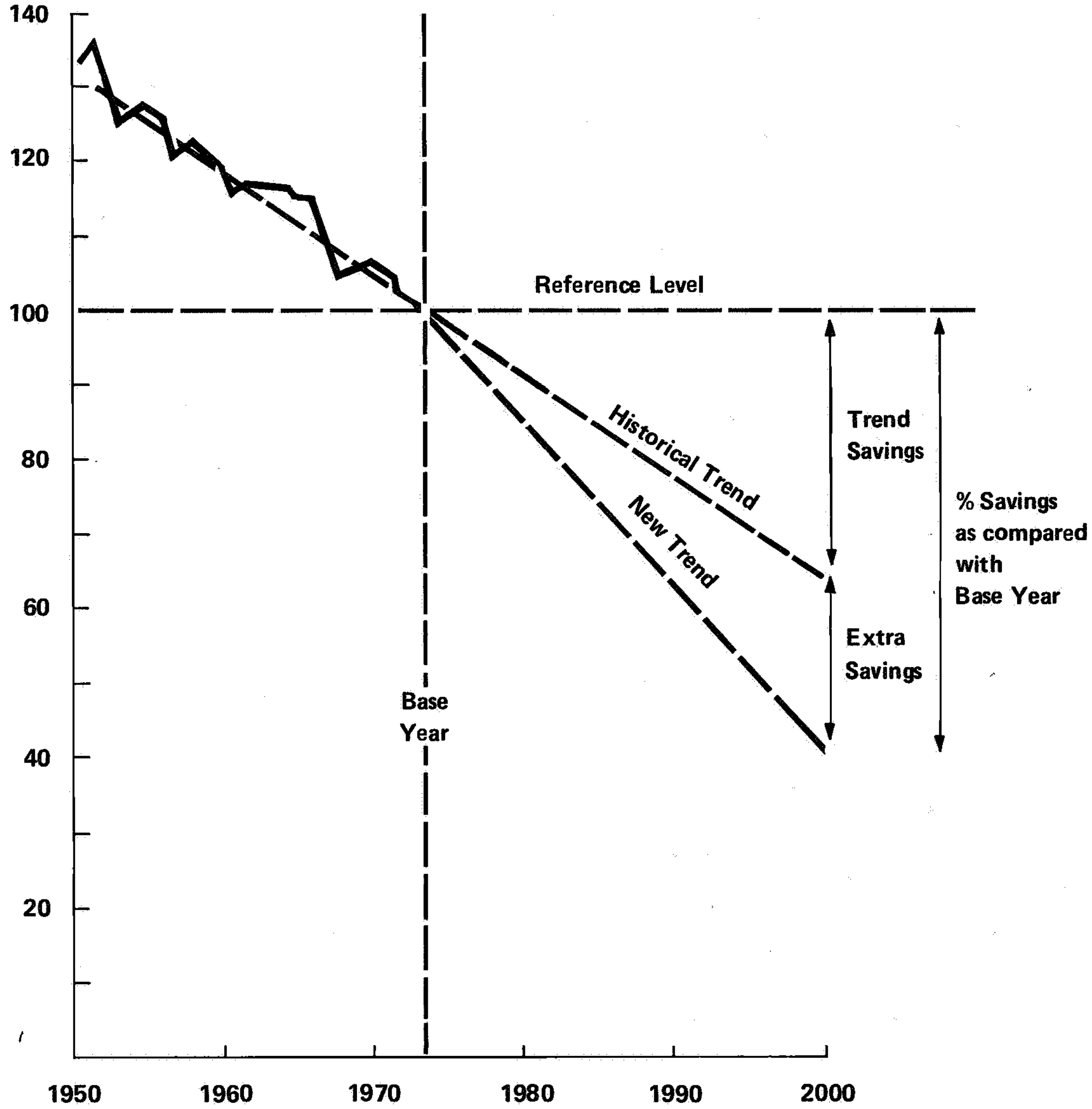

Fig. A1
A pragmatic definition of energy savings: % reduction in energy per unit of activity (to be chosen for each energy consuming segment under consideration) as compared with a chosen base year. Any previous trend is incorporated in this.

This definition is by no means water-tight; but it enables us to indicate percent savings in a future year as compared with what would have been used in that year, if all energy-using equipment were of the base year's quality and were used according to the average practice in the base year.

For "unit of activity" we chose suitable indicators for each energy use such as "Manufacturing output at constant prices", "degree days floorspace" and "passenger miles".

In most cases the energy use per unit of activity has not been constant in the past. For instance, the energy use per unit of manufacturing output has been gradually decreasing. Our "percent reduction" applies to one chosen base year, not to the "trend" which is incorporated in the total (see Fig.A1).

A.4 Energy/GDP

In considering the total energy use of a nation, one widely used efficiency measure is "Primary Energy per unit of Gross Domestic Product". Without dwelling on the shortcomings of GDP as an indicator of economic activity (let alone of well-being), it is necessary to realise that the final outcome of Energy/GDP over time is the result of change in:

- The productive economic structure (agriculture/mining/heavy industries/light industries/services)
- Expenditure pattern (e.g. disposable private income)
- the mix of associated "activities" in terms of home heating and appliances, passenger and ton miles, industrial production, and so on.
- the end use efficiency of these various activities.
- the conversion efficiencies in the energy transformation sector (electricity generation, oil refining etc.)
- the mix of the delivered fuels (especially electricity)

Thus various trends can easily cancel each other out: for instance, improved end use efficiency in transport, domestic and industry could be offset by a higher than average growth of the electricity share, hence greater consumption of primary energy.

A.5 Conclusions

From all the above it follows that:

- the definition of conservation is arbitrary and "soft"
- the effect of energy efficiency improvements can never be precisely measured and proven in a growing and changing economy.

- conservation measures should never be considered in isolation but always in context of primary energy and against the other factors involved: raw materials, capital and labour.

APPENDIX B

INTERNATIONAL COMPARISON OF ENERGY/GDP

The way energy is used has, of course, been strongly influenced by the availability and price of the various forms of energy. Thus in countries with abundant indigenous, low-cost energy supplies, the economies of capital versus operating costs have induced a relatively casual use of energy. In countries relying mainly on importd energy, the inherent higher price has dictated more investment for a more efficient use.

Import dependent countries such as Japan, France and Germany use less energy for a comparable standard of living than countries like the U.S.A., Canada and the U.K. Calling the latter economies "wasteful" or "profligate" must not imply a moral judgement, since there were very sound economic reasons for their energy utilisations to evolve the way they have (and also some less sound regulatory reasons). It can refer only to the prospect that persistence of their present consumption patterns, in the face of higher future energy prices, could in the long run be detrimental to the functioning of their economies.

Comparison of energy use per GDP is fraught with dangers. Some of the more obvious pitfalls are:

- the climate
- the geographical make-up
- the mix of the productive economy
- the imperfection of equating effective purchasing power from one currency into another
- the imperfection of GDP itself, both in statistical definition and as a measure of economic activity and economic well-being.

Thus, simple comparison of energy/GDP between countries to indicate "profligate economies" or to indicate the scope of improvement for a country is of doubtful value.

Slightly less hazardous are international comparisons for specific industrial processes, such as energy per ton of crude steel, or energy per ton of cement. Here too, however, a careful, detailed analysis should be made to determine the actual difference in efficiency, since local circumstances - such as the use of low-grade ore, the impossibility of achieving economies of scale, the climate, etc. - are often part of the apparent difference.

The above is not meant to discredit international comparison as a learning tool, only to warn against over simplified statements. International studies can play a significant role in alerting countries to the experience gained by others, and the exchange of information on these matters is of great value.

PRIMARY ENERGY/CAPITA *versus* GDP/CAPITA IN 1973

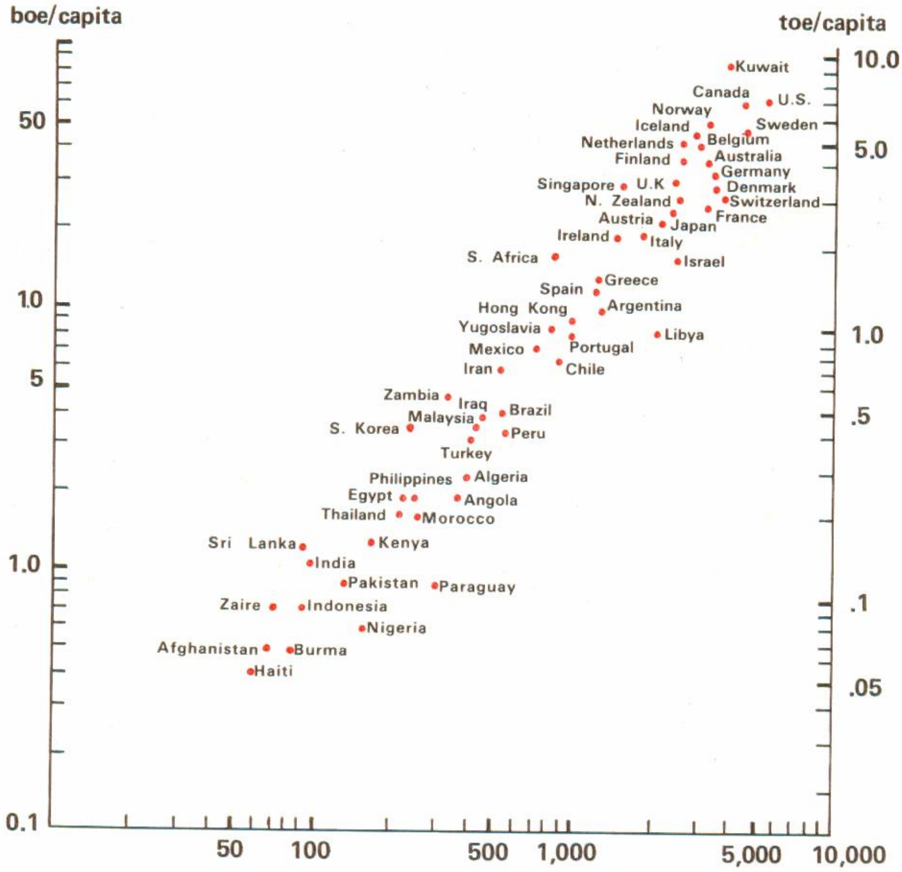

Fig. B1

Clearly there is some relation between economic activity and energy consumed. However, this is not an "iron link". Specific energy uses differ significantly for countries with a similar GDP and energy/GDP over time for any particular country can also vary.

BREAKDOWN OF ENERGY CONSUMPTION PER UNIT OF GDP BY MARKET SEGMENT 1974

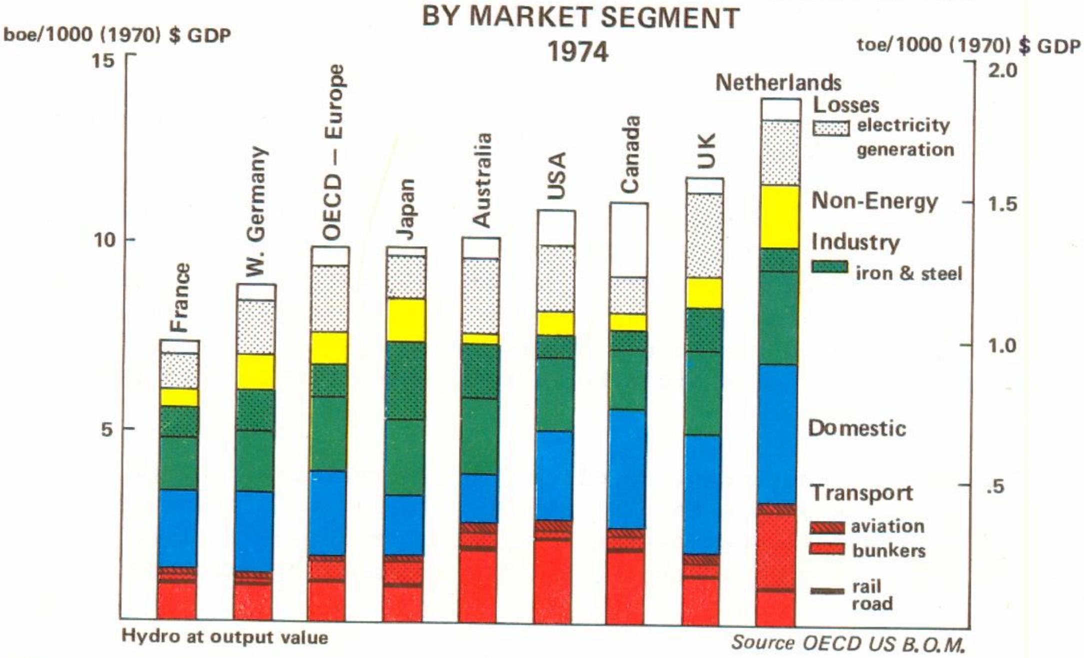

Fig. B2

Primary Energy per unit of GDP by main end use for some OECD countries. The relative height is not a conclusive measure of energy efficiency, depending as it does on the weakness of definition of GDP as an indicator for economic activity and the translation of one currency into another. The segments show how end-use can differ by country depending on climate, economic structure and usage practice.

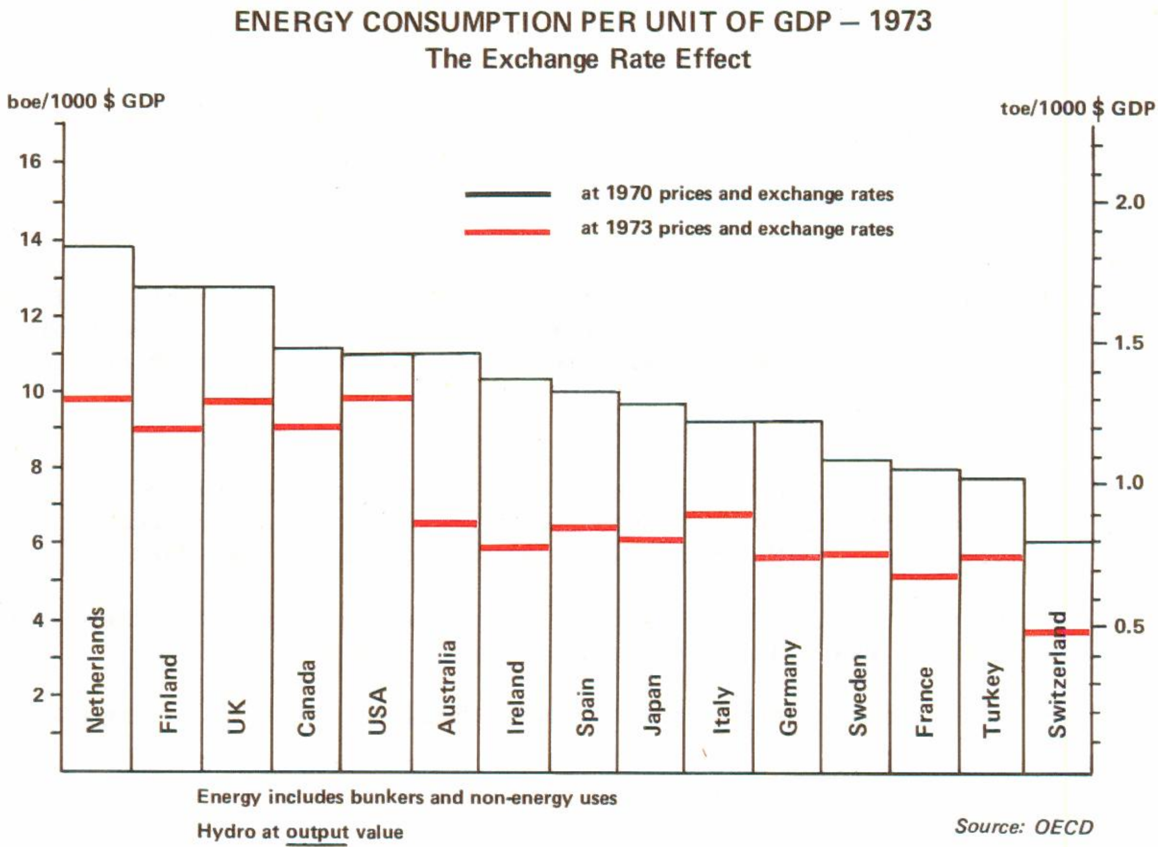

Fig. B.3
The comparison of Energy per unit of GDP between various countries is very hazardous. Apart from the defects of GDP as an economic indicator, the translation of one currency into another can hardly be meaningfully done. In the above example the relative position of the various countries changes markedly with the year of exchange rate chosen. The fact that the U.S. dollar went down against the weighted average had very little to do with energy efficiency. Translation of currencies by relative internal buying power is slightly better than by exchange rate, but even this does not remove the fundamental problem in incomparability.

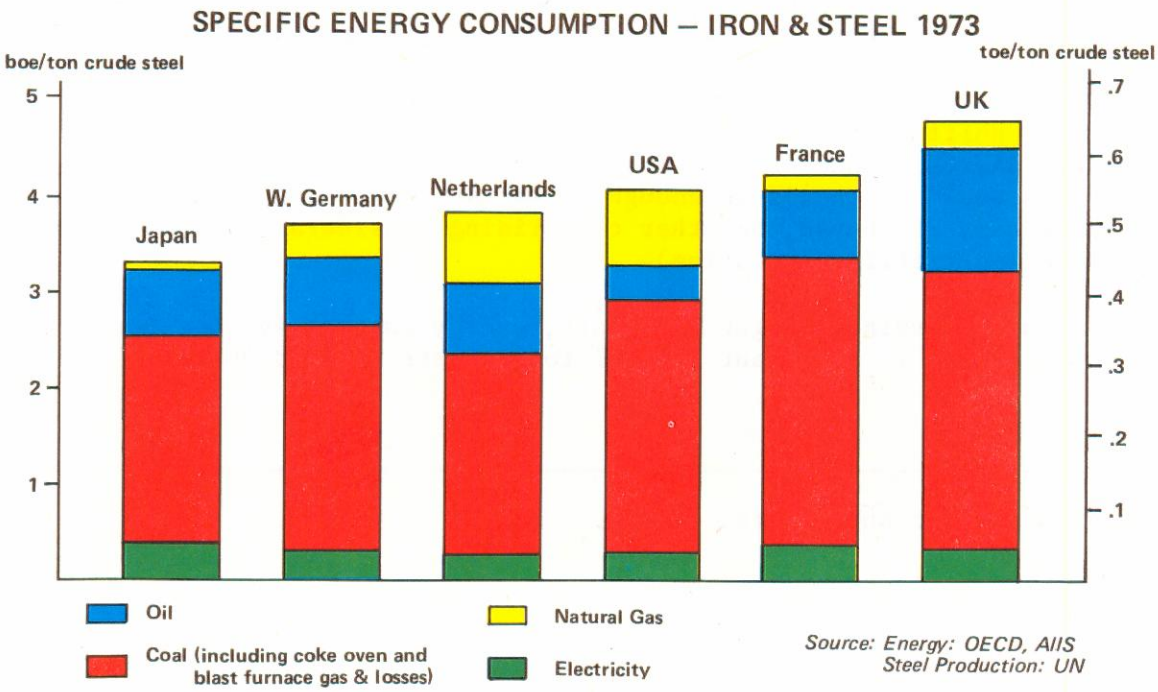

Fig B.4
An illustration of an international comparison for a specific process as an indication of the possible scope for improvements. The differences do not necessarily imply a greater efficiency but can contain local constraints such as local low grade ore, scrap ratio and ratio of continuous/discontinuous operation.

APPENDIX C

ANALYSIS BY SECTOR

1. C.1 Transport

The transport sector is in a way the easiest sector to describe, since it has one main predominant factor: the automative engine. It is, therefore, the preferred market for study and has been the subject of much analysis. For this reason we will be relatively brief on this subject.

Some important features are:

- apart from countries such as USA, Canada and Australia, the Transport sector* accounts for a relatively small proportion of total energy (W. Europe 15%, Japan 13%, versus USA 25%).

- private transport is by far the largest part of total transport (70% in USA, 53% in W. Europe, 51% in Japan).

- all transport markets are almost completely geared to liquid fuels.

C.1-a Freight

The energy intensity for moving freight is, roughly speaking, lowest for water transport (waterways, coastal and ocean), approximately equal for rail and road (with -- depending mainly on the distance and possible load factor -- a slight advantage for rail), and highest for aviation. These proportions have applied for a very long time: for this and other reasons the regional and urban infrastructures have developed in such a way that the various forms now largely have confined themselves to those fields of operations where their competitive advantage is greatest. The scope for conserving energy by shifting freight from one mode of transport to another is therefore rather limited within the existing regional and urban infrastructures. The issue most frequently discussed/debated is that of shifting freight from road to rail; but various studies and trials (e.g. USA, UK, France and Germany) have shown that resultant energy savings would not be large enough to warrant enforcing such a shift. (There can, of course, be other over-riding considerations such as road damage and traffic congestion).

In commercial freight transport, energy costs have long been recognised as an important part of total costs (around 30%)

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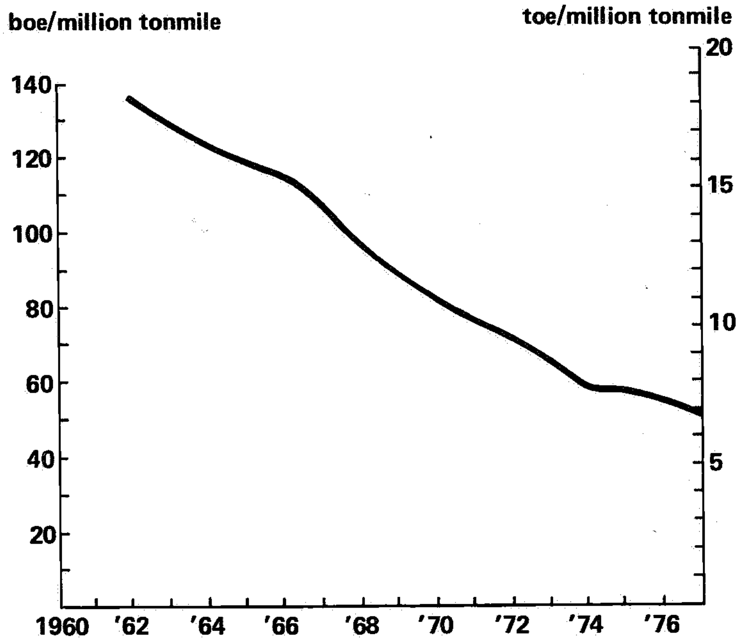
* Excluding ocean bunkers

SPECIFIC ENERGY CONSUMPTION BUNKERS
WOCA Fleet Average



Source: Energy – SIPC
Tonmiles – Fearnley & Egers, Chartering Co Ltd. Reviews

Fig C.1
Energy per ton mile has been coming down considerably for the world average merchant fleet. Contributing factors were that energy costs form a sizeable part of total shipping costs and that Very Large Crude Carriers rapidly increased their relative share of freight ton miles in the sixties.

DENSITY OF CARS
vs CONSUMER PRIVATE EXPENDITURE/CAPITA

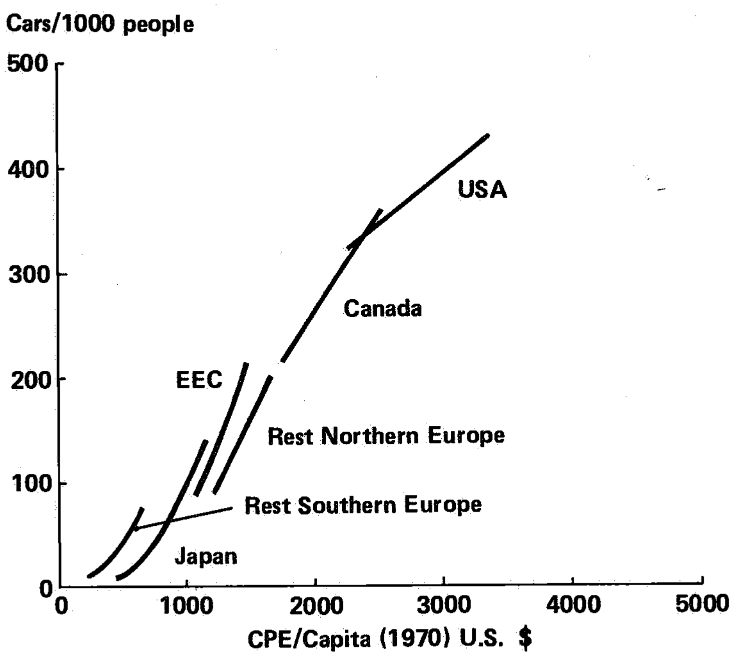


Fig C.2
The density of car population will not grow indefinitely; signs of an "S" curve are already emerging. Current estimates of "ultimate" car densities (cars/1000 people) are: USA 600, W. Europe 500, Japan 400, reflecting the geographic characteristics of these regions.

Hence significant efficiency improvements have already been made -- e.g. the high proportion of diesel engines in the commercial transport market in W. Europe and Japan. The energy per ton-mile for ocean bunkers has almost been halved in the period 1960-1975. A significant part of this is attributable to the rapid growth of the share of Very Large Crude Carriers. This growth rate will, of course, be significantly slower in future.

Lastly, there could be some thought of regulatory improvement of load factors for road freight. However, such measures could easily become counter-productive (e.g. filling up with ballast to provide an apparent full load) and a more rational scheduling of freight operations can be expected automatically from the rapid development of information processing.

C.1-b Passenger Transport

Passenger transport by sea has steadily lost ground against air transport, and is now confined mostly to pleasure cruises. Similarly, passenger transport by waterways has virtually ceased to be an alternative to other modes of transport, except for recreational purposes.

Air transport outside North America is confined largely to international flights, although the importance of domestic air traffic is growing, in all regions including non-OECD areas. In the technical sense, estimates for energy efficiency improvements are the same as those for freight, since both passengers and freight are often carried together. Significant scope for improvement of the specific fuel consumption would result from an increase in average load factor, which -- on international scheduled flights -- can be as low as 50 per cent.

However, national airlines are often created for prestige rather than economic reasons, and this inhibits the rationalisation of international scheduled flights. Morever low load factors are inherent in scheduled mass transport, if the frequency is to be such that passengers can fly at their own convenience rather than the carrier's.

Thus, despite the significant improvement in load factor of domestic and intra-European flights since 1973, and the current upsurge on the Atlantic routes as a result of the new low special tariffs, there could be a slight deterioration -- rather than an improvement -- in the medium term. Given the high component of fuel costs in airlines' total costs, one can expect a continuation of efforts to optimise future energy use, within other operational constraints.

Focusing now on land transport, one immediately runs into the controversy of public versus private transport -- a question that has many socio-political overtones, and goes well beyond the issue of energy conservation (although the conservation issue has been welcomed by the proponents of subsidised public transport as an argument in its favour). Without giving judgement on the non-energy issues (such as traffic congestion, noise and air pollution, traffic accidents and the desirability of offering tansport to everyone -- including those who

ENERGY INTENSITY OF VARIOUS FORMS OF TRANSPORT AT FULL LOAD

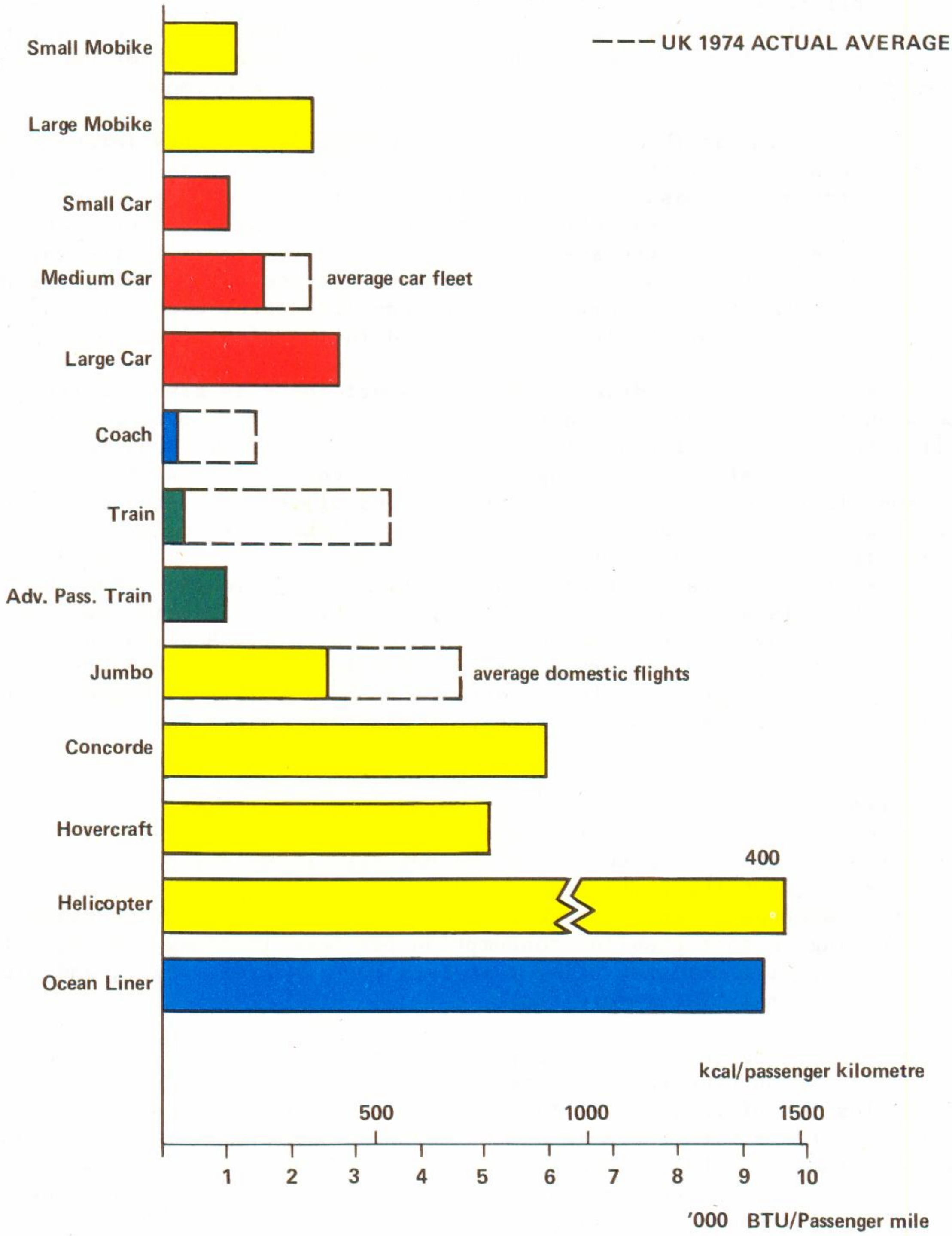


Fig C.3
Various modes of transport differ greatly in their energy intensity. At full load, trains and buses are the most efficient. The trade-off between frequency of public service and load factors, however, generally leads to low load factors, if scheduled services are to compete with the instant availability of the private car. As an illustration, estimates are shown for the UK in 1974. The estimated total primary fuel consumed by passenger cars, buses and coaches, rail (including London Underground) and domestic flights divided by the estimated passenger miles by sector, gives an indication of overall fuel efficiency. The scheduled services clearly suffer from low load factors, while not offering comparable service in terms of instantly available "door-to-door" transport.

In built-up, high density areas and along commuter lines, the specific efficiencies of scheduled transport can, of course, be much higher.

cannot afford a private car), it should be noted that the public bus and train are not necessarily more energy efficient than the private motor car. In fact, in many cases, scheduled mass transport systems emerge as somewhat less energy efficient than priviate or charter modes.

The reason for this lies in the following. The energy intensity of the various modes of transport (see fig. C.3) at full load shows how a train carrying 450 passengers and a bus carrying 45 passengers are significantly more energy efficient than a car containing four people. This is the origin of the statement that public transport is the more energy efficient. Thus a chartered sight-seeing coach 75% full will use only 25% of the fuel consumed by 15 medium-sized cars, each carrying two-and-a-half people (fairly typical load factors for pleasure trips).

However, for scheduled public transport there is always a trade-off between frequency and load factor. Frequent, inter-connecting services offer the passenger transport according to his own logic, and the potential discomfort of waiting for the next connection can be kept within reasonable boundaries. But high frequencies almost automatically reduce the load factor, often to very low levels (10% or less during off-peak times is not uncommon). Offering less frequent services will tend to increase the load factor (and hence the energy efficiency) if no alternative is available, but too infrequent or erratic services will discourage many people from making a journey at all. Hence with the advent of the private motorbike and automobile, which offer door-to-door transport -- at the traveller's rather than a time-table's logic -- the relative proportion of public transport passenger miles has been steadily falling.

From the available statistics, no one can doubt that the value of private transport is very high to the consumer. In Scandinavia, there has long been a substantial surtax on the new cars (from 80% in Sweden to 170% in Denmark), but the number of cars per person is yet slightly above the European average (even if corrected for GDP/head). The Danish example is interesting in that gasoline consumption per head is among the highest in Europe, one of the causes being that cars have to last longer, and old cars consume relatively more fuel.

Thus, those in favour of a policy promoting scheduled public mass transit systems (generally taking the form of an enforced fee from subsidies out of tax, and of tax and physical impediments against the private car) -- with the sole aim of conserving energy - should realise that, although probably successful in reducing somewhat the growth of gasoline and diesel consumption, it will do so mainly by slowing down the growth in passenger miles (i.e. through types (1) and (2), rather than (3), in our earlier sub-division in Chapter II on page 2). It can also expect a mixed reception from the electorate.

The above considerations are included to help clarify the energy issues in the scheduled public/private transport debate. This essay does not venture any judgement beyond this -- apart from the observation that mass transit systems have their greatest scope in high population desity areas, on the main commuter routes, and on the medium Inter-City haul, and that objections against the private car (and unlimited travel as such) have their greatest justification in environmental considerations.

Unscheduled public transport, such as taxis, are an important intermediate between scheduled and private transport. Taxis, being commercial vehicles, have a high proportion of diesel engines, and, being used predominantly in towns, could improve the average energy consumption per passenger mile by substituting for private gasoline car miles. Such towns that limit access to taxis to specific taxi-bays only, could think of allowing taxis to be flagged in the street, thereby enhancing the chance of the traveller to obtain transport when he wants it and thus his willingness to leave his own car at home.

Car pooling and minibus services, aimed at increasing the load factor of commuter cars, are essentially voluntary ventures. Apart from removing some potential insurance and/or income tax problems, there seems little that regulation could achieve. Such propositions as limiting access to towns to cars carrying three or more persons only, would, apart from being highly unpopular, probably merely give rise to a booming "rent a passenger" industry.

The introduction of national highway speed limits has produced less effect on energy consumption than was expected (however, the number of traffic accidents fell more than expected in the US). This was not just due to the fact that these limits are "less than universally observed", but is mainly caused by the circumstance that almost half of the car trips are made within the confines of built up areas, where speed limits were already in place (60% of all car trips in the UK in 1973 were less than 5 miles). A further lowering of speed limits could be expected to provide very little scope for further overall savings.

Attempting an objective assessment of the next ten years from the above it is felt that the greatest scope for energy savings in passenger land transport lies in formulating performance standards for cars (in due consultation with the manufacturers) and requiring clear sales information on specific consumption -- as is now well underway in most OECD countries. It is interesting to note that the US car manufacturers, although naturally fighting against being regulated, are in fact ahead of the targets set.

Technical scope for improvement of the gasoline car is indeed significant, not only in the US where it is greatest, but also in W.Europe and even in Japan where specific consumption is currently lowest. For Western Europe, figures now quoted for potential improvement in miles per gallon lie in the range of 30-50%.

This significant scope for improvement of the gasoline car places a question mark against the prediction that diesel engines are the most attractive option to aim for. The average passenger diesel car now has a clear edge of some 30-40% over the gasoline engine under varying local conditions in town traffic, although for long-haul motorway traffic this advantage is not more than say 5-10%. (These figures relate to energy rather than volume per car mile and incorporate the higher refining loss of gasoline versus diesel fuel). Further scope for improving the diesel engine is thought to be much more limited than that of the gasoline engine.

In addition, there are intrinsic features of the diesel engine that detract from its relative fuel economy advantages. These include: higher first cost; noisier operation; a tendancy to produce more visible and odorous exhaust fumes, which -- while lower in carbon monoxide and unburnt hydrocarbons than gasoline exhaust - contain higher levels of nitrogen oxides; a greater engine weight for the same acceleration performance in comparison with the gasoline engine, which lowers the fuel economy advantage of the diesel to 10-15% on an equal acceleration potential basis. For these reasons, current favourable developments in Western Europe for diesel passenger cars may not necessarily be sustained. For the car buyer the economics dictating the choice of a gasoline or a diesel car can overridingly be determined by tax considerations, since gasoline sales tax can account for over half of the sales price.

Hence fuel sales tax, more than fuel economics, will probably direct any shift to diesel. Currently existing tax regimes should therefore be re-examined, assessing whether they provide the right sort of incentive (either favouring or discouraging diesel passenger cars) that is consistent with the consensus aim: optimising fuel economics, minimising noise and fume effluents, or maximising sales tax revenue.

Although the Scandinavian example illustrates that the car cannot be taxed away, nevertheless a car tax regime can have an influence on the composition of the incremental car fleet.

A selective car sales tax (and/or road licence tax) favouring the better performance cars can supplement mandatory sales information on specific fuel consumption. Car tax by weight can have its influence too, although in Europe a shift toward larger cars is developing that may be difficult to stem.

In summary, the main policy instrument for achieving conservation in land transport is improving the performance of cars, the following means for which seem to be the most appropriate:

- a mandatory display of sales information on performance
- selective car sales tax, favouring the better performance models
- agreeing and setting performance norms and standards

Current estimates of the scope for further technical improvements (as compared with 1973) can be summarised as follows:

Passenger Cars	Per Cent
engine	15
transmission	5
lubricants	5
design: weight, drag reduction, etc.	15
Total*	35

* Percentage savings are not linearly cumulative

Trucks and Buses	
engine	5
weight reduction	5
reduced air drag using a deflection foil	5
Total*	14
Trains	10
Ships	
engines	15
drag reduction by anti-fouling paints	15
other	5
Total*	31
Aviation	
engines	15
component efficiency	5
drag reduction/improved aerodynamics/ weight reduction	10
Total*	27

Lastly, we should mention the possible impact on travel of the rapid evolution of communication systems. Features such as "confravision", facsimile transmission and interlinked data systems could greatly reduce the need for business travel and, possibly, even for commuting, by allowing much office work to be done at home. Provisional essays on this subject generally highlight the need for personal contact in many transactions, and suggest that improved communications could spark off an even greater demand for physical travel as it opens up more business opportunies, in the same way as telephone and TV are believed to have stimulated rather than reduced travel in the past. At this moment in time, where both the rate of introduction of new communication systems and of their future utilisation are difficult to assess, all that can be said is that development plans for costly transport infrastructures should maintain an awareness of the possible impact of the communications revolution on their business.

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* Percentage savings are not linearly cumulative

C.2 Industry

The very significant spread in energy intensity (i.e. the energy consumption per unit output) of industrial sectors (see fig. C4) is a reflection of the diversity of items manufactured and the processes employed in their production. The primary transformation (heavy) industries -- basic metals, minerals including glass, bricks and cement, and chemicals -- are the most energy-intensive sectors in most countries. The remaining fabrication industries are less so, although individual component industries within these aggregated sectors, can have significantly higher energy intensities than the average: e.g. the pulp and paper-making industry included under paper etc., and the texile dyeing and finishing industry included under textiles etc. in fig. C.4. From the breakdown of output and energy consumption by industry sector (fig. C.5), it is apparent that heavy industries account for some 20% of output, but consume over 50% of delivered energy. For this reason, these industries are the first to be considered in conservation studies, although the importance of energy as an element in their manufacturing costs will largely have ensured that considerable attention has already been given to improving their energy utilisation even before 1973. Indeed, delivered energy per unit of manufacturing output for total industry has been continuously decreasing in the OECD regions. This reduction is the result of three factors:

a) the declining share of heavy industry's contribution to total manufacturing output,

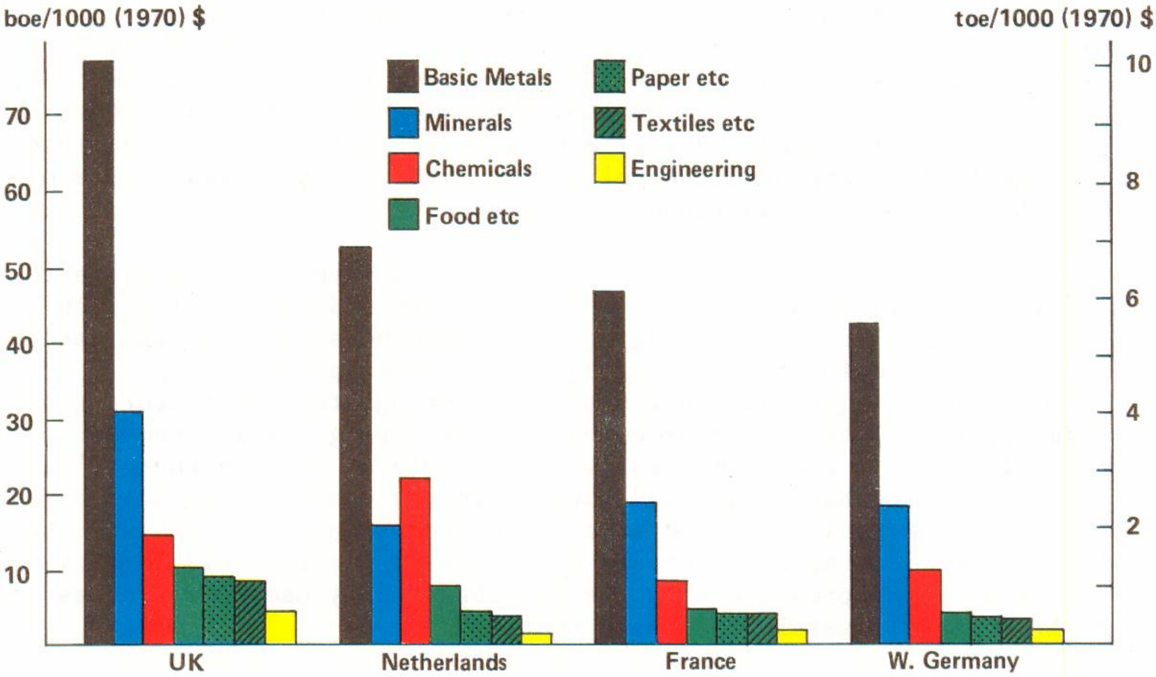
b) substitution of coal burning boilers by more efficient oil and gas-fired installations (a trend which has had a significant impact in overall fuel consumption in industry because of the high proportion of delivered energy consumed in steam generation).

c) introduction of new processes which -- for the heavy energy intensive industries -- are likely to have been optimised for efficient energy use as well as for other cost elements. (For the less energy-intensive industries prior to 1973, process developments were usually predominantly aimed at reducing other cost elements, mostly labour, although some reappraisal of priorities has occurred since then).

These sustained improvements in industrial energy performance prior to 1973 were achieved during a period when energy prices were falling in real terms, and the incentive to conserve energy might have been expected to decline.

Energy use in the heavy industries is often associated with direct process heating, and as such can be linked to large capital-intensive equipment which will tend to have long lifetimes. In such cases, the main opportunity for conservation arises from retrofit of energy-saving devices associated with improved process control, fuel substitution, waste heat recovery etc. For lighter industry, steam-raising and space heating often constitute the largest end uses. Further improvements in energy use in

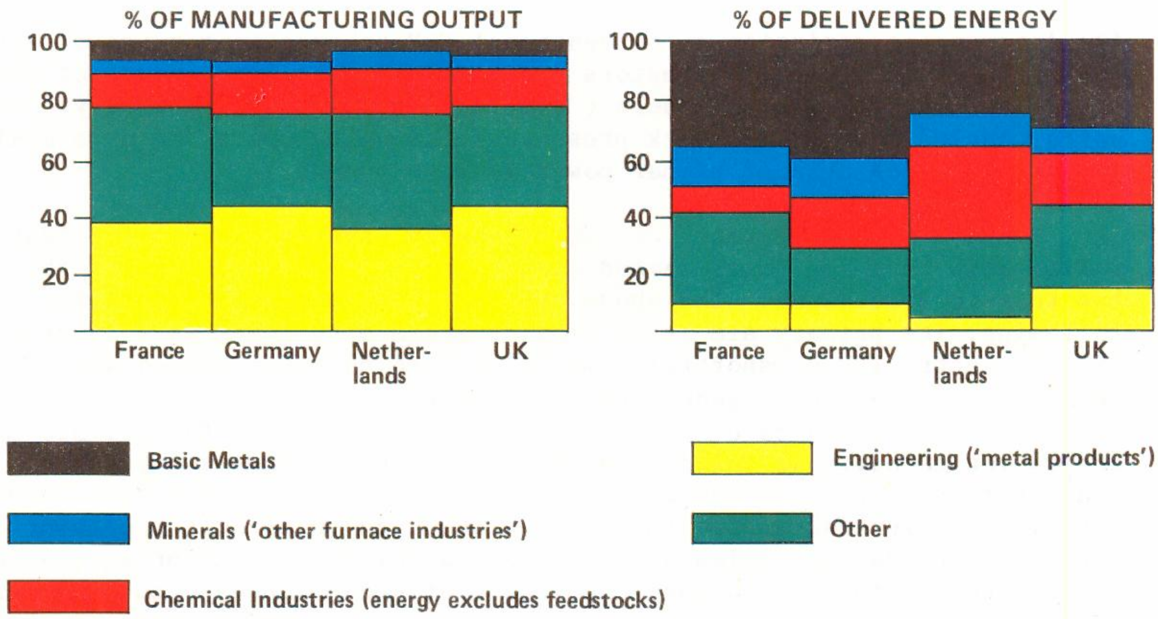
ENERGY INTENSITY OF VARIOUS TYPES OF INDUSTRY 1970



Source: Eurostat

Fig. C.4
The energy intensity of the various branches of industry: delivered energy per unit of manufacturing output value. This energy is the so-called "direct" energy and does not include energy consumed in building production facilities.

BREAKDOWN OF OUTPUT AND ENERGY CONSUMPTION IN INDUSTRY 1970



Source: Eurostat

Fig. C.5
Due to the very different energy intensities (Fig. C.4) of various industries one fifth of the output consumes over half of the delivered energy. Thus, the greatest scope for conservation lies in this sector. But significant improvements had already been made before 1973 and the medium term growth prospects for the basic industries is currently not bright, limiting the impact of new, much more efficient plants.

steam-raising are possible by improved instrumentation and control of systems. With space heating, the main constraint on energy conservation is the design of buildings and their use for operations for which they were not originally intended (e.g., factories in which all activities are performed within 12 feet of the floor, and yet the roof is 30 feet high). Savings on space heating are made by improving insulation and reducing draughts, selecting the heating techniques appropriate to the activity being performed, improved control of the system, and increased use of waste heat from the associated processes.

A great potential for conservation exists when it is possible to integrate energy demand in various parts of an industrial site. In principle, this involves arranging energy demand so that an appropriate use can be found for the energy rejected by each process step, as it gradually becomes degraded while passing through the manufacturing system (from the high intensity source that exists during initial combustion of the fuel, down to low-grade heat). An example of such an energy 'cascade' is the use of combined heat and power. In the conventional set-up for this process a fuel is burned in a boiler to produce high-pressure steam, which in part is expanded through a turbine to generate electricity, and -- as medium/low pressure steam -- is subsequently used for process heating, and ultimately for space heating.

The use of such systems has been limited by two major constraints:

a) the capital cost, per kilowatt installed, of small units is prohibitive

b) the percentage of heat input converted to electricity is low, and is less as the required process steam temperature increases; thus there must be a large steam demand in order to make "back-pressuring" worthwhile, which limits its use to large factories.

(An interesting variation on conventional CHP schemes is the use of gas turbines as the primary combustors which utilise the free energy of the high flame temperatures of fuels (2000 C) to generate electricity. Such units coupled to pass out/back pressure steam units operating at a maximum of 590 C, are capable of higher power to heat output.)

Since a "co-generation" or "total energy" system cannot efficiently follow both heat and power demand simultaneously, one or other of the two has to take precedence. The above system is essentially heat load following: its primary aim is to provide steam with power as a by-product. Excess electricity or shortfalls would have to be interchanged with the public grid. Centrally generated power is generally either not taxed or taxed at a "utility" rate, whereas the return on capital for private power generation capacity is taxed at a 40% to 50% rate. Thus the private generator is at a disadvantage which in many cases is prohibitive. This condition is generally also the root of the industrialist's complaint that the price central utilities are prepared to pay for excess privately generated power is too low to make combined heat and power systems worthwhile.

Another form of co-generation is the use of natural gas, or other suitable premium fuels, in internal combustion engines where the high specific heat fuel is used to generate power at a high efficiency -- in smaller unit sizes and with higher power to heat ratios -- and the heat, produced as a by-product, used for low temperature heat processes. The greatest virtue of this form of on-site power generation is that its unit size allows the use of multiple units to follow a factory's power demand and no excess electricity needs to be sold externally. This makes it also suitable for installation in large commercial buildings and office blocks. These systems can be designed to have reliability equal to that of the public grid system.

Although the anticipated potential for energy conservation from using small unit internal combustion engines is significant, some major reservations on the part of industrial operators will have to be overcome:

- excess heat could be sold to other buildings or industries, but there is generally a reluctance to be dependent on other factories for the purchase of heat. This confines the utilisation of waste heat to applications within the same plant

- there is a general reluctance to be completely independent of the public grid, as this places the full responsibility for failures of the power supply within the plant

- there is a general reluctance to invest in equipment which does not increase production in the eye of the industrialist

Outside energy management services could be instrumental in overcoming these barriers.

A striking example of how important reliability can be to industralists was the surge in private stand-by generating capacity in the U.K. in 1974, as a response to the industrial unrest in the public power utilities. This private stand-by capacity was purely seen as an insurance premium against possible cut-offs, and their anticipated rate of actual utilization was very low and hence uneconomic. However, the cost of not being able to operate a factory is so great that the purchase of (idle) generating capacity is seen as a worthwhile insurance premium. This illustrates the minor part energy investment cost plays in most industries. (In this context it should be noted that if firms are less concerned about marginal reductions in energy costs than about flexibility of energy sources in production, this may well have a serious negative influence on conservation.)

With the recent rises in energy costs, it might be expected that industry now has a greater incentive to conserve energy. In reality, many industries feel that the increase in fuel prices has been eroded by subsequent rises in raw material and labour costs to the extent that the balance of production costs in some cases is now not very different from to that which existed before the 1973 oil crisis. What the price rise did accomplish was to highlight the need to conserve energy and to stimulate industry's interest in savings opportunities. Even when apparently attractive proposals are considered, however, economic constraints limit those that are acceptable. Such constraints are:

a) the capital outlay on any one project must be only a minor part of the total capital available regardless of the return and pay-out time

b) expenditure on cost-saving measures come secondary to strategic market share capex, and the pay-back requirements demanded of them are often much more severe (typically cost-saving measures are discounted over 1-4 years, as opposed to 15 years for other ventures)

c) the main burden of energy conserving investment falls on heavy industries that probably have a depressed decade ahead in most OECD countries with little money to spare for such expenditures

In general, the scope for conservation in industry is large and awareness is fairly high, but concern and know-how are still rather limited.

C.3 The Domestic Sector

C.3a General Observations

The domestic sector covers energy used in all non-industrial buildings. One of its most important features is that buildings and houses have very long lifetimes, generally some 25 to 80 years. The need for retrofitting is therefore essential, because -- even if stricter building regulations ensured that new buildings used only half as much energy as the 1973 average -- the percentage reduction in energy use by the overall building stock can change only gradually.

For example, if one assumes that a gradual retrofitting programme reduced energy consumption in existing buildings by some 20% between 1975 and 1985 and that building regulations cut the consumption of new stock built after 1980 by half (which is quite feasible), by the turn of the century, the average housing stock will have achieved only half of its ultimate savings potential, due to the slow rate of replacement of existing buildings and relatively slow construction of new units. Thus, investment-type measures - although the best solution in the long-term - cannot bring quick results in this sector (See Fig. C.7).

C.3b Thermal Comfort

Looking at domestic energy use in the USA and mid-Western Europe, some 60-70% is used for space heating and another 10% for providing hot water. The first item to be considered, therefore, is space heating.*

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* Heating demand may saturate, but then cooling/air conditioning could become important - particularly in faster growing areas like southern US, OPEC, etc. Economic development so far has overwhelmingly taken place in temperate regions, but we expect future development to be faster in sub-tropical/tropical area. There, cooling rather than heating should be considered.

TURNOVER OF HOUSING STOCK – EEC

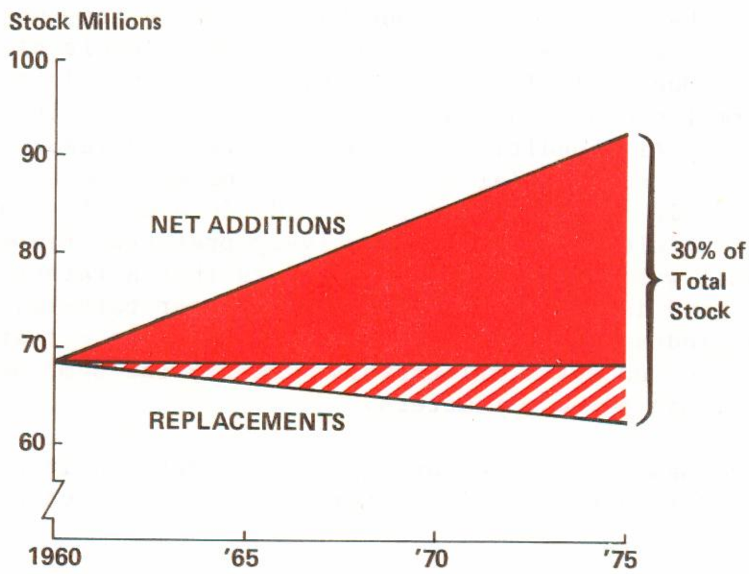

Fig. C.6
A third of the Residential housing stock in the EEC was built in the sixties and early seventies, when energy prices were falling. The high housing growth of this period has left an inheritance of very low energy efficiency that will last for the rest of this century. In the same period anticipatory legislation provided Scandinavian countries with high insulation homes that require a similar consumption per household as in the EEC, notwithstanding the much colder climate.

EXAMPLE OF THE INFLUENCE OF EXISTING INFRASTRUCTURE ON THE AVERAGE SAVINGS FACTOR – RESIDENTIAL MARKET

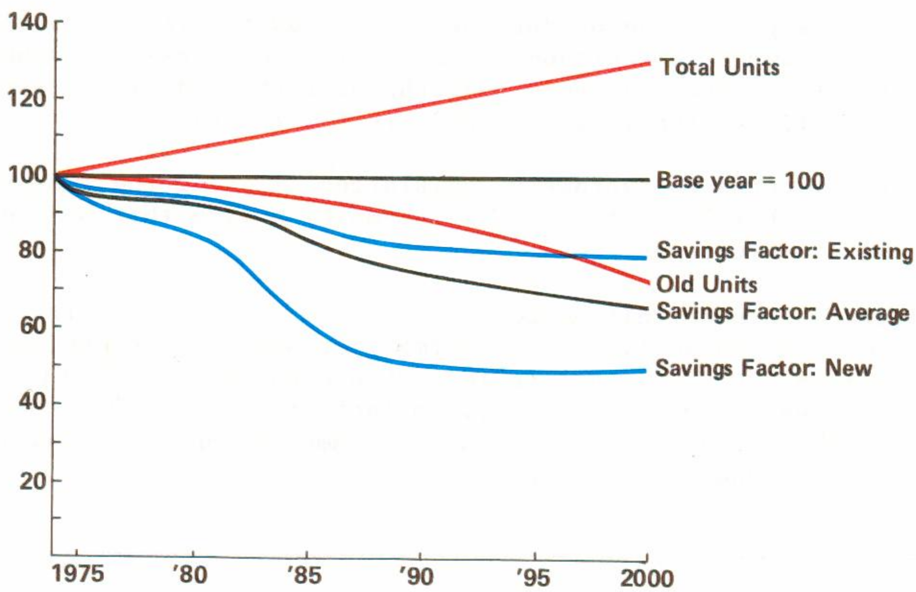

Fig. C.7
The very long lifetimes of buildings make for a slow impact of new efficient houses. Shown are for Western Europe the total number of dwelling units together with the remainder of old units existing in 1973. By the turn of the century more than half of the 1973 stock will still be consuming energy. Assuming that this existing infrastructure can be improved by 20% and that a new unit will consume 50% of the average unit in 1973 by 1985, then, by 2000, the average unit will display an improvement against 1973 of only 30% whilst still changing.

Domestic heating energy is purchased not for its own sake, nor even for the heat it contains, but for the preferred levels of thermal comfort it provides. Hence, it is essential to look at the ultimate relationship between thermal comfort and energy. Research done at the Danish Laboratory for Heating and Air-Conditioning found interesting results which corroborated the substantial body of existing knowledge on this subject. By testing people from all over the world, in a similar environment and wearing uniform clothing, the subjectively preferred temperature range of the individual was established. It appears that a rather narrow temperature band is generally preferred. Winter bathers, workers from the meat-packing industry and inhabitants of the Sahara - tested without being acclimatised to Denmark - all expressed nearly the same narrow range of preference within given parameters.

The findings of this research can be summarised in a comfort diagram. There are four parameters which determine the preferred ambient temperature:

- body and mental activity
- degree of insulation of clothes
- the air speed
- air humidity

In static indoor conditions (no draught), humidity is the least sensitive parameter. If, moreover, it is assumed that the mean radiant temperature equals the air temperature* and that draught proofing has reduced air speed to negligible levels, then the two main parameters left are the thermal resistance of clothing and the body and mental activity. The "Fanger Chart" shown (see fig. C.8) indicates several interesting lessons:

- with a projection of current trends towards lighter weight clothing and a continued increase in sedentary as opposed to physical work, one sees that the ultimately desired temperature will lie in the range of 22-24 C (72-75 F).

- hence current government legislation limiting the temperature in public buildings to 20 C is stemming a tide that has not yet run its full course.

- there is a definite upper limit to subjectively desired temperature for a given activity and thermal resistance of clothing, hence demand for space heating fuel should not be expected to grow exponentially indefinitely. In fact, there are clear signs that demand for space heating in North America and Scandinavia is slowing down and "plateauing".

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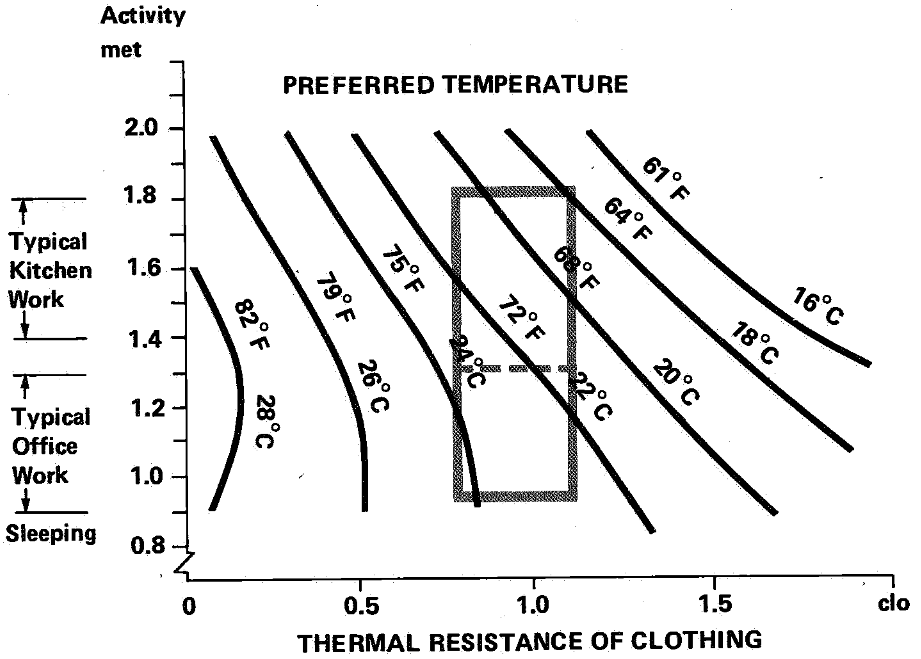
* it should be noted that the preferred air temperature can be significantly lowered by increasing the mean radiant temperature; e.g. in Industry "heating the man" by some radiant source can allow significantly lower air temperatures in assembly halls.

SUBJECTIVE PREFERENCE OF THERMAL COMFORT



Source: "Thermal Comfort", P.O. Fanger

Fig. C.8
The two major parameters of preferred ambient temperature for subjective individual thermal comfort are the thermal resistance of clothing and the degree of bodily activity (airspeed negligible, mean radiant temperature equal to air temperature). The box indicates the anticipated average thermal resistance of clothing projecting present trends, the dotted line indicates the area for sedentary activities (such as watching TV), the proportion of which is still increasing. The preferred temperature of 21–24 degrees Centigrade is well above the 20 degrees Centrigrade currently prescribed in some countries.

ENERGY SAVINGS ESTIMATES – WESTERN EUROPE
% Reduction from 1973 practice

	Technical Potential	1976	1985	2000
TRANSPORT				
Cars	20–35	3–5	5–20	15–25
Trucks	10–15	0–2	2–5	5–10
Ships	30–40	4–6	5–10	10–25
Aircraft	20–30	5–7	5–20	10–25
INDUSTRY				
Iron & steel	25–35	0	10–15	15–30
Other furnace	25–35	3–5	10–20	15–30
Chemicals (fuel)	15–25	0–2	5–15	15–20
Other	20–35	4–8	10–15	15–25
DOMESTIC				
Residential	40–60	3–10	10–20	20–40
Comm/Public	40–50	3–6	10–15	15–35

Fig. C.9
A brief summary of the potential of Energy Conservation in Western Europe. These estimates relate to the reduction of specific energy consumption of the average stock as compared to 1973 and assume that no quality improvements would occur. (e.g. no higher indoors temperatures).

- human beings are very adaptable: by increasing the clothing value of 1 clo * (representing the Western European business suit) to a 1.5 by wearing thicker underwear, a waistcoat and/or cardigan and thicker socks, the preferred temperature could be lowered to around 18 C (64 F). However, under circumstances of increasing affluence exhortations for wearing higher resistance clothing will probably be as ineffective as, for instance, the offical exhortations to close curtains at night in the Netherlands. Research in high insulation lightweight clothing (providing sufficient ventilation) might perhaps be seen as a promising proposition.

Since each degree centigrade of indoor temperature amounts to roughly 5-10% of space heat consumption in mid-Western Europe, the inclusion of future indoor temperatures in considerations of energy conservation is clearly essential.

C.3c The Commerical/Public Sector

Non-industrial buildings fall into two broad categories: commerical/public buildings and residential buildings.

Commercial/public buildings (offices, shops, warehouses, schools, hotels, hospitals, churches etc.,) differ widely in the services they provide; but, in principle, they can all be expected to evaluate their costs in the same way as industry.

A significant improvement in this sector could be expected from heat management in large office blocks, or for instance hospitals, where an "energy manager" would earn his keep by continually watching costs. This sector is a typical example of a business opportunity: heat management services and consultancies seeking out customers would greatly accelerate the introduction of energy-saving equipment and, for instance, by heat management contracts, would ensure a continued rational and economic operation.

C.3d The Residential Sector

The residential sector is occupied by private individuals. The two main distinctions to be made in this sector are:

a) The percentage of owner-occupiers versus tenants
b) The percentage of individually heated houses versus collectively heated houses

Collectively heated blocks of dwellings have the attraction of one common investment in the heating equipment, and hence shared cost of the investment. However, where the collectively provided heat is not individually metered, profligate use of energy can easily occur. An

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* the thermal resistance of clothing is indicated by its "clo" value. A Western business suit without waistcoat has a value of roughly 1 clo.

example is Sweden, where the collective heating of houses is very popular, and where collective metering is considered to be preferable for social reasons. Control of the indoor temperature is frequently achieved by opening windows, thereby increasing the energy use per dwelling unit to levels well above that of individually heated houses.

The issue of collective versus individual heating is clouded by the following features:

a) collective heating is mostly confined to apartments in tower flat blocks. The space heat demand of such apartments is intrinsically lower than that of detached houses, due to their lower outer-skin/volume ratio. Thus, when comparing collective with individual heating "averages", one is often comparing like with unlike

b) collective heating is often not individually metered and, as a result, is not sparingly used.

This makes a proper assessment of the energy efficiency of collective versus individual heating systems very difficult from the currently available statistics. The feeling of many fuel marketers is that individual boilers are by and large more efficient due to their individual load following capabilities. This, combined with the difficulty of properly metering heat, is an argument in favour of individual heating systems. However, a central boiler provides, in theory, a greater flexibility as to fuels and would facilitate professional heat management. The question of metering is not in doubt: individual metering solicits a much more rational energy utilisation.

The distinction of owner-occupier and tenant is meaningful if we consider the conflict of interest between the landlord who, in principle, pays for the capital investment in heating equipment, and the tenant who pays the running costs.* The introduction of more energy efficient equipment is inhibited because the investor is asked to pay a higher capital cost to achieve the advantage of lower running costs for someone else - a conflict of interest that is increasingly being recognised. Sometimes it is in the owner's interest to ensure that rented buildings are well heated in order to prevent condensation and deterioration of the fabric, and this my be another reason to install collective heating, allowing the tenant no choice in the matter of heating his house.

Looking now more specifically at the owner-occupier part of the housing stock, there are some important observations to be made.

The low income groups and first time buyers tend to be fully stretched in mortgage terms with little flexibility to raise more capital for investment in energy conservation measures which would reduce operating costs. (This is reflected in the tendency to prefer low capital cost/high running

* A recent example was given in several London council housing estates, where electrical resistance heating was installed because of its low cost, and the tenants now find it difficult to pay the sharply increased electricity bills.

cost - type of equipment).

The high income groups, on the other hand, are better placed to raise capital through building societies and/or banks and could possibly gain favourable tax advantages on the interest paid, but may not feel disposed to raise capital to reduce operating costs which are a relatively small proportion of their spending power. On the other hand, a considerable portion of total residential energy is used by the middle to higher income groups. Hence tax rebates for interest paid on loans for energy saving equipment can be very effective for higher income groups (because of their higher marginal tax rates), and - although there might be resistance to giving "unfair advantage" to these income groups - this would be an effective way to reduce energy consumption. Means of making cheap capital or easy purchasing measures (hire purchase, mortgaging, leasing) available to all income groups is necessary if significant conservation measures are to be undertaken.

Retrofit investments are often not privately mortgageable as such. Once a conservation measure has been applied to a house - and provided it increases the value of the house to prospective buyers - this added value can be taken up in the new buyer's mortgage. At present, home loans are often not readily available just for energy improving investments.

The time horizon for investment decisions is usually much shorter than the lifetime of the resultant asset. It could, for example, be argued that the investment in insulation should be spread out over the full physical lifetime of the asset, i.e. 80+ years. In real life, however, this is meaningless. Where the longest term for a mortgage is about 30 years, it would seem reasonable to amortise the investment cost of insulation over 25 years. In practice, however, most people insist on a typical pay-out time of only two years. (This very important aspect is discussed in Chapters III and IV).

Finally, the fashion and status content of goods bought is often as important as their primary function. In California, for example, every fifth house is reputed to have a solar panel - although the economics of solar heating, even in sunny California, are not all that favourable, but an energy panel on the roof is visible to the neighbours.* It is not possible to assess the fashion and status components that should be added to any simple economic evaluation of energy-saving equipment. However, it is important to recognise that these considerations might override any others.

<u>It must be easy to get things done.</u> Currently there are many suppliers competing for the consumers' attention to deliver energy. However, there are not as yet many energy saving salesmen, apart from some insulation companies and some double glazing dealers. It must, therefore, be seen as a significant opportunity to get energy conservation going in the domestic sector, by allowing and encouraging it to be developed as a business opportunity.

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* the "solar boom" in California started off with the ban on use of gas for heating swimming pools, and most solar panels there are probably limited to this application.

APPENDIX D

SUMMARY OF CONSERVATION MEASURES

The possible alternative options available today for energy conservation are legion; many more will doubtless be forthcoming from research and development, which has greatly increased since 1973, and an exhaustive list of currently known options would be prohibitively long. Therefore, the following lists only a few of the more effective measures by market sector, plus some measures which we perceive to be less promising, but which are often presented as attractive. Let us first consider those measures which together - if implemented against sound economic criteria, including the current energy price - would ensure a reduction in overall energy per unit of activity of the order of 15 to 30%.

SOME ATTRACTIVE OPTIONS

TRANSPORT

Road Transport

- improved engine design (possibly involving lean burn/high compression units or stratified charge engines) and improved engine matching to the performance required.

- further use of diesel engines in passenger cars and small trucks.

- better control systems for engine operation and the development of improved transmission.

- weight reduction through materials substitution and improved design.

- reduction in rolling friction and air drag by improved tyre design and better aerodynamics.

- other energy saving developments including regenerative braking using, for example, flywheels as storage devices; improved fuels and lubricants etc.; new engine concepts and applications; use of micro processors for improved ignition, transmission etc., and as an aid to improved driving habits.

- developments in traffic control systems and road design.

Other Transport

- weight reduction through materials substitution and improved design.

- improvements in engine technology, e.g. further development and application of high by-pass ratio jet engines

- reduction in drag by improving the surface finish of ships' hulls and the development of improved aircraft wing designs incorporating changes in aerofoil section and laminar flow control etc.

INDUSTRY

- Choice of the most up-to-date process in new factories
  The greatest scope for savings must be expected from new processes, or simply by ensuring that for new factories the most up-to-date process is selected. A proper choice between major technological alternatives could lead to much more significant energy saving than just better industrial housekeeping. Ready examples are the oxygen steelmaking process, the dry versus wet process in cement manufacture, the tunnel kiln in brickmaking, knitting versus wearing etc.

  Correct choice of the type of energy used combined with good combustion technology
  In various sectors of energy utilisation the judicious choice of the type of energy employed, together with the appropriate technology related to that energy, can have an important (sometimes very large) effect on utilisation efficiency. To illustrate this point we can mention a few examples.

  . Industrial processes

    Substantial amounts of primary fuel can be saved by the substitution of direct firing of processes, in place of indirect heating by steam which has to be generated in a central boiler, transmitted round the factory, and used via a further heat exchanger to provide the thermal requirements of the process. In many different cases it is possible to use relatively new techniques of direct firing to eliminate the steam boiler, with considerable energy savings. For instance, direct gas-fired immersion tubes are now able to replace steam coils for heating process liquids in treatment tanks and vats, with over 40% savings in fuel usage. Also in processes involving product drying, including food products such as dried milk, it is possible to use direct firing with a clean fuel such as natural gas, LPG or electricity, instead of steam-heated air, with savings in fuel which can again amount to 40%. The virtual elimination of the traditional steam boiler in many process plants could save very large amounts of energy.

  . Commercial/Industrial plant

    Again, in situations where space heating is required in large working areas, direct firing techniques can be superior to the use of central heating boilers. In particular, spot radiant heating by gas-fired "low temperature" radiant tubes can sometimes save as much as 60% of the fuel used compared with general heating using steam or hot water.

  As in the above examples, there are many opportunities for substantially improving the efficiency of energy utilisation simply by selecting the best fuel and technology for the job to be done.

- Integrated design of processes resulting in energy savings through:

  . optimising energy flows allowing the heat rejected by higher temperature process stages to be used in lower temperature applications, e.g. using the heat exhausted from brick kilns to dry "green" bricks in the dryer prior to firing.

. adjusting material flow and processing by using, for instance, continuous rather than batch techniques, counterflow of processing medium and the material being treated, e.g. hot water in washing of textile products, and improving the yield of processes so minimising factory returns.

. optimising the order of operations as to subsequent heating and cooling.

. modifying processes to reduce energy needs by, for example, developing chemically assisted low temperature techniques to replace high temperature processes, e.g. textile dyeing.

. improving process control and monitoring, and better scheduling of work so reducing "no-load" periods (when, of course, all plant operates at zero efficiency).

- Waste heat recovery Reducing primary energy needs by utilising waste heat as, for example, in the following:

  . pre-heating air and fuels in boilers by heat contained in the flue gases.

  . pre-heating combustion gases by passing them over the cooling products of high temperature processes, e.g. as in cement kilns, brick and pottery kilns etc., so recovering the sensible heat of products.

  . pre-heating incoming raw materials by passing exhaust gases from combustion over them, e.g. as in blast furnaces and cement kilns.

  . recovering heat from exhaust vapours, e.g. from dryers, for use in space heating and pre-heating boiler feed water etc.

- Combined heat and power utilising back pressure and pass-out steam turbines, diesel generators or gas turbines with waste heat boiler for the generation of electricity and the production of heat for process use. Overall the provision of power and heat in this way is more efficient than the separate generation of electricity at remote sites and the provision of steam supplies from package boilers. This option has also relevance for a substantial part of the Commercial/Public sector.

- Insulation

  . of buildings, reducing draughts where possible from exterior openings, e.g. loading bays, by fitting appropriate doors etc.

  . of process equipment, e.g. furnaces, drying units, vats, etc.

  . of service pipes and ducts carrying steam and hot water or products.

. selecting space heating equipment appropriate to the activities performed, e.g. radiant heat in large workhouses for local heating of working areas.

- Heat Management encompasses the education and encouragement of the work force to conserve energy and the monitoring of the energy performance of equipment, particularly major users such as boilers where incorrect combustion conditions can result in large losses.

DOMESTIC

- Insulation. Loft insulation, roof insulation, cavity wall insulation and lagging of hot water pipes, hot water storage tank and boilers are all very cost effective, and can easily save up to 30 per cent of the energy consumed in an average uninsulated single dwelling.

  In the Commercial/Public sector judgement should be qualified. Offices are generally more than one storey high and well draught proofed. They generally have a relatively high volume to skin ratio. (The cube has a better volume to skin ratio than a flat oblong, be it horizontal (detached home) or vertical (high rise block)). The occupancy ratio during day time (people/m^2) is relatively high, and so is the lighting level. The result is a high proportion of self-generated "waste" or "free" heat from occupants, lighting and apparatus. This implies that office buildings require typically less heating but more cooling over the year as compared with residential houses. In Western Europe it is said that many offices require cooling rather than heating as soon as the outside temperature rises above 5-10°C. "Simple" building codes and regulations laying down insulation standards could easily produce counterproductive results in this sector if this phenomenon were not properly taken into account.

- Boiler improvement. Boilers are still subject to further improvements. Low capacity, high insulation boilers with increased combustion efficiency (e.g. air/fuel ratio control in large boilers), adapted to optimal load following and modulating rather than snap-action control (i.e. varying the flamelength rather than switching on and off a flame of constant height) can still improve significantly on the seasonal efficiency of current boilers.*

  Developments are under way in several countries of "condensation heat recuperators". Their application seems to be limited to gas boilers (due to corrosion problems), and larger radiator surfaces are required in order to reduce the temperature of the water returning to the boiler to a level low enough to condense the flue gases. Nevertheless this device could save 10 to 20% of the fuel used in current average domestic boilers.

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* boiler efficiency is often lower under partial load than under full design load. Thus insulation, by reducing the heat demand, can cause an existing boiler to operate sub-optimally. It is often worthwhile to reconsider the sizing of the boiler after insulation, draught reduction etc., have reduced the heat load.

- Improved Central Heating controls. There is further scope for reducing the required amount of useful heat produced by the boiler through better control of water temperature against the desired indoor temperature and the prevailing outdoor temperature, and also by such simple measures as a night setback and programmable switch, e.g. switch on in time for the return of absent occupants. The advent of micro-processors has opened new possibilities of sophisticated controls for the flow of heat. One further example is individual room thermostats, especially in large office type buildings. By adjusting the heat supplied to the need of each room, better use is made of the incident solar heat and local overheating is avoided. However, a window left open could easily destroy the effectiveness of this conservation device.

- Heat exchangers. The heat contained in the outflowing air can be used to preheat the inflowing air. This option is most effective in large office type buildings with controlled air circulation.

- Draught sealing. Draught is the greatest contributor to heat loss after heat loss through ceilings and walls, and can have a disproportionate effect on the perceived comfort level in an otherwise warm room. Reduction of air turn-over in a building naturally decreases the energy required to heat the inflowing air. Ventilation could be reduced to 1-2 changes per hour, compared with the current average of 2-4 changes per hour. Draught sealing of windows, closing chimneys when they are not in use, and automatically closing doors all significantly reduce draught. However, care should be taken that the air quality does not suffer, that condensation does not occur due to insufficient moisture offtake and that sufficient ventilation is allowed for supplying the air requirements of heating appliances that are not room sealed. A survey found that the main reason for opening windows in winter was stated to be "stuffiness" rather than temperature. Thus, over-ambitious reduction of draught could lead to unnecessary opening of windows, resulting in considerable heat loss.

- Double Glazing. As with other heat saving measures, cost effectiveness of double glazing depends on the coldness of the climate. In Finland, for instance, double glazing is widespread and useful. However, in more moderate climates, such as Mid-Western Europe, the cost-effectiveness of double glazing as an energy conservation measure is economically rather more doubtful, as is shown in the chapter on economics. The main advantage of double glazing is its reduction of draught.* Other non-energy considerations are its sound-proofing quality and elimination of condensation. Lastly, it also has definite status qualities. The greatest attraction of double glazing therefore is not so much reduction in heating costs, but rather more general improvements in comfort. Double glazing is currently spreading much faster than insulation - a prime example of how factors other than heating economics determine what happens.

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* reducing draught and temperature gradients can allow a lower air temperature, with ensuing energy savings.

- Improved appliances. Gas cookers, washing machines, clothes driers, dish-washers, toasters, etc., use only a relatively small fraction of total direct energy consumed in households. Hence, their energy efficiency has hardly been considered by either the manufacturer or the consumer. Considerable improvements are estimated to be possible in this field: for instance, the replacement of a gas pilot light in a gas cooker by electric ignition could save about 30% of the energy consumed by the cooker; longer spinning in the washing centrifuge can save considerable energy in the clothes dryer. Although more efficient appliances should certainly be considered, it should be recognised that the overall savings would be modest, due to the small proportion of total energy consumed. Retrofitting existing appliances is probably not worthwhile.

- Diagnostic services, energy conservation packages and contracted heat management. Many energy suppliers are competing to sell their products to the domestic consumer, but few comparable services are available in the field of energy conservation. Sellers of comprehensive energy conservation packages, including diagnosis, evaluation, implementation and where necessary, financing could probably achieve far greater reductions in energy consumption than just insulators and double glazers on their own. For collectively heated apartments and buildings, contracted heat management would ensure a continued rational use of energy-using equipment. The potential for this kind of comprehensive application of energy-saving technology should be seen as very significant indeed.

D.2 SOME QUESTIONABLE OPTIONS

The keen observer will miss some items in the above list that are being widely discussed.

Inverted Energy Tariffs are currently being advocated as a means of inducing energy conservation. The conventional utility (tariff giving diminishing unit cost for additional offtake by one consumer) is based on the principle that the cost connecting a customer to the grid should be recovered in his tariff. Since the costs of connecting a small user are essentially the same as for a large user, the small consumer naturally pays a higher unit cost on his low consumption. This is the basis for multiple-tier tariff structures, where large consumers are charged progressively less for incremental volumes. In practice, the large consumer has often been subsidising the small one because his lower unit cost has often not fully reflected the above principle.

Proposals that large volume consumers should pay more rather than less for incremental volumes unbalances the above tariff procedure and undermines one of the objective standards in public utilities' tariffs: cost. Large users are not necessarily wasteful simply by being large; in practice the large Industrial and Commercial consumers may use the energy purchased much more efficiently than the small ones, and his ability to reduce demand may be less flexible. Inverted public utility tariffs can easily lead the large user to spread his energy purchases over different types of fuels, thereby reducing the overall efficiency by increasing distribution investment.

Another measure already introduced in some countries is the limiting of indoor temperature within buildings to 20° C. As we have seen in the chart of subjectively preferred thermal comfort, the limit of 20° C is below the ultimately desired level. Hence, legislators might find it difficult under circumstances of increasing disposable incomes to maintain this limit - certainly within the private residential sector.

As discussed under Insulation in the Domestic sector, many office blocks require typically some form of cooling during part of the official "heating season". Where many heating control systems in offices follow a temperature set by the thermostat by either heating or cooling the circulated air (enforced circulation), a law limiting indoor temperatures to some specified maximum could result in unnecessary cooling during, say, the months March-May and October-December.

Thus a law limiting indoor comfort should read somewhat like "indoor temperature (air temperature = mean radiant temperature) may not be higher than x°C above ambient temperature when heating is required in any particular building and not be lower than y°C below ambient temperature when cooling is required". Of course such a law would be even more unenforcible than current laws laying down "a maximum of 20°C during the heating season".

Lastly, the enforced introduction of scheduled public mass transport systems has been discussed in the transportation sector. We reiterate here our belief that the most effective conservation measure in this field is the improvement of gasoline and diesel engines.

D.3 SOME TECHNICO/ECONOMIC QUESTION-MARKS

We would finally like to mention some issues which currently should be classified as technico/economic question-marks:

Utilisation of solar energy and wind do not look very attractive on an economic basis in mid-Western Europe. Solar heating, combined with seasonal storage that can transfer the heat gained during the summer to the winter currently looks unattractive - even against doubled energy prices in real terms. In the more southern countries, of course, solar heat for domestic hot water can be attractive. This is not to say that solar has no future: considerations other than strict heating economics can subscribe to the attractiveness of this renewable resource. Utilisation of wind to generate electricity is currently prohibitively expensive, due mainly to wide variations in availability of wind, and consequently the requirements of storage.

District Heating. The provision of heat to a number of buildings from one central source has been popular in the Northern and Eastern European countries for a long time. From this it is often inferred that the introduction of district heating in regions such as mid-Western Europe would lead to savings in energy use. However, apart from its higher investment costs, there is some doubt as to the efficiency of district heating. Heat loss during transmission from the central source to the consuming units can be considerable; more important, firing of the central boiler to supply just heat to one or two of the houses when the others require no heat, can lead to significant under-utilisation losses. Conclusive evidence on this subject is difficult to obtain; but many marketers in the energy business state that, in their experience, heating by individual boilers is in fact more energy efficient than centralised district heating, due to its more optimal heat load following. (This applies, of course, only to district heating using fossil fuels directly). It should however be pointed out that district heating using central boilers allows a greater flexibility in the choice of fuels used; the burning of coal by fluidised bed combustion is possible, while this is not as yet feasible in individual boilers. It also has great attraction for the consumer by being "easy": everything is being taken care of by professionals. This also simplifies the application of effective "heat management".

Yet another method is district heating using waste heat from electrical power generation. This mode of combining heat and power is also popular in Scandinavia. What is not clear is why evaluations of district heating from power stations in, say, France and the UK come up with vastly less attractive economics. The main reason for this is probably the following: district heating power stations in the Scandinavian countries produce primarily heat and follow the heat demand load, while the by-product electricity is pushed into the grid. The national grids of the Scandinavian countries, having virtually been integrated into one, are in the fortunate position that about half of their generating capacity consists of hydro, which is eminently suitable for demand load balancing. Thus, the energy efficiency and cost-effectiveness of a power station that would have to follow simultaneously both heat demand and electricity demand would be vastly less attractive than the Scandinavian schemes. In conclusion, it can be stated that, for non-hydro countries, the proposition of district heating should be carefully studied on its local merits.

The Fuel Cell

Fuel cells produce electricity directly from a suitable fuel without an intermediary heat engine. Very high thermal efficiencies are possible with fuel cells (40-70%) and waste heat is available at 60°C or higher (often above 100°C) for cogeneration. Furthermore a small fuel cell is as efficient as a large one and so these devices lend themselves to the distributed generation of electrical power. Fuel cells are inherently quiet and give very low atmospheric pollution.

In order to make fuel cells operate on a convenient fuel either methanol or some other hydrocarbon fuel may be converted to a hydrogen-rich gas which is then fed to a hydrogen-air fuel cell. A 4.8 MW fuel cell power system of this type is being installed in New York City this year (1979). The problem with this approach is the complexity and cost of the equipment which converts the liquid fuel into hydrogen. Nevertheless, U.S. sources are optimistic that an economically viable system can result from this approach.

A much simpler and potentially less costly approach is to develop a fuel cell which operates on methanol directly. The problems with this approach are chiefly the development of low cost catalysts, but encouraging results are being achieved.

The potential energy savings from successful fuel cells in both electricity generation and transport are so great as to justify prolonged and intensive research in this field.

The Heat Pump

The heat pump is a device to extract low grade heat from a heat source, and to upgrade this heat to a higher temperature using external higher-grade energy. Thus, a refrigerator's cooling unit pumps heat out of the refrigerator into the room. Similarly, it could pump heat from the outside environment into the room in winter, while by a reversal of the input and output ducts the same device could also be used to cool the room during summer.

The principle behind this device is the property of an expanding gas to extract heat from its environment. Thus, gas, compressed into liquid form, is allowed to expand and extracts heat from the environment through the "cooling coil". In order to be re-used it then has to be recompressed, which raises its temperature and allows it to give off heat to the environment (the "heating coil"). Compression can either be achieved by mechanical means ("compression" type) or by chemical absorption in a liquid and subsequent expulsion by heating ("absorption" type).

Thus, a heat pump, using high-grade energy as input, can upgrade low-grade heat out of an environment to a (modestly) higher temperature, yielding an amount of heat greater than the calorific equivalent of the input energy. The "Coefficient of Performance" (COP) can be in the order of 2-4 for a "compression" type and some 1.2-1.5 for an "absorption" type. The COP is strongly dependent on the temperature difference to be overcome, falling off rapidly the higher the difference. This reduces significantly the seasonal COP. During cold days a heat pump needs some backing up facilities, which, if in the form of electrical resistance heating, would pose unacceptable peak demands on the central electricity generation capacity. Therefore the heat pump needs an additional conventional heating back-up facility, which increases the already considerable costs.

In the southern part of the USA, where it can both heat the house in winter and cool it in summer, the electrically driven "dual purpose" compression heat pump has firmly taken off during the last ten years, as an alternative to the combination of electrical resistance heating with a "cooling only" heat pump ("air conditioner"). Mechanical reliability seems to have been improved substantially, although the lifetime of the equipment in service is still subject to doubts. Another problem is noise, although this is felt to be less of a problem in the southern US, where houses are predominantly heated by hot air systems in order to utilise the same duct system for both heating and cooling. Hence the inhabitants are used to the continuous hissing of blown air. However, noise in the garden from a neighbour's external fan can also pose problems.

The gas operated "absorption" type of heat pump is mostly used as a cooling unit in commercial buildings.

In Western Europe, with its generally colder climate and virtually no need for residential space cooling (North of the Alps), the heatpump is currently not quite economic. However, interest has been aroused (especially in W. Germany) and several development projects are under way.

Electrically driven "compression" types would compete with electrical resistance heating. A heating only "absorption" type is being studied as an alternative to central heating boilers in large commercial buildings. Another option being looked at is a small gas engine driven "compression" type, which also uses the engine's waste heat and supplements gas combustion directly during very cold spells. It is too early to comment on the economic future of these options, but against doubled energy prices (in real terms) and/or a relative abundance of electricity from nuclear, the proposition could become much more attractive.

In conclusion, theoretically the heat pump would seem to be the ultimate device for maintaining indoor temperatures, but as yet the rate of development and introduction remain open questions.

Cheap and Efficient Storage

It is estimated that at least half of the energy consumed is produced because it cannot be stored. For example, a house receives sufficient heat in the summer to heat it in the winter if this heat could be stored. Energy spent in climbing hills and acceleration in transport could be largely recouped during descent and deceleration. The whole problem of load management inhibiting the full possiblity of "cascading", would disappear. Thus, if a cheap, efficient, low volume energy store were to be developed - absorbing and yielding energy fast on request - any current energy projection should be revised.

The impact of the successful development of such an energy storage cannot be exaggerated. Unfortunately, the chances of such a discovery seem exceedingly small. Currently available devices, such as the electric battery, fly wheel, rocks, water and eutectics, all have severe limitations which so far seem insurmountable.

It is worthwhile, nevertheless, to recognise the enormous rewards of any significant improvement in this field.

INVESTMENT, COST AND TIME HORIZON FOR ENERGY SAVINGS IN VARIOUS MARKETS

	INVESTMENT 1975 US$ PER BDOE SAVED	LIFE TIME YEARS	DCF TIME YEARS	COST: $/BOE AMORT-ISATION OVER DCF TIME @ 5% PA CONST. MONEY	PERCEIVED TIME HORIZON YEARS	COST: $/BOE AMORT-ISATION OVER TIME-HORIZON @ 5% PA CONST. MONEY	PAY OUT TIME YEARS 5% PA CONST. MONEY. ENERGY PRICE AS INDICATED
INDUSTRY							@12 $/BOE
HEAT RECOVERY	5-35,000	20	15	1 - 9	2-15	4 - 26	1 - 10.5
RESIDENTIAL							@20 $/BOE
APPLIANCES							
GAS APPLIANCES	7-10,000	10	10	2.5 - 3.5	3	7 - 10	1 - 1.5
CH IMPROVEMENT	7-10,000	10	10	2.5 - 3.5	3	7 - 10	1 - 1.5
ELECTR.APPLIANCES	13-17,000	10	10	4.5 - 6.0	3	13 - 17	.5 - 2.1*
CONDENSE HEAT REC.	16-18,000	10	10	6.0 - 6.5	3	16 - 18	2.5 - 3
EXISTING HOUSES							
INSULATION	20-35,000	60	25	4 - 7	3	20 - 35	3 - 5.5
THERMOSTATS	40-50,000	20	20	9 - 11	3	40 - 50	6.5 - 8.5
DOUBLE GLAZING	60-90,000	40	25	12 - 17	3	60 - 70	11 - 20
COMPLETELY INSULATED NEW HOUSE	35-45,000	80	25	7 - 9	10	12 - 16	5.5 - 7.5
PUBLIC/COMMERCIAL							@20 $/BOE
THERMOSTATS	14-18,000	20	15	4 - 5	2-15	21 - 27	2 - 3
HEAT EXCHANGES	20-25,000	20	15	5 - 7	2-15	29 - 37	3 - 4
							@60 $/BOE
PRIVATE CARS	50-65,000	8	8	21 - 27	2-3	50 - 65	2.5 - 3.5

* against electricity prices of 60-80 $/boe

NOTA BENE

In calculating energy conservation investments, some complications are:

- Quality improvement may reduce savings. For example, when a house is insulated in which the temperature was lower than actually desired by the occupant, the calculated savings are often partially lost because a higher temperature is subsequently maintained.

- Human behaviour. Windows opened in a fully-insulated, draught sealed house.

- Initial quality of the stock matters. One gets bigger gains by improving bad stock. Thus, in the US, UK and Netherlands, where houses are relatively poorly insulated, the first measure applied will easily gain 10-15%.

- The order of measures taken matters (first applied is most effective). If the boiler is improved before insulating the house, the residual gains from insulation will be less in absolute terms; hence the capital cost per unit of energy saved will be higher.

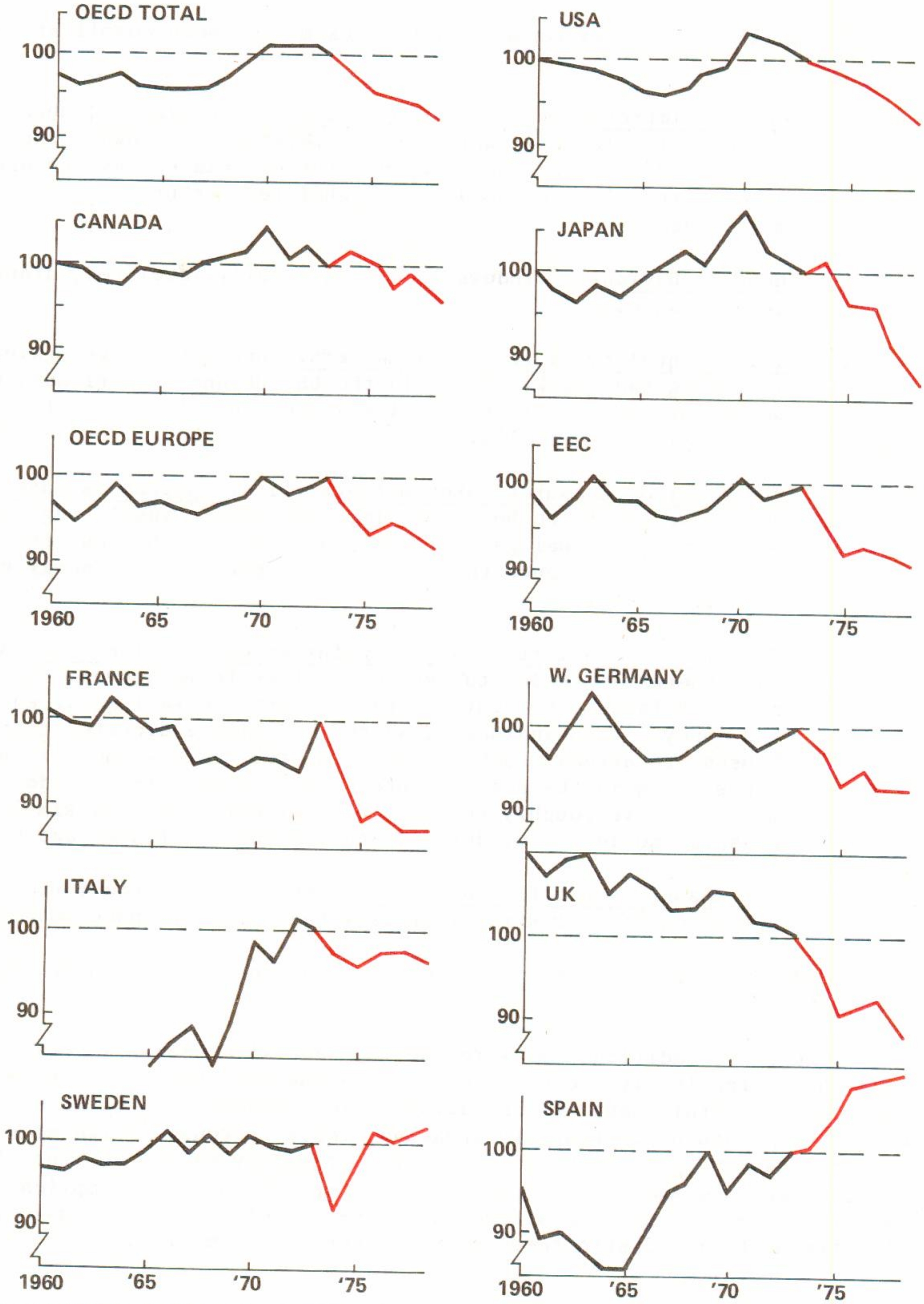
- The climate can matter (bigger gains in colder climate). As more energy is needed to overcome colder temperatures, the same measures (and cost) achieve greater absolute savings of energy and money. In Scandinavia, where the climate dictates that houses are already much better insulated and designed (in heating terms) than in the rest of Europe, more sophisticated additional measures have roughly the same cost effectiveness as simple measures do in the milder climates of the UK, France and Germany.

- One measure can offset another. Less off heat from improved appliances and lighting increases the need for space heating.

These factors have been taken into account in the investment examples calculated.

Generally, additional measures of the same kind become increasingly less cost effective if added on top of previous measures (for instance increasing the thickness of insulation rapidly reaches the point of diminishing returns). Properly speaking, costs of conservation measures should be shown against the incremental energy they save. However, for a general overview such as the underlying report, this would complicate matters too much, and ranges have simply been indicated which would provide significant but realistic reductions of energy consumption.

TOTAL PRIMARY INLAND ENERGY PER UNIT OF GDP
1973 = 100



Source: GDP OECD (In US $ @ 1970 prices and exchange rates)
Energy USA BOM Canada Nat Stats.
Others OECD.

Fig. F.1
Energy/GDP has been reasonably constant over the sixties for most OECD countries. However, swings of 5% were not uncommon. In all OECD areas (but not for all OECD countries) Energy/GDP has fallen since 1973. Although this is not conclusive proof that Energy Conservation is happening, it is a strong indication.

APPENDIX F

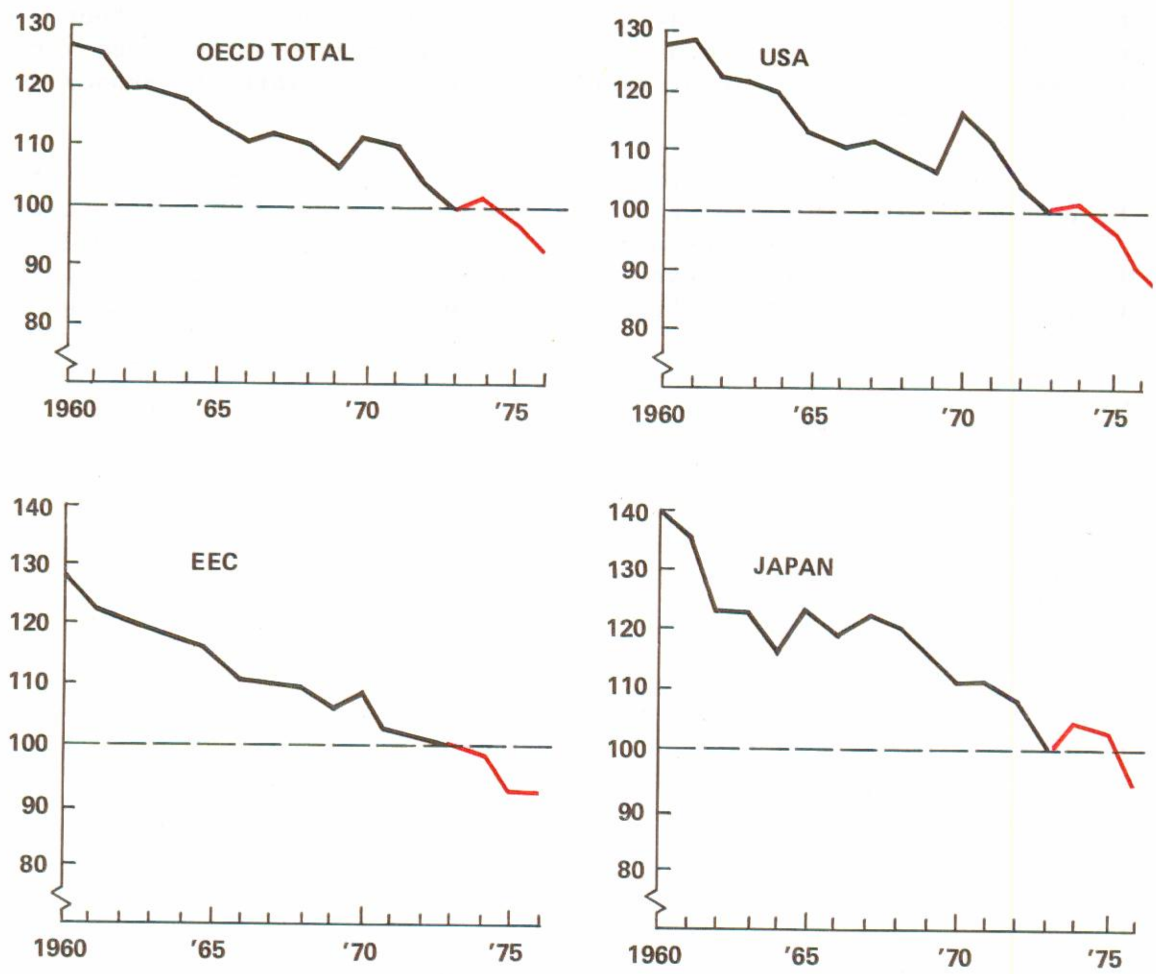
IS ENERGY CONSERVATION BEGINNING TO SHOW?

In 1974/75, energy consumption in the OECD area actually went down for the first time since the mid-fifties. However, most of this could be explained by the economic downturn and mild winters in W. Europe.

But the energy per unit of GDP has continued to fall since then. For the OECD, this factor was some 6% less in 1977 than it was in 1973. Even though not all of this is "savings" in our sense (industrial output - and specifically the energy-intensive, heavy industries - has not recovered to the same extent as GDP), conservation is apparently largely responsible for this reduction.

It is encouraging to note that the Industrial Energy per unit of Manufacturing Output, after a slight hesitation in 1974/75 due to low utilisation of capacity, has decreased sharply since then and dived even below trend. Hence we believe that much could be in the pipeline that will yet show up, and that the savings wave has at least started to roll.

TOTAL INDUSTRY: DELIVERED ENERGY PER UNIT OF MANUFACTURING OUTPUT 1973 = 100



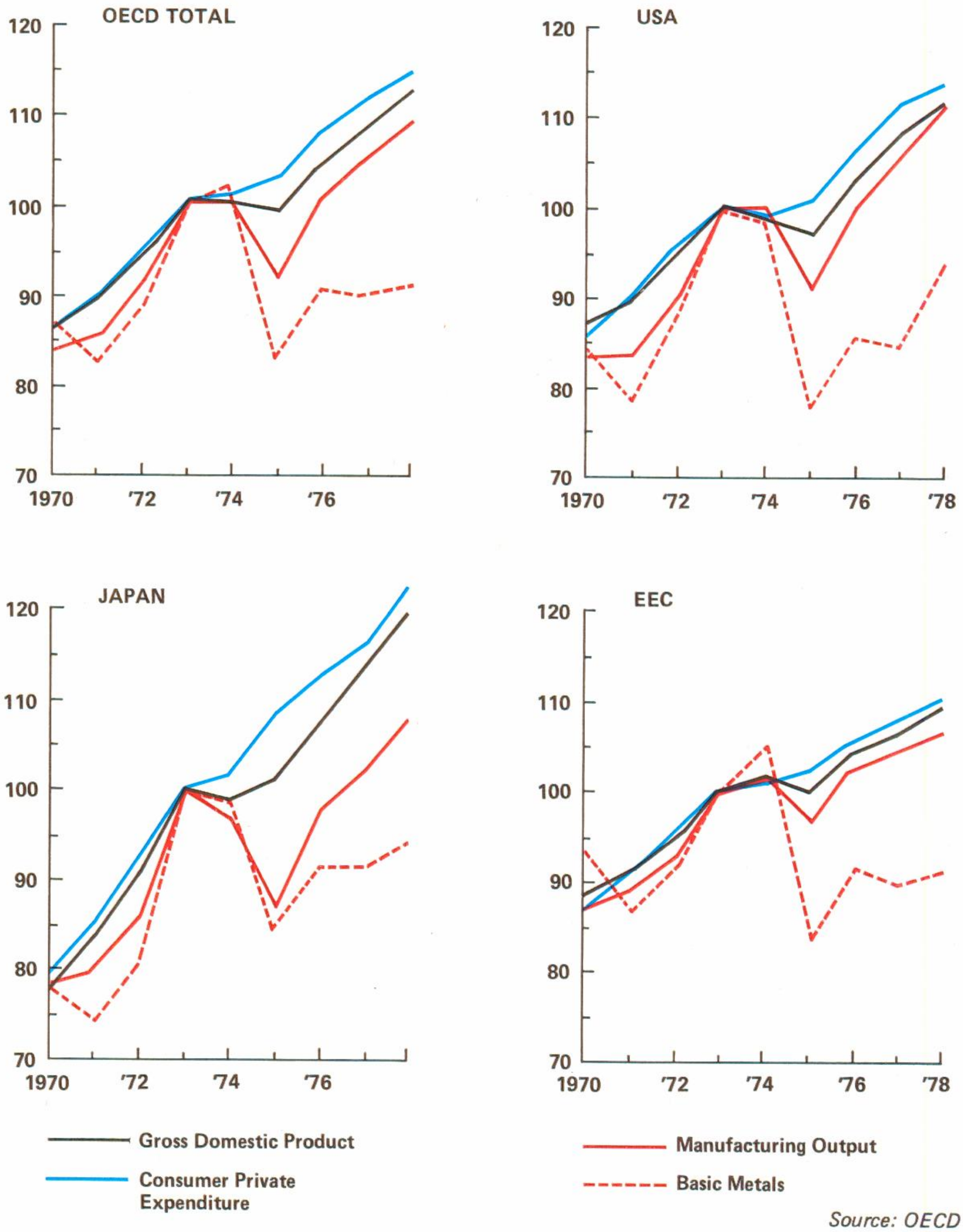
Source: Manufacturing Output. OECD.
Energy: USA: BOM, Edison Inst.
Other: OECD.

Fig. F.2
Delivered energy per unit of Manufacturing output has been coming down in all OECD areas (though not in all OECD countries). This is the result of

a) heavy industries' declining share of total output (with the exception of Chemicals, which increased its share).
b) a shift from old coal furnaces to new oil and gas equipment.
c) new processes.

Since 1973 there has been an apparent saving of some 8% in the OECD as a whole. Although well in line with the previous trend, this may indicate that retrofit improvements are being carried out, since very little new plant was built in that period.

OECD ECONOMIC INDICATORS



Source: OECD

Fig. F.3
Part of the reduction in primary energy per unit of GDP since 1973 in the OECD areas is due to a shift in economic structure. Industrial output has not recovered to the same amount as GDP (specifically the energy intensive basic industries, basic metals, basic minerals and chemicals are still producing at or below 1973 levels), whereas reflationary measures have kept private consumer expenditure artifically high (at the expense of investment and trade imbalances). This structural offset is probably temporary, and hence part of the apparent savings should be discounted in future projections.

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TECHNICAL PAPER

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COMPLETE PAPER ON "ENERGY"

ENERGY - OVERVIEW
- LIQUID FUELS
- COAL AND ELECTRICITY
- NUCLEAR FUELS AND ENERGY
- SOLAR AND OTHER SOURCES OF ENERGY

Dr H. Wright, 7.12.79

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E N E R G Y

- OVERVIEW
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O V E R V I E W

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ENERGY - OVERVIEW 1. Perspective

TABLE 1
Economic structure of the energy sector, Australia, 1976-77

Industry	Persons employed at 30 June 1977	Value added - At factor cost	Value added - Indirect taxation (a)	Total Capital Expenditure to June 1977 (b)
		$M	$M	$M
Oil and Gas - Exploration, development, and production	2 200	510 (c)	400	2 000
Oil refining	4 300	170	-	700
Oil marketing and distribution	65 000 (d)	1 700	820	2 400
Gas transportation and distribution	9 000 (d)	250	-	1 000
Coal - Production and distribution	24 800	1 300	180	1 600
Uranium - Production	400	(e)	-	70
Electricity - Production and distribution	64 500	1 800	-	9 500
TOTAL	170 200	5 730 (c)	1 400	17 270

(a) Includes levies, excise, and customs taxes.
(b) At historical cost. Includes expenditure on oil and gas exploration.
(c) Value added is in terms of prices actually received by producers less any crude oil levy included in the price. If production has been valued at import parity prices, value added for the crude petroleum industry (not excluding any crude oil levies) would have amounted to $2.1 billion, and total value added to $8.3 billion. Although it is difficult to determine world parity values for natural gas and coal, pricing these materials at world parity would probably have increased total value added to approximately $9 billion.
(d) Estimate.
(e) Not available.

Source: D. National Development (1979).

TABLE 2

Australia's domestic primary fuel consumption and estimates of producers' sales revenue, 1976-77

Commodity	Quantity	Energy share %	Value, $M
Imported crude oil & petroleum products (net of exports except LPG)	12.2 Gl	15	777
Domestic crude oil & petroleum products	24.3 Gl	31	364
Black coal (at $13/t)	30.0 Mt	29	390
Brown coal (at $1.90/t)	31.8 Mt	11	60
Natural gas (at $1/GJ)	257 PJ	9.0	257
Hydroelectricity (at 1c/kWh	49 PJ	1.7	136
Wood & Bagasse	-	3.3	-
TOTAL	2866 PJ	100	1984

Sources: D. National Development(1978), Australian Institute of Petroleum (1978)

1 Gl = 1 gigalitre = 10^9 litre = 6.29 million barrel

1 PJ = 1 petajoule = 10^{15} joule = 948 x 10^9 BTU

1 Mt = 1 megatonne = 10^6 tonne = 0.984 x 10^6 ton

TABLE 3

Demonstrated, economic and recoverable energy resources and consumption in 1976-77

Resource	Quantity of Recoverable Reserves	Energy content, 10^{18} joules	Annual Consumption, 10^{15} joules	Reserves/ Consumption#, years
Crude oil & Condensate	329×10^{9} l	12	1320*	9
LPG and natural gas	327×10^{12} l	13	257	51
Black coal	20×10^{9} t	580	836	687
Brown coal	39×10^{9} t	380	310	1258
Uranium	289×10^{3} t	160	-	-

* This figure includes the consumption of imported oil and petroleum products.

\# This ratio is changing with increases in both the reserves and the production rate. It is given as a crude estimate only, of the resource lifetime. See text for further comment.

Source: NEAC (1977)

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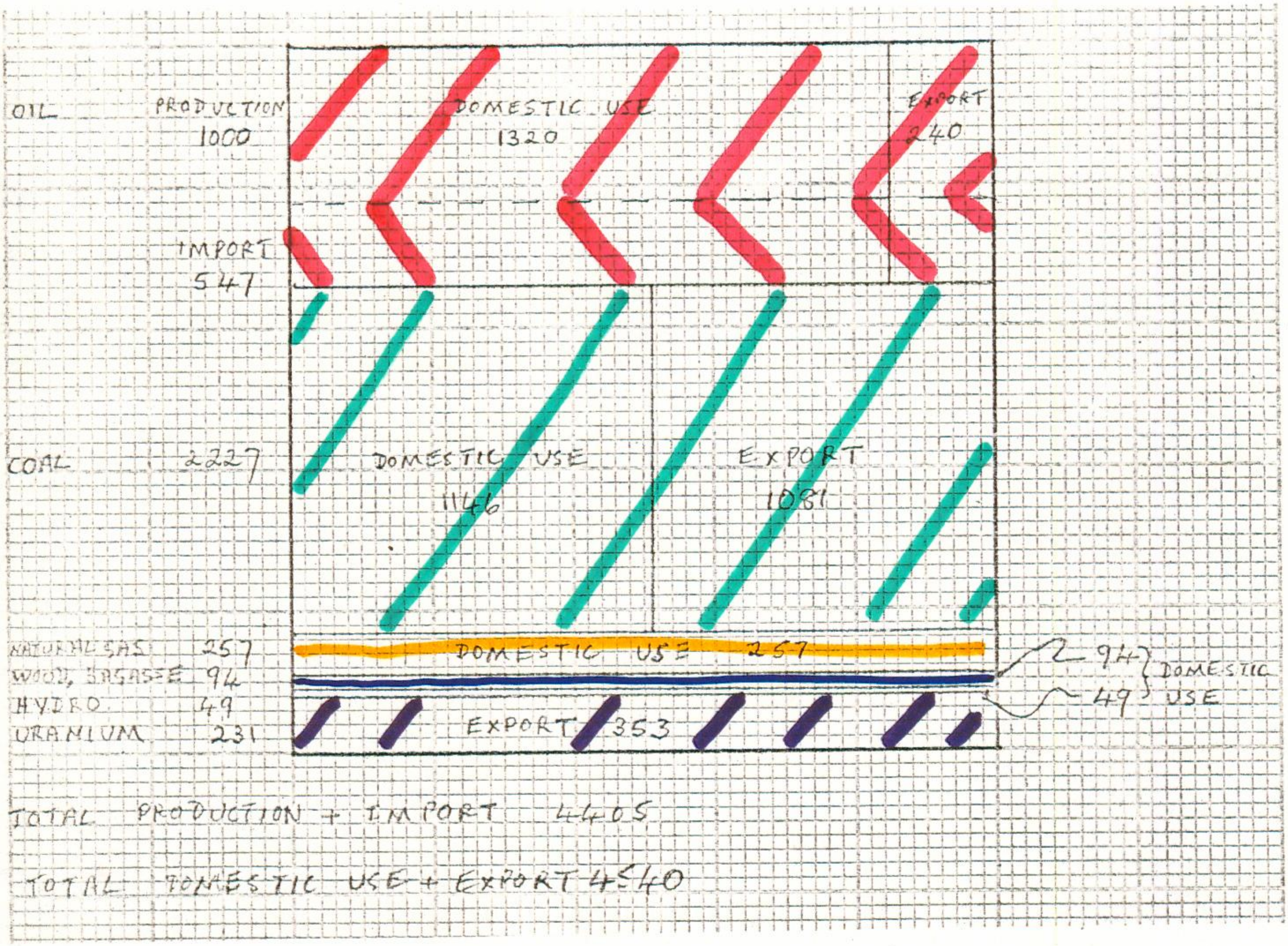
FIGURE 1 Australia's primary energy sources: production and imports versus domestic use and exports, 1976-77. Energy in PJ (10^{15} joules)

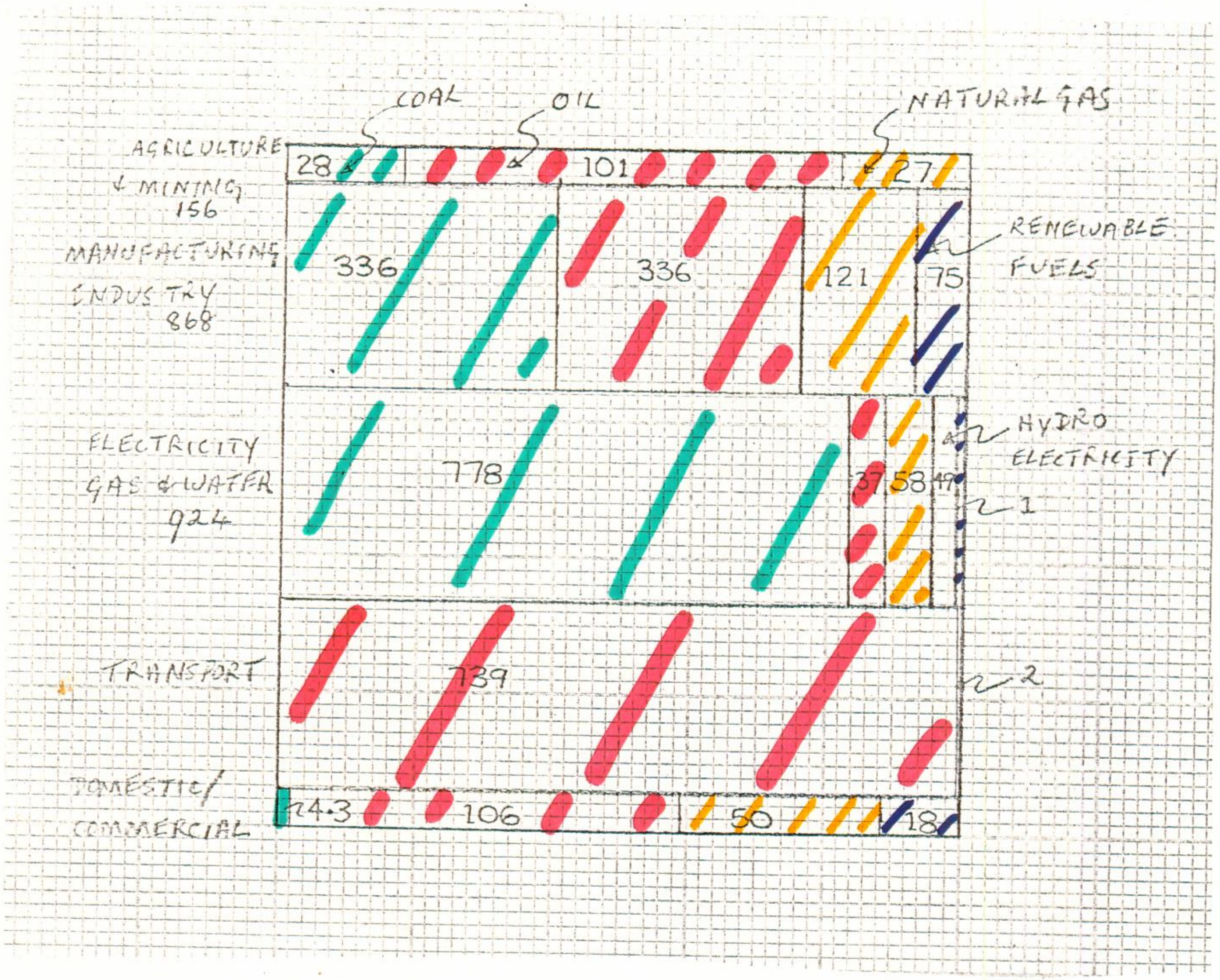


Note: Differences in aggregate inputs and outputs are due to flows to or from stockpiles.

Sources: D. National Development (1978), Joint Coal Board (1979).

FIGURE 2 Use of fuels within Australia by fuel type and industry sector, 1976-77.

Energy in PJ (10^{15} joules), total energy 2866 PJ.



Source: D. National Development (1978)

We use energy to make our lives more comfortable through the use of heat and light and the substitition of human toil by powered machines. The degree of energy dependence of Australia's technically based society is shown by its 6.5 kW continuous rate of total energy consumption averaged over the whole population*. This compares with 12.5 kW in the U.S.A., about 5.5 kW in UK and West Germany and 2.8 kW in Spain. The biological food requirement for an adult is about 100 W. It must be emphasised that energy is an essential, non-substitutable component of our modern society and that while some reduction in per capita consumption could comfortably be achieved, a drastic reduction in consumption (e.g. a halving) could not be achieved readily without some major changes in the nature of our society.

Employment, value added and capital expenditure in the various energy industries are given in Table 1. Figure 1 shows Australia's total primary energy production and imports, together with domestic end use and exports of various energy types. Australia's use of primary fuel in 1976-77 is given in Table 2 together with estimates of the producer's sales revenue. The use of the different energy forms in different sectors of the economy is shown in Figure 2. Demonstrated economic and recoverable resources are shown in Table 3. In 1976-77, the total value added in the energy sector was approximately $7 billion or 9% of gross domestic product. Capital expenditure in the energy industries amounted in 1976-77 to nearly $1.5 billion, or about 8% of total gross investment, and direct employment in these industries amounted to about 170 000 persons. Exports of energy materials amounted to $1.6 billion or about 14% of total exports, and imports to $1.1 billion (D. National Development, 1979).

Some important features deserve comment.

1. Crude oil imports supply only 15% of our energy consumption, yet the cost of imported oil was 40% of expenditure on primary fuels in 1976-77. Current domestic reserves of oil can supply only two thirds of Australia's oil requirements, and with an increasing demand the degree of self-sufficiency will decline if nothing is done. Increased self-sufficiency

Reserves vs prod'n. Why self-sufficiency

* Domestic consumption of 2.86×10^{18} J consumed by 14.0 million people in 1976-7.

in oil can be achieved by a variety of means. Oil can be used more wisely, domestic oil reserves can be expanded by exploration, and processing plants can be established to make liquid fuels from other primary fuels.

2. Australia's transport sector is almost wholly dependent on oil based fuels and uses about 60% of all liquid fuels.

3. About 75% of electricity generated is from coal fired stations based on large domestic resources. This is unlike many major Western countries such as U.S.A., England and Japan which have a large proportion of oil or gas fired generating capacity.

4. About half of Australia's coal production is currently exported and this export trade is growing more rapidly than domestic consumption. Based on large domestic coal reserves Australia's total coal production is expected to expand four fold to almost 300 Mt/y by the year 2000 (see later section on Coal and Electricity).

5. Household and commercial energy consumption in Australia is only about 6%. This is low by comparison with industrialised countries in the northern hemisphere where 20% to 30% would be typical. The low space heating requirement in Australia's mild climate is the reason for the difference.

6. The highest employment areas are in the distribution of energy products, oil, gas and electricity. Oil marketing and distribution employs about 65 000 people (Table 1).

The most pressing and serious energy problem in Australia is the need to provide a greater proportion of our transport fuels.

The distribution of energy resources between states, and particularly the proximity of resources to population centres, affects the pattern of energy usage. This has been outlined by Thomas (1977).

In New South Wales coal is used for electricity generation. Natural gas became available from South Australia in 1976, but without further discoveries New South Wales will face supply shortfalls in gas supplies sometime after 1985. Connection to Victorian natural gas supplies is envisaged.

Victoria uses brown coal for electricity generation and has contracts with Bass Strait producers for natural gas supplies until 2005.

Queensland draws much of its energy from its extensive coal reserves with some natural gas from Roma. However, more natural gas could be used if it were available, and there will be a need to replace or augment supplies by around 1980.

South Australia has considerable reserves of sub-bituminous coal but also uses natural gas for power generation. However, under the current contract arrangements natural gas consumption from the Cooper Basin cannot be increased after 1981.

Western Australia has recently converted its oil fired electricity generation to coal firing. Gas reserves at Dongara are sufficient for about another ten years. It is likely that gas from the North West Shelf will be an important source of future supplies.

Tasmania derives about 32 per cent of its primary energy from hydro-electric sources and imports all its other supplies.

The Northern Territory imports (from the States and overseas) all of its energy requirements, mainly in the form of petroleum products.

2. Technologies

A brief outline is given here of the major technological developments which are discussed in greater detail in later sections.

Liquid fuels

The discovery of new Australian oil fields would be the simplest means of overcoming oil shortages in the short term. Statistical estimates indicate that it is unlikely that sufficient oil would be found to provide total self-sufficiency. Further it is clearly imprudent to rely on probablistic events to satisfy the needs for a crucially important product. Other alternatives must be developed but in the event of large discoveries they would then be stopped.

May need to ensure some place for them.

More prudent use of crude oil will lead to a reduced overall requirement and an increased self-sufficiency. Refinery developments to convert heavy fractions such as fuel oil to transport fuels would reduce overall crude oil requirements for transport fuels. This necessitates the substitution of alternative fuels for the heavy fractions. Approximately one quarter of the requirements for motor spirit could be obtained by this rationalisation. Vehicle emission regulations can lead to less efficient use of fuel. At some expense, technological options may resolve the conflict.

Liquified petroleum gas (LPG) is rapidly increasing in use as a motor vehicle fuel. Conversion costs limit its use to high mileage consumers. Domestic supplies of LPG are sufficient to displace over 15% of current petrol requirements without disruption to other domestic requirements of LPG.

Methanol in petrol blends can be used in present vehicles with minor adjustments and replacement. It has the advantage of reducing the lead requirements in petrol and the disadvantages of being toxic itself (prior to combustion) and of causing phase separation in blends. Methanol could be made at an acceptable cost with known technology from natural gas or coal. When made from biomass the cost is much greater. The maximum petrol saving when using a methanol blend would be about 10%.

Ethanol, too, can be successfully used in blends as a petrol extender. On most counts it is an easier blend to use than a methanol blend. The estimated cost of ethanol is greater than the cost of other liquid fuel substitutes, mainly because of costs associated with the dispersed nature of the fermentable biomass from which it is made. Availability of land might limit the total potential of biomass fuels to about half of the total petrol requirements.

Both methanol and ethanol can be used alone as vehicle fuels but the vehicles require major engine adaptation for their use. Such use is not practical in the short term.

A crude oil can be retorted from oil shales of which Australia has enormous deposits. The technology is known but has to be developed to make a commercially viable process using the medium grade shales available. Given the investment, all oil requirements could be met from this source.

Environmental problems.

Hydrocarbon oils can be produced from coal by three main methods. The Fischer Tropsch synthesis process is currently in use in South Africa. The oil product is expensive and the energy efficiency of conversion is low. Pyrolysis and hydrogenation processes are not yet in commercial operation but better efficiencies and costs are envisaged. They can only be used with selected coals unlike the synthesis process which is not selective to feedstock. The oil products would be suitable refinery feedstocks and given massive development it would be possible to provide all oil requirements. Oil from coal yields are of the order of 30% (weight basis), and an enormous coal consumption would be required.

Coal and Electricity

There are many instances where scarcer more valuable fuel (especially oil products) can be replaced by more abundent, cheaper fuels. Non-transport uses of oil products are about 40% of total. Virtually all stationary heating applications can use alternatives such as gas, coal or for low temperatures, solar energy.

The availability of gas can be a restriction in many instances. For very small applications gas is the most practical substitute. Coal, while cheap, suffers from handling and emission problems. For small applications, fluidised bed combustion techniques show promise for overcoming many of these problems. Where coal is more readily available than natural gas, the coal may be gasified to produce a more acceptable fuel for some purposes.

The efficiency of electricity generation can be improved by magnetohydrodynamic (MHD) generation of power from mobile ionised gases, using coal as a fuel. Commercialisation has yet to be achieved.

Co-generation of both electricity and process heat is already well established in many industries where there is a suitable balance of electricity and heat demands. Greater overall fuel efficiency would be obtained if further use were made of underutilised electricity generating potential where fuel consumers were mainly interested in making heat. To realise this potential extra generators would need to be installed and arrangements made for the sale of electricity to the grid.

Electricity will tend to be used more for space heating, and stored off-peak space heating could be particularly advantageous in large and well insulated buildings in colder climates. Several times as much heat is obtained when electricity is used for reverse cycle air conditioners but the capital costs are very high.

Nuclear Energy and Fuels

Nuclear fission is in commercial use for electricity generation in many countries but in the east coast of Australia it would be unlikely to be cost competitive with coal based electricity. Australia's large uranium resources and the availability of cheap electric power offer a natural resource advantage for providing isotopically enriched uranium for thermal nuclear reactors. The commercial diffusion enrichment process is disadvantaged by a very high energy consumption. The new diffusion enrichment process, while not yet commercial has a much lower energy consumption and economic plants can be built in small modules. Fast breeder reactors offer fuel efficiencies 50 to 100 times greater than those of thermal reactors. Breeder reactors are still being developed and a couple of small units are producing electricity for consumption. Concern about radioactive and fissile products, is greater for fast breeder reactors because of the large amounts of plutonium involved. Fusion power offers the hope of ample clean non-polluting nuclear energy. This is still in an early development stage with a very long time to go to commercial use.

Solar and other energy sources

Solar hot water heating is economically attractive in some localities and its use is growing rapidly. Developments which enable high water temperatures to be obtained would extend the areas of usefulness, particularly in industry. Generally, such use can only be as a fuel saver because an alternative back up supply is needed.

Photovoltaic conversion of sunlight to electricity is currently expensive but promises to be cheaper soon. For most practical use, storage is necessary, and this could be a limiting factor to large scale utilisation.

Coal, through the generation of electricity, is effectively the primary fuel for electric vehicles. An increasing use of electric vehicles will reduce the demand for petrol in conventional vehicles but electric vehicles will be restricted to short city trips because of the lack of range and the long recharging times. Super-light petrol powered vehicles would also give a similar service and result in substantial fuel savings.

High temperature thermochemical processes (focussed solar energy or nuclear energy) can produce chemical fuels, including hydrogen which has special merits. Hydrogen is currently produced from fossil fuels and can also be produced electrochemically, although the efficiency is not great. Hydrogen is cheap to transport by pipe and is conveniently burnt or converted to electricity. Storage methods for small mobile applications (mainly vehicles) have yet to be proven practical. In the long term, when present fossil fuels are depleted, hydrogen is likely to be the energy medium for societies based on solar or nuclear primary energy sources.

Conservation

Many conservation options have been discussed in the course of the relevant topic, e.g. changes in vehicles to save liquid fuel. The most important are briefly summarised here.

Fuel conservation in vehicles can be improved in many ways: smaller, lighter vehicles, other vehicle improvements, improved traffic flow, and a change in the pattern of use - higher occupancy rates and greater use of public transport.

In industry, process improvements and changes, and general energy conservation programmes, will improve energy efficiency. Computerised control of processes will help significantly in this area. Better, more exact control of individual processes will improve the efficiency of that process. In the overall production environment computer aided scheduling and production planning will give further efficiencies in both raw materials (including energy) and plant utilisation. Interfuel substitution is already noted.

Total energy systems in large commercial buildings can be designed to minimise peak demands for electric power as well as reducing total power consumption by more efficient use. This can be particularly advantageous to the supply authorities if the start-up demand peak can be reduced, by spreading it over a longer time. Computerised control systems are used to programme and control different energy uses in a building according to a heirarchy of priorities. The technology is now available to introduce time-of-day charging for electricity consumption and to have interaction between the supply authority and the consumer's control computer.

The use of energy in buildings in Australia is estimated at 20% (Rawlings, 1979). In domestic dwellings it is further estimated that 26% of the total energy input is used for space heating and cooling. Much of the space heating requirement can be reduced by appropriate measures. Ceiling insulation and foil insulation in brick veneer walls, can each reduce heat requirements by about 25%. Much better utilisation of passive solar heating can also be made at no extra cost during the design and construction phase. Changes to existing buildings to improve their thermal efficiency are far more expensive to add later rather than during construction. Building and planning codes can be written to improve the thermal quality of new buildings. As energy costs rise relative to building material costs it will become increasingly attractive to insulate existing buildings.

3. Environment for energy production

OPEC oil: prices and supply

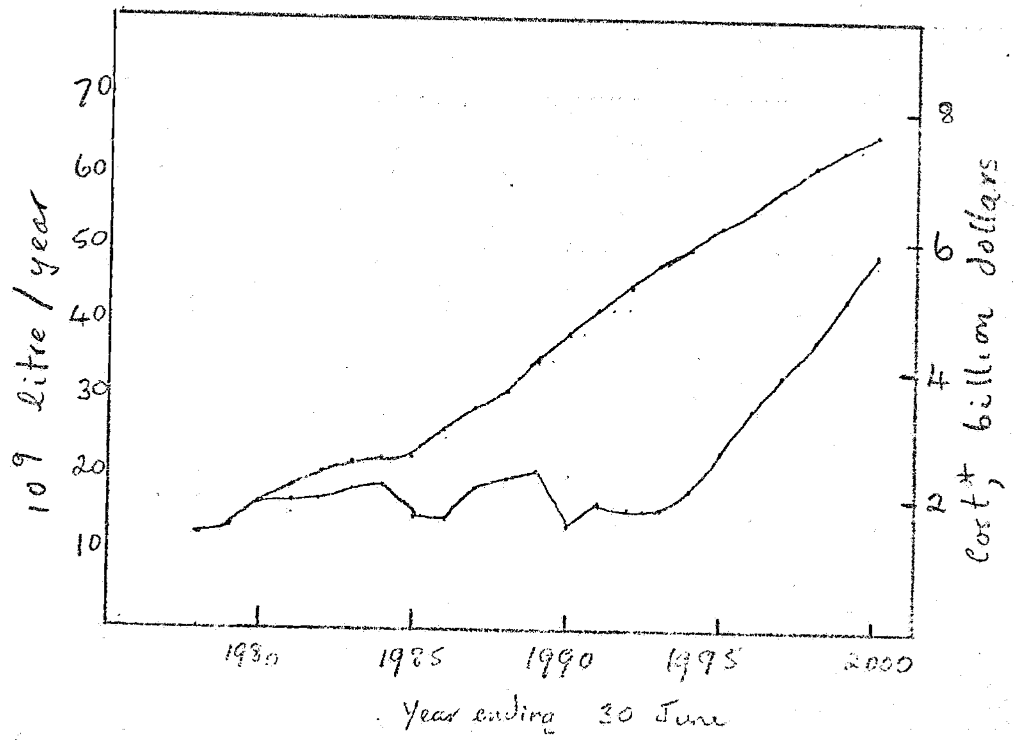
The OPEC oil price rises of 1973-74 gave the first indication of how the transport sector, and society generally is so critically dependent on petroleum derived liquid fuels. The 1979 Iranian revolution further indicated that the oil producing countries controlled not only the price but the production level. The fixing of the production rate is of grave concern to countries such as Australia which import substantial quantities of oil and have declining domestic reserves. Supply shortfalls have already occurred and the possibility of further substantial price rises or embargoes are a possibility.

Several major factors affect the availability of oil from the OPEC cartel. One is the degree to which the USA can curtail its enormous oil consumption (over 1000 Gl/y, c.f. Australia's 35 Gl/y). Even after the 1973-74 price rises the USA's oil imports have increased in volume and value and have played a major part in that country's balance of payments problem and have caused international monetary difficulties (McColl, 1979). The second factor is the degree to which Saudi Arabia as the worlds largest supplier (and holder of reserves) is willing to increase production and also to vary its production in order to promote price stability by damping out temporary supply shortfalls and excesses.

Overseas countries which have been largely dependent on oil for generating electricity are now looking to coal and uranium for their electricity production. Recent analyses by the International Energy Authority predict that Australia will be the largest supplier of steaming coal by the year 2000. A total production of 285 Mt/y is envisaged compared with current production of about 70 Mt/y. Australia is in the position to supply considerable quantities of uranium yellow cake and could also provide enriched U^{235} reactor fuel.

Recent estimates of Australia's future oil demand were discussed in the section on Liquid Fuels (S2). The expected shortfall in domestic supply without any new discoveries is shown in Figure 3 together with the associated import cost for the oil at the late 1979 price of $117.5/kl. Smaller shortfalls (curve 2) are indicated when new discoveries, with a 50% probability of being found, are included in the supply estimates. The future supply situation is not a promising one - a 39 Gl/y shortfall by 1990 (costing $4600 million at current prices and values) if there are no new discoveries, and even with new discoveries of median probability, the year 2000 shortfall is 49 Gl (costing $5800 million). With the current world supply situation, a major effort to reduce oil consumption, to find new oil fields and to produce alternative liquid fuels is clearly and urgently required.

FIGURE 3 <u>Australian crude oil shortfalls (and imported cost) relative to domestic production estimates</u>



* Cost based on present import parity of $117.5/kl ($18.69/bbl)

Curve 1 The expected shortfall without any new discoveries of oil in Australia.

Curve 2 The expected shortfall if oil fields with a 50% probability of discovery are brought into production.

Note These curves represent the difference between curves 1 and 2 and curves 1 and 4 respectively in Figure 2 in the section on Liquid Fuels. The cost scale is based on the current import parity price of $117.5/kl. ($18.68/bbl).

Australian demand for primary fuels

The Department of National Development (1978) has made projections of the Australian demand for primary fuels to the year 1987. These econometric estimates are based on an assumed 4% annual growth rate in gross domestic product. The average annual growth rates over the period 1973 to 1987 are;

oil	2.63%
coal	4.23%
natural gas	10.45%
hydroelectricity	1.07%
renewable fuels	0.31%
total (energy basis)	3.99%

These projections were made before the Iranian situation caused a further large rise in OPEC oil prices in June. The more recent estimates for reduced oil consumption assume the substitution of fuels such as gas and coal. Moreover the recent large estimates for steaming coal exports (annual growth in total coal production of 6.5% - see Coal section) are not included since they are not for domestic use.

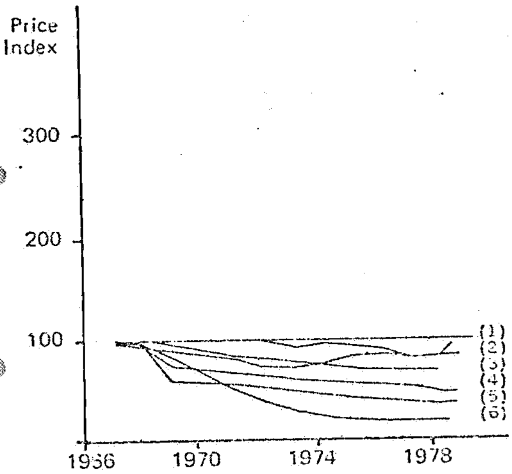
The use of nuclear energy has not been included in these estimates because there is no likelihood of its use in Australia up to 1987. But beyond this date it may be considered as an option in the coal deficient states, W.A. and S.A. The West Australian government has foreshadowed nuclear power as a possible option for future designated power station sites.

Australia's abundent and easily won coal resources provide cheap electricity which is currently attracting energy intensive industries such as alumina smelters. Inability to satisfy all requests for electricity for this export based industry has led to recent plans to speed up and increase electricity generating capacity.

Energy prices

In real terms, energy prices in Australia have fallen since 1967. Figure 4 from the Department of National Development illustrates the situation.

FIGURE 4 Trends in Australian energy price levels, 1967-1979 in constant 1966-67 values



Key: (1) Retail, premium motor spirit, Melbourne. Source: Australian Institute of Petroleum, Royal Automobile Club of Victoria and Departmental estimates.

(2) Steaming coal, N.S.W., for local consumption. Source: Electricity Supply Association, Australia and Joint Coal Board.

(3) Unit revenue of all electricity sales. Source : ESAA

(4) Residential gas tariff, Melbourne. Source: Gas and Fuel Corporation

(5) Industrial/commercial gas tariff, Melbourne. Source: G & FC.

(6) Unit revenue of all town gas and natural gas sales.

Note: Price series were deflated to 1966-67 base year values using the CPI for the motor spirit and residential gas series and the implicit GNE price deflator for the industrial, commercial and unit revenue series.

Source: D. National Development (1979).

Current (November 1979) fuel costs on an energy basis are given by the following approximate values.

TABLE 4 Approximate current costs of different forms of energy

	Unit Cost	Energy Cost $/GJ
Crude oil (import parity price)	$117.5/kl	2.6
LPG (approx. export price)	$110 /t	2.2
LPG (approx. retail price)	13¢ /l	5.0
Natural gas (approx. domestic rate)	0.3¢ /MJ	3.0
Premium motor spirit (retail)	27¢ /l	7.8
Electricity (approx. domestic rate)	4¢ /kWh	14.4
Steaming coal (f.o.b. export)	$25 /t	1.0
Coking coal (f.o.b. export)	$50 /t	1.9

While substitution of one fuel for another is not always simple or even possible, the approximate prices give some indication of the potential for economic savings by fuel substitution.

Resources, consumption and resource lifetimes

Table 3 outlined Australia's demonstrated economic and recoverable non-renewable energy resources together with the annual consumption in 1976-77 and the reserves/consumption ratio (ratio of preceding two columns). A broad perspective indicates that while Australia has a serious liquid fuels problem it is well endowed with other energy resources and has the scope for enlarging its exports in energy resources such as coal and uranium. There is also scope for conversion and substitution of energy resources especially to provide more liquid fuels. The abundance and future need for resources needs to be considered in framing future domestic and export requirements of each fuel.

The "demonstrated, economic and recoverable" resources are the most certain estimates of energy resources because they are the amount which can be extracted from demonstrated resources, economically at present day values for the product. An increase in the value of the resource, increases the economic reserves because reserves which are now sub-economic can be profitably extracted. The recovery factors used for the reserves are the best estimates for the current technology but new techniques could give better recovery factors and an increase in recoverable resources. Although reserves may be enlarged by an increase in price, not only is the energy more costly to extract, but more energy will be expended in its extraction. Current energy for extraction is small but could become significant.

The reserves/consumption ratio is the lifetime of the resource if the current production rate and consumption pattern remains constant, however, this is a most unlikely situation. Overall domestic consumption of energy is likely to increase modestly due to both population growth and increase in per capita consumption. The earlier projections for domestic consumption up to 1987 do not take account of the likely large increases in exports of steaming coal, liquified natural gas and uranium nor of the probability at a later date of increased coal extraction for conversion to hydrocarbon liquids. The rapid decreases in the resource lifetime due to a continual growth in consumption are shown in the following table.

TABLE 5 Decline in resource life caused by increases in the rate of consumption

Resource Life with no increase in rate of consumption (years)	Resource Life with annual increases in rate of consumption of:			
	1%	2%	5%	8%
10	9.5	9.1	8.1	7.3
100	69.3	55	36	28
1000	239	152	79	55

Hence, given some of the possible and substantial stepwise increases in demand for energy resources, the apparently high reserves/consumption ratios are not so high as to consider the resources limitless, or to allow unlimited exports without a regard to long term domestic requirements.

Manpower and infrastructure availability

Australia's mineral and energy resource projects are characteristically of world scale and efficiency and the products compete favourably in the world market. One major drawback however is that many deposits (already established or proposed for development) are in remote areas and do not have supporting infrastructure. For example, the large Bowen Basin coal mines producing export coking coal required new towns, roads, railways, water supplies and electric power. Much of these facilities were provided by the developing companies. Further developments in the same area will benefit from the existing infrastructure, especially the growing service industries in the adjacent coastal towns, but major dedicated services such as rail, water and power will be required individually for each new development project.

Australia's largest single development project, the North West Shelf natural gas project, faces a similar situation. Out of a total project cost of about $2 billion (1974 values) the provision of social infrastructure is estimated to be about $550 million (Pilbara Study, 1974).

Coal developments in Victoria's Latrobe Valley and N.S.W.'s Hunter Valley will be well supported by existing social infrastructure. Only dedicated services will be required as would be the case for any major project irrespective of the degree of development in the local region.

Manpower requirements during construction phases of development may not be adequate in some instances. The North West Shelf development envisages a development work force of about 5,000, and a production work force of 800 (D. Industry and Commerce, 1979). Medium size projects such as BHP's Gregory coal mine were estimated to need 1,000 men during construction and 500 during production (D. Industry and Commerce 1979). It was concluded that not all manpower requirements for the North West Shelf project could be met from existing Australian resources (Ploum, 1979), and as a consequence the West Australian Government has started an emergency programme to train tradesmen for development projects in the State.

A submission from Monash University to this Inquiry (Endersbee, 1979) noted the upsurge in major resource developments and claimed that Australia was not producing enough tradesmen, technicians and engineers. A variety of educational proposals were made including scholarships for engineering students. The rapid rate of technological change was noted and hence the need for particular courses to train people in the emerging technologies. Offshore oil exploration and development technology is an example. There are many unique trade skills in this area.

Organisation and responsibilities for energy

There are large numbers of organisations responsible for organisation and production in the energy sector. The structural interrelationships of the sector indicate its unco-ordinated evolution, however recent changes are leading to a more rationally organised system than that derived historically.

Australia became a member of the International Energy Agency (IEA) in May 1979. The IEA is the major forum for continuing consultation and co-operation on energy matters between most of the major industrialised nations. The IEA includes in its activities the management of an emergency oil sharing scheme for its members.

The main Federal responsibility for energy lies with the Minister for National Development whose responsibility includes;

- the Department of National Development whose functions include advising the Minister on policy, planning and research on energy matters,

- the National Energy Advisory Committee (NEAC) composed of a cross-section of representative experts which advises on all matters relating to national energy policy,

- the National Energy Research Development and Demonstration Council (NERDDC) which advises on the national effort and the disbursement of grants for energy research development and administration,

- the Australian Atomic Energy Commission (AAEC) which is concerned with many aspects of uranium developments and atomic energy,

- the Pipeline Authority which operates natural gas pipelines,

- the Snowy Mountains Hydro-Electric Authority.

Other portfolios concerned with energy include Science (responsible for CSIRO), and Trade and Resources the Minister of which chairs the Australian Minerals and Energy Council (AMEC). AMEC is composed of Commonwealth and State Ministers with responsibilities in minerals and energy and AMEC's role is one of co-ordination in these matters where there are interacting responsibilities.

At the state level there are departments usually termed the Department of Minerals (or Mines) and Energy. The operations and responsibilities of these are outlined by ASTEC (1978).

Most production activities for oil, gas, coal and uranium are carried out by the private sector. Public utilities provide most electricity (and operate some collieries) and national gas distribution is a government function (the Pipeline Authority).

Energy research and development is performed in many areas detailed by ASTEC (1978). These include universities, CSIRO, goverment laboratories, public utilities and many industrial research laboratories.

Social and environmental restraints

Particular aspects of future energy options which have potentially undesirable consequences are noted here.

Increased open cut and particularly open pit mining can pose long term aesthetic and dust generation problems. Disposal of fine tailings from coal washing operations poses problems in some areas.

Oil drilling in the Great Barrier Reef region has been stopped by the Government until the results of research are known. Damage to the Reef is feared through oil spills which could cover large areas of the Reef at low tide. Despite continued efforts, oil spills occur from tanker mishaps (either loading or through collision) or through well blowouts such as in the Gulf of Mexico. Difficult navigation in the Reef area further increase the potential hazards from shipping accidents.

Uranium mining and enrichment is an area of complex issues. Some of the potential problems include;

- conflicts over Aboriginal lands and the Kakadu National Park
- release of radioactive and chemical wastes into streams
- health risks to workers
- the production of reactor fuels is seen as assisting the production of long lived radioactive wastes for which satisfactory long term disposal methods have yet to be put into commercial practise.

Oil shale mining will involve dumping very large tonnages of overburden and the production of retorted shale which could be more readily leached and contaminate water supplies.

Coal conversion will involve plants producing carcinogenic materials which could pose a health threat to the workers.

LIQUID FUELS

LIQUID FUELS

1. Perspective

2. Technologies

2.1 Petroleum

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2.2 Oil shale

2.3 Coal conversion

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LIQUID FUELS

1. Perspective

TABLE 1

Recoverable petroleum reserves in Australia

	Crude Oil, Gl*	Condensate, Gl	LPG, Gl	Natural Gas, Tl*
Victoria	463.7	32.6	87.6	220.6
South Australia	8.6	6.9	39.6	113.2
Western Australia	46.0	66.4	64.6	477.3
Central Australia	10.3	1.5	3.9	25.5
Queensland	3.9	0.2	-	6.4
Total (before production)	532.5	107.6	195.7	843.0
Total at 31-3-79	331.7	104.4	174.3	798.7
1978 Production	25.2	-	3.54(b)	7.3(a)
Reserves/Production, years	13	-	49	109(a)

(a) The planned production rate of 13.6 Tl from the North West Shelf lowers reserves/production to 38 years.

(b) estimate

Sources: B.M.R. (1979), Keith (1979)

* 1 Gl = 1 gigalitre = 10^9 l = 6.29 x 10^6 barrels
1 Tl = 1 teralitre = 10^{12} l = 10^9 m^3 = 35.3 x 10^9 ft^3

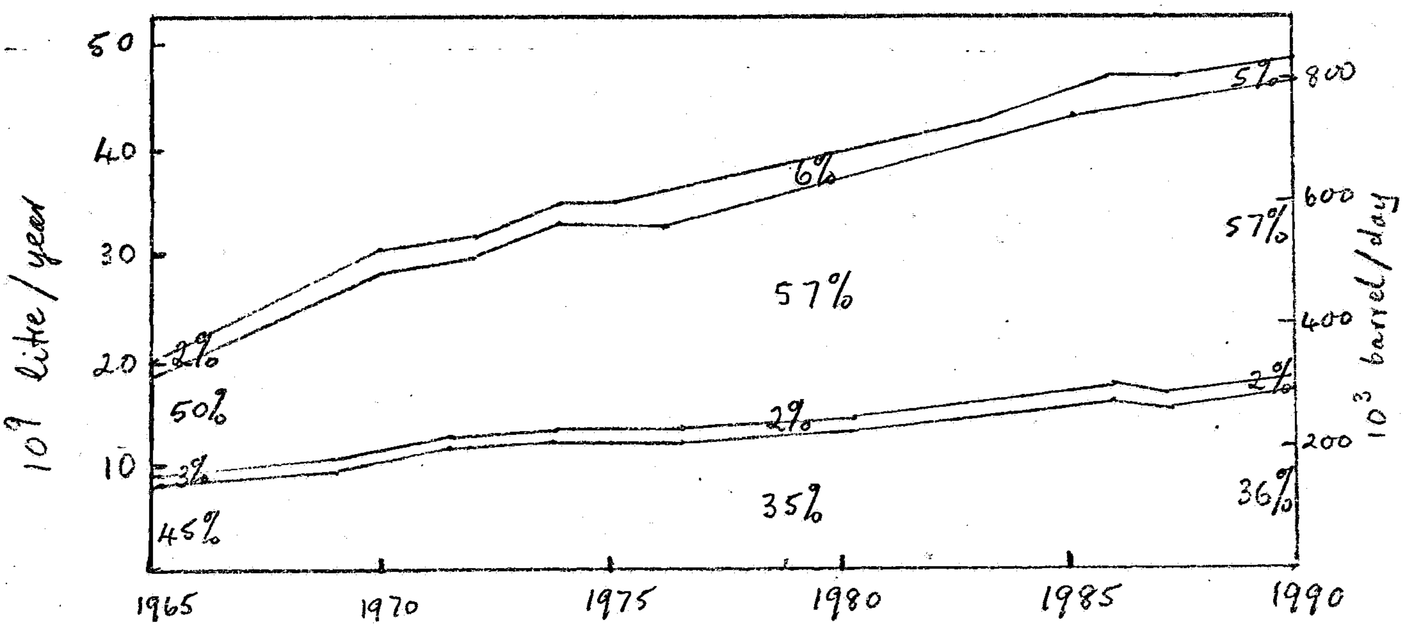
TABLE 2

Consumption of petroleum products, 1977

Product	Volume, Ml	Percentage	
Motor Spirit	14212	37	
Automotive distillate	6106	16	58%
Aviation gasoline	114	0.3	transport
Aviation turbine fuel	1948	5.1	
Industrial diesel fuel	1977	5.2	
Lighting and power kerosene	303	0.8	
Heating oil	914	2.4	
Fuel oil	6695	18	
Lubricants	442	1.2	
Bitumen	563	1.5	
Solvents	145	0.4	
Liquified petroleum gas	840	2.2	
Refinery gas	113	0.3	
Other products	1030	2.7	
Refinery fuel	2694	7.1	
TOTAL	38096	100	

Source: Australian Institute of Petroleum (1978a)

FIGURE 1 Australia's oil consumption by end use



Source: Esso (1979)

TABLE 3 Brown coal (ASIC 1202) + crude petroleum (incl. natural gas) (ASIC 1300).

Year	Establishments at end of June No	Total employment at 30 June No	Turnover $M	Value Added $M	Fixed Capital expenditure (a) $M
1968-69	11	2 973	89.8	63.1	112.8
1969-70	12	3 231	123.3	103.2	104.5
1970-71	13	3 176	265.8	233.8	80.8
1971-72	14	3 707	362.7	294.0	33.9
1972-73	14	3 402	367.3	327.2	33.4
1973-74	14	2 776	444.8	391.9	38.7
1974-75	14	2 956	526.6	474.0	82.9
1975-76	13	2 938	568.0	511.0	88.6
1976-77	13	3 178	628.1	567.7	97.5
1977-78	14	3 138	795.3	719.1	108.1

(a) Outlay on fixed tangible assets less disposals.

Source: ABS Census of Mining Establishments.

TABLE 4 Petroleum refining (ASIC 273).

Year	Establishments at end of June No	Total employment at 30 June No	Turnover $M	Value added $M	Fixed capital expenditure (a) $M
1968-69	20	4 396	263.4	95.1	14.3
1969-70	19	4 162	207.5	96.9	35.6
1970-71	-	-	-	-	-
1971-72	17	4 147	256.4	115.2	16.9
1972-73	16	4 190	255.3	111.2	20.5
1973-74	14	4 417	276.9	132.9	17.1
1974-75	12	4 561	288.7	130.0	24.0
1975-76	11	4 392	357.1	132.9	18.0
1976-77	12	4 544	450.8	155.5	42.2
1977-78	12	-	540.5	198.0	87.5

(a) Outlay on fixed tangible assets less disposals.

Source: ABS Census of Manufacturing Establishments.

TABLE 5 Gas production and distribution (ASIC 3620)

Year	Establishments at 30 June No	Total employment at end of June No	Turnover $M	Value added $M	Fixed Capital expenditure $M
1968-69	56	10 182	123.3	82.4	29.6
1969-70	55	9 650	128.7	83.9	26.1
1971-72	40	8 707	147.7	91.1	43.1
1974-75	37	8 994	253.6	151.1	68.7

Source: ABS Census of Manufacturing Establishments.

The statistics for crude petroleum (including natural gas) in Table 3 are in an aggregate with brown coal mining. Individual figures for this sector in 1976-77 are given by the Department of National Development (1979). Oil refining, oil marketing and gas distribution statistics are also given (see Table 6).

TABLE 6 Oil industry, 1976-77

	Persons employed at 30 June 1977	Value added: At factor cost $M	Value added: Indirect Taxation[a] $M	Total capital expenditure[b] to June 77 $M
Oil and Gas - Exploration development and production	2 200	510	400	2 000
Oil refining	4 300	170	-	700
Oil marketing and distribution	65 000[c]	17 000	820	2 400
Gas transportation and distribution	9 000[c]	250	-	1 000

(a) Includes levies, excise, and customs taxes.
(b) At historical cost. Includes expenditure on oil and gas exploration.
(c) Estimate.

Employment levels in the industries covered in Tables 3, 4 and 5 are seen to be essentially constant in the last 10 years.

In 1976-77 Australia's oil trade was made up of

	Volume, Gl	Value, $M
imports of crude oil and petroleum products	14.43	980
exports of crude oil and petroleum products	2.23	203
production of Australian crude oil and petroleum products	24.3	364

(Sources: Australian Institute of Petroleum, (1979) and ABS).

Levies, excise, and customs taxes yield significant government revenue from this industry. In 1976-77 such indirect taxes were $400 million for oil and gas exploration and $820 million for oil marketing and distribution. Since the 1977-78 budget the Government has successively raised the crude oil levy such that now all crude oil is sold to refineries at full import parity price. It is anticipated that this oil levy will contribute about $2023 million to Commonwealth revenue in 1979-80, an increase of $834 million of the previous year.

Australia is only two-thirds self-sufficient in crude oil supplies (see Table 1, Energy - Overview) and as production rates from Bass Strait have already reached a plateau and as demand continues to increase, the dependence on foreign supplies and alternative liquid fuels will increase (see Figure 2).

Australia's urgent and dominant energy need is for new sources of liquid fuels.

2. Technologies

2.1 Petroleum

- Exploration

Exploration offers the hope of providing the cheapest but least certain means of increasing our liquid fuels self-sufficiency. The production cost of oil has for some time been a small fraction of the OPEC levied price. Up till the 1977 budget, producers were being paid only $2.33/bbl ($14.65/kl) yet were still operating at a profit; imported oil at that time cost about $13/bbl ($82/kl) and is currently $18.68/bbl ($117.5/kl) or more. Present indigenous supplies of oil are dramatically cheaper to the nation as a whole than imported oil or liquid fuels obtained from coal or biomass. In Australia the prospects for future oil discoveries are not considered high by world standards (NEAC, 1978b). The Exmouth Plateau off Western Australia is considered to be the most likely area for finding a large reserve of oil or more gas. However, drilling costs are high (up to $10 M for an offshore well) and failure to find a commercial field is more likely than not. Development costs and hence oil costs will be high also and this is part of the justification for allowing producers the full import parity price for new oil discoveries.

Estimates by the Bureau of Mineral Resources of undiscovered reserves of oil in Australia have been quoted by Folie and Ulph (1979) and are shown in Table 7. The projected production from these undiscovered new reserves is discussed later (see Section 3 and Figure 2).

In recent years rapidly developing technology has increased the chances of successfully drilling a productive well, as well as opening up vast areas of deeper offshore prospective sites - Exmouth Plateau being such an example. In the last 10 years the water depth capability on a drilling site has advanced from 300 m to over 1200 m (Mukhtar, 1979). The recent Zeewulf 1 well was drilled in 1192 m of water (without commercial success). Although exploration capabilities extend to such water depths, production capabilities for oil production well heads extend to water depths of only about 300 m. The proposed North Rankin gas well being investigated by the North West Shelf Joint Venturers would involve a platform standing in 125 m of water and represents one of the deepest underwater gas production ventures in the world. Yet current exploration in the Exmouth Plateau is in water depths of 600 m to 3000 m. If economic reserves are found, development concepts will have to be put into operating practice.

The technological development in offshore exploration is being done by the major oil companies already operating in other offshore fields, e.g.

North Sea. It would appear that Australia will have to continue to buy this technology as it needs it. The availability and use of these rapidly developing and expensive overseas skills appear to offer Australia a means to greatly enhance its energy resources position and even the possibility to become self-sufficient in oil for the short-term at least. Planned exploration expenditure of $500 M in the next five years will also have strong stimulating effects on the supporting industries.

TABLE 7

Undiscovered reserves of oil (Gl)

Zone	Description	Probability of finding at least the stated reserves		
		80%	Mean (50%)	20%
Area 1	Onshore and offshore in water depths less than 200 metres	111	157	178
Area 2	Medium depth water 200 m to 500 m	52	125	152
Area 3	Deep water below 500 m	163	453	639

Source: Folie and Ulph (1979)

The recovery of oil from reserves varies considerably between different reserves. The world average recovery figure is about 25% whereas recovery from Australia's major supplier in Bass Strait is at least 60%. Our other reserves have lower recovery factors. Secondary recovery processes can be used to get further oil from reserves. Such processes include the injection of steam and detergents to increase the recovery. These processes are expensive due to reagent costs. An Australian development envisages the injection of bacteria to produce detergents from the oil in situ and hence improve the recovery. The greatest potential for secondary recovery processes is at Barrow Island where primary recovery is only about 12%. Other small fields are also potential candidates (McKay, 1979). Improved recovery methods may provide some short term respite but do little to change the long term oil supply situation.

Refining

The refining of crude oil is a complex combination of processes involving basically, distillation and chemical reforming of hydrocarbons. The processes can be varied in many ways to suit the raw materials and the desired mix of products.

Only lower boiling point hydrocarbons are suitable as transport fuels for internal combustion engines (motor spirit, diesel and aviation fuels). The higher boiling fractions (heavies - containing about 11% hydrogen by weight) are used for fuel oil or can be cracked and hydrogenated to form both light fractions (with about 14% hydrogen) and tars and chars with a low hydrogen content. Australian refineries currently produce about 5 Mt of fuel oils a year. Saluzinsky (1978) suggests that the use of more than 4 Mt/y of industrial fuel oil could be replaced with coal or gas. He claims that a catalytic cracking plant costing about $500 M could use 5 Mt of fuel oil to produce about 2 Mt of transport fuels. At much greater expense a further 2 Mt/y of transport fuel could be produced by hydrocracking. Thus, with the same crude oil consumption, Australia could increase its transport fuel requirements by at least 25% or it could import less crude and still produce the present amount of transport fuel. The C.S.I.R.O. submission to this Committee (Sanders, 1979) suggests that the oil industry would introduce the necessary technology for catalytic cracking of these heavier fractions if appropriate incentives and constraints are applied by Government. Mobil Oil Australia has indicated that it is seriously considering these refinery developments (Maher, 1979). 134

If the refineries converted significant amounts of the fuel oil to transport fuels present users of fuel oil would need to use alternative fuels. Substitution by gas and coal are discussed in the respective sections on these fuels. For low temperature process heat, solar energy would offer another alternative.

LPG and natural gas

Table 1 shows that the reserves of LPG and natural gas are large by comparison with recent domestic consumption. However, production from the North West Shelf Venture would lower the lifetime of the gas reserves to 38 years assuming a constant domestic consumption.

With a suitable reticulation system natural gas can be used instead of oil for many fixed heating applications (process heat, space heating, etc.). It was noted in the discussion on refining that the saving of fuel oil by replacement with gas, enabled more transport fuels to be made from a given amount of crude oil.

The future availability of gas in Sydney has been enhanced by the Government's intention to eventually construct a gas pipeline linking the Bass Strait fields with Sydney (Fraser, 1979) thus ensuring a continuing gas supply when the Cooper Basin supply from South Australia is depleted.

Compressed natural gas (CNG) can be used as a vehicle fuel. Because of the stronger and hence heavier container required and because of refilling considerations, it is likely to be useful only for heavy commercial vehicles making single round trips which allow them to refuel at their base. It is unlikely to contribute more than 1% to transport fuel requirements.

The North West Shelf project is a massive resource development concept. It involves the construction of an offshore platform on the North Rankine field and it is envisaged that if this project is developed it will produce:

- 3.8 Tl of natural gas/year by pipe to Perth,
- 1.7 Mt of condensates/year,
- 6.5 Mt of LNG (liquified natural gas)/year (equivalent to 9.8 Tl of gas before liquifaction with 80% conversion).

The LNG would be exported and thus less than half of this energy resource and less than one third of the gas would be utilised in Australia. The nature of the project is such that a large production rate must be attained to repay the massive development and construction costs. It has been debated whether this resource would not be better utilised in the national interest by either piping or shipping the gas from W.A. to the east coast or by converting the gas to methanol for blending with petrol. The proponents of exporting LNG say that it is better to earn foreign exchange by export and that gas can be made from the abundant coal reserves on the east coast.

A $50 M feasibility study of the North West Shelf project is currently in progress and a decision on the eventual development proposal should be known in 1980. It is envisaged that the project would cost about $4 billion and would employ 3000 to 4000 people in the five year construction phase (Harrison, 1979). There would be continuing direct employment for about 500 people. The project would involve the building of a new town and facilities, offshore rig, onshore liquifaction plant and processing facilities, and a gas pipeline to Perth. There would be a large boost to the economy from the expenditure involved in the project. There will be greatly increased turnover and expansion in the supporting industries. It has been estimated that annual government revenue from the project would be $743 M (Bambrick 1978).

LPG is a less volatile hydrocarbon gas than natural gas. It can be readily stored in relatively light pressurised gas bottles. Most of Australia's present LPG production is a by-product from the Bass Strait oil fields. Most of it is currently exported. LPG is a good fuel for motor vehicles. Engine life is increased and emission levels are very much lower,

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however higher operating temperatures may necessitate more durable valves. LPG has a measured volumetric consumption rate in vehicles about 10% higher than that of motor spirit.

LPG can be used as a petrochemical feedstock instead of using naptha derived from crude oil. The Sixth Report of the Royal Commission on Petroleum (1976) predicts that almost 1 Mt/y of LPG could be used in this way. At the new high prices of OPEC oil ($117/kl or $18.7/bbl) it is likely that this substitution will take place.

2.2 Oil shale

Australia has very large reserves of medium quality oil shales. The National Energy Advisory Committee (1977) gives the inferred subeconomic resources of oil in shale as 455,000 Gl (over 1000 times Australia's remaining economic oil reserves - see Table 1). The great majority is in the Toolebuc formation, which extends the length of Western Queensland from N.S.W. & S.A. to the Gulf of Carpentaria. The Julia Creek deposit in the Toolebuc formation has indicated reserves of about 50 Gl and inferred reserves of 180 Gl (The Miner, 1979). The oil content averages 72 l/t. The Rundle deposit near the coastal Queensland town of Gladstone contains an estimated 360 Gl of in situ oil at an average grade of 77 l/t and with an overburden to shale ratio of only 1.2 (Southern Pacific 1979). The Rundle reserve is about the same size as Australia's present oil reserves (Table 1).

By heating the shale in retorts to temperatures of about 500^{o} C the organic kerogen material in the shale is broken down to oil, gas, and a carbon residue which is left in the shale. The oil product varies with the process used to produce it, but it can be roughly equated with a heavy crude petroleum. Small amounts of petroleum products have been produced from Australia's oil shales in the past, especially during war-time shortages. The deposits in the Toolebuc formation contain minor amounts of vanadium, uranium and selenium, and vanadium extraction has been considered for economic extraction as a by-product.

Methods of recovering oil from oil shale are being developed, principally in the U.S.A. In situ underground retorting (e.g. the Occidental process) is claimed to be the most promising way of treating low grade shales (less than 50 l/t). Various commercial retorts are available which are being assessed for treating crushed oil shale. The companies planning to develop the Rundle deposit are proposing to use a combination of retorts (Superior and Lurgi) for treating large and fine (-10mm) shale particles respectively. Full scale production at Rundle will require a massive open cut mining effort to shift over one million tonnes a day. Full scale oil output from 27 retorts is envisaged to be 42 Ml/day (265,000 barrels/day) or 15.3 Gl/year (Pierce, 1979) (equal to Australia's present petrol consumption). The total capital cost is estimated to be $2,132 million. Initial production with 2 retorts is scheduled to be 1.5 Gl/year with a capital cost of $272 million.

An above ground mining operation of this scale is likely to have major environmental problems compared with in situ retorting. Leaching of the spent shale could lead to alkaline and metal contamination of surface and ground waters (NEAC, 1977).

The heavy oil obtained from oil shale needs to be hydrogenated and also needs to have undesirable nitrogen and sulphur compounds removed before it can be readily used in a refinery to produce petrol. It is therefore more simply used as fuel oil. A probable cost of producing oil from the Rundle deposit is given as $126/kl ($20/barrel) (Folie and Ulph 1979). Much development work needs to be done to get better estimates of the technical and economic factors. Given the massive size of Australia's shale resources and the close to breakeven price predictions for their development, further enlarged development effort is being accelerated.

2.3 Coal conversion

There are a variety of processes for converting coal to liquid transport fuels and descriptions of these processes by the Joint Coal Board (1978) are used here. The production of methanol from coal or natural gas is discussed later and the use of solvent refined coal is mentioned in the discussion on coking in the Coal and Electricity section.

There are three main processes for producing oil fuels from coal:

(i) Pyrolysis

(ii) Hydrogenation including solvent extraction 138

(iii) Gasification to carbon monoxide and hydrogen followed by Fischer-Tropsch synthesis to petroleum substitutes or methanol.

Because of the large output of char, pyrolysis plants cannot make a major contribution in volume unless they are linked to a power station which uses the char. However in view of the valuable anti-knock properties of the aromatic compounds derived from pyrolysis it seems prudent that a part of our liquid fuel comes from this process. One could envisage a plant with pyrolysis and hydrogenation streams in parallel where the by-product char is used to make hydrogen and power for both systems. A Lurgi-type gasifier may also incorporate a carbonisation section to produce aromatics.

The thermal efficiencies of the several processes, assuming all products are used, are reported to be:

Pyrolysis	85-95%
Solvent Refining	65-70%
Direct Hydrogenation	65-70%
Methanol from coal	30-35%
Fischer Tropsch	30-40%

The first three processes are selective as to quality of feed. Ideally they require high volatile, reactive coals. The gasification (Fischer-Tropsch and methanol) processes need only a source of carbon and work satisfactorily on low grade coals.

(i) Pyrolysis This process has been used since 1798 for the production of coal gas and is still used on a large scale in coke production. For maximum yield of tar, temperatures in the range of 500 to 600°C would be used. Pyrolysis is attractive in that it does not require high pressures and the technology is established. However the by-product char is likely to be a difficult fuel for boilers and the ratio of char to transport fuel is so large that pyrolysis cannot be expected to make a major contribution to our liquid fuel supply. Moreover, agglomeration can be a problem in fluidised pyrolysis of bituminous coals.

It has been found that flash pyrolysis followed by immediate removal and cooling of the volatiles gives an improved yield of oils as compared with static processes. C.S.I.R.O. is currently doing research on flash pyrolysis.

(ii) <u>Hydrogenation</u> In this process coal is directly combined with hydrogen with the acid of a catalyst. Pressure is typically 20 MPa (200 atmospheres) and temperature 450^{o}C to 500^{o}C. Hydrogenation has the potential for producing the highest yield of liquid fuels at the highest overall thermal efficiency.

Solvent Extraction is a hydrogenation process. Coal is dissolved in an organic solvent and combined with hydrogen at high pressure and temperature, typically 700 kPa (7 atmospheres) and 450^{o}C. When boiler fuel only is required this is a relatively simple process in conception. There are some formidable problems which so far have prevented the design of a commercial plant, particularly the filtration of finely divided ash from a viscous fluid at high temperature and pressure.

(iii) <u>Gasification Synthesis</u> The coal is reacted under moderate pressure with steam and oxygen to produce synthesis gas (hydrogen and carbon monoxide). This gas is then converted to hydrocarbons by Fischer-Tropsch synthesis over an iron-based catalyst.

The process has the advantage that coal quality is not critical, as only a source of carbon is required. On the other hand the addition of oxygen is an adverse step which necessitates the rejection of carbon dioxide later in the circuit. Consequently the efficiency is relatively low.

The Sasol II plant in South Africa, now under construction, will have catalysts designed to increase the liquid yield and is designed to produce 2 Mt/y of liquid fuels from 12.2 Mt/y of low grade coal.

The large water consumption is a disadvantage of this process.

Further details of these processes may be found in papers which discuss the technology in an Australian context (Stewart, 1977; Edwards, 1978; Australian Institute of Petroleum, 1978). Stewart (1977) details the requirements and implications of a significant oil from coal program. A fully developed hydrogenation process with its high energy efficiency promises greater advantages than existing Fischer-Tropsch technology.

The claimed capital costs for proposed plants vary from $125,000 to $250,000 per kl/day ($20,000 to $40,000 per barrel/day). However for Sasol II the figure is approximately $375,000 per kl/day. The lowest cost estimate indicates that a 5.8 Gl/y plant (100,000 bbl/day) would cost $2 billion: this capacity compares with Australias total annual liquid fuel input of about 35 Gl. Expenditure on such a plant provides an extra supply of oil and saves $680 million per year on import costs ($117.5/kl or $18.7/bbl).

Stewart shows that a large coal liquifaction plant is a comparable development to a 2000 MW power station. The table below compares major parameters for a power station, a power station with flash pyrolysis, and a hydrogenation plant producing syncrude.

TABLE 8 Major features of power station and coal conversion plants

	2000 MW power plant	2000 MW power + pyrolysis	5.8 Gl/y hydrogenation
Syncrude production, Gl/y	0	1.7	5.8
Coal consumption, Mt/y	9.1	11.0	14.6
Capital costs - plant, $ M	500	750	1500
- mines, $ M	150	180	250
Water requirements, Gl/y	83	85	8.9

A major study on oil from coal conversion options is being carried out by a West German consortium (Imhausen) for the Federal Government and the State Governments of Queensland, N.S.W. and Victoria. The study, costing about $4 million, will report on the feasibility of establishing commercial plants on the east coast.

It is noted in the section on Coal and Electricity that an investigation is being made into the establishment of a solvent refined coal plant using Victorian brown coal. This would be a good starting point for gaining operating experience in coal hydrogenation in Australia.

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NERDDC grants supporting 17 other coal conversion investigations in Australia totalled $2.6 million in 1978-79.

2.4 Methanol - from natural gas , coal or biomass

Methanol can be used as a fuel either neat or in blends with petrol in most spark ignition engines. When methanol is used on its own, engine modifications are required but when used in blends of up to 15% methanol, only carburettor adjustment is generally required although some carburettor parts may need to be changed because of corrosion (Milkens, 1979). The high volatility of methanol can cause vapour lock problems in blends. To overcome this problem the volatility range of the blending petrol needs to be reduced. This can be done by reducing the condensates, changing the proportion of aromatics or by the addition of higher alcohols. Because of phase separation problems when transported in ships, petrol and methanol would have to be shipped separately and blended onshore. Milkens (1979) reports that 15% blends of methanol in motor spirit give an increased fuel consumption of 4%. About 14 volumes of methanol in such blends gives the same range as 10 volumes of motor spirit (Stewart et al, 1979). The high octane rating of methanol enables the lead content to be lowered in blends made with methanol.

Methanol can be produced from natural gas or coal and with Australia's reasonable gas reserves and large coal reserves, methanol could contribute significantly to our liquid fuel requirements for the medium term. Costs of producing methanol in Australia have been estimated by Bradley and Robinson (1978) for a variety of feedstock sources and costs. The prices range from 6.17 c/l for methanol produced from natural gas (at $1/GJ) at Dampier to 7.37 c/l when produced from brown coal in the Latrobe Valley.

These authors also calculated that if methanol was priced at 6.43 c/l and crude oil cost $92.5/kl, ($14.7/bbl), a 15% methanol blend would have the same cost effectiveness as petrol costing 20.9 c/l. Now that the price of oil has reached the price they used, according to their assumptions and calculations it would be economically attractive to produce methanol from North West Shelf gas.

Methanol is currently produced from natural gas in the U.S.A., by the well established steam reforming process to synthesis gas. When using coal as a feedstock, the Lurgi process is used to make the synthesis gas (hydrogen & carbon monoxide). The nature of the coal is not a critical factor when producing synthesis gas.

Resource requirements and product yields of Bradley and Robinson's scenarios are as follows:

TABLE 9

Summary of requirements and product yields for methanol production

Feedstock requirement	Mt/y	Capital Cost, $M	Methanol produced Mt/y
Natural gas	1.2 (1.4 Tl)	235	1.65 (2.34 Gl)
Blackcoal at Newcastle	3.0	396	1.65 (2.34 Gl)

Like coal or natural gas, cellulose can be gasified to carbon monoxide and hydrogen which can then be converted to methanol. Stewart et al (1979) estimated that production from crop and forestry residues and new plantings would yield methanol with an energy content of 287 PJ* (c.f. energy of motor spirit of 482 PJ in 1976-77). An estimated production cost of 20 c/l gives a retail cost range the same as for ethanol, 37 to 54 c/l.

* 1 PJ = 1 petajoule = 10^{15} joule = 948 x 10^{9} BTU

Methanol from biomass suffers from the same disadvantages as ethanol; expensive and dispersed raw materials. There appear to be less opportunities for technical developments to economise on the process.

There is little prospect that this development will be significant at present when methanol can be produced from gas or coal at an estimated cost of 6 to 8 c/l.

The Government proposes to have a study carried out on the use of methanol as a petrol extender.

2.5 Methanol to petrol

A catalyst recently developed by Mobil can be used to convert methanol to liquid hydrocarbon fuels. The process has only been tested in a 600 l/day pilot plant and the efficiencies and costs are not accurately known. Methanol can be produced from natural gas (from e.g. North West Shelf) and then with the Mobil process, petrol can be formed. McWaters (1978) has estimated the costs of such a project based on the North West Shelf natural gas resource. The main features are shown in Table 10.

TABLE 10

Requirements and production rates of a natural gas to petrol plant

Natural gas, required, Mt/y	Capital cost $M	Cost of petrol c/l ex Dampier	Petrol production, Gl/y
6.5	1100	12.9*	4.7

* Milkens (1979) uses a higher estimated cost of methanol to recalculate the petrol cost at 16.2 c/l.

This is an area of rapid technological change and prices may be reduced as the process is optimised. Other processes are being developed which use a catalyst to convert natural gas directly into petroleum fuels (Wainwright, 1978). This work is still in the experimental stage but it could provide a cheaper means of achieving the same end.

The size of such ventures in terms of both capital and resources is large but not as big as some natural resource projects such as the proposed North West Shelf venture (costing about $4 billion). The 1.4 Tl consumption of natural gas for methanol production is less than the planned 9.8 Tl/y production rate of natural gas needed for LNG production of 6.5 Mt/y. The 2.3 Gl of methanol produced would provide a 15% (by volume) addition to the total motor spirit requirements. The production of petrol from all of the natural gas designated for LNG would satisfy 1/3 of our petrol requirements of 14 Gl/y.

2.6 Biomass

Plant materials are produced with the aid of solar energy and these materials can be used as a raw material for producing a variety of liquid and gaseous fuels and chemicals. Trees, agricultural crops, water plants, algae, and plant and animal wastes, can be converted into fluid fuels such as ethanol, methanol, methane, and some hydrocarbon products. CSIRO have recently made a comprehensive review of the production of ethanol and methanol from biomass (Stewart et al 1979; Weiss 1979).

Ethanol

Ethanol has been tested both alone and as admixtures to conventional motor spirit.

The use of neat ethanol as a fuel requires modifications to the fuel mixture and inlet system (Milkens, 1979). The research octane number is advantageously high at 106 to 110 and the greatest fuel efficiency would be obtained in high compression engines. Emissions are similar to those for petrol.

Ethanol can be used satisfactorily in blends up to 20% in motor spirit, but tuning adjustments are required. Like methanol, its use in blends allows the lead content to be lowered.

The use of ethanol as a motor fuel and motor spirit extender is being developed rapidly in Brazil. In an ambitious programme they plan to produce 4.3 Gl/y by 1982 and ultimately 28.7 Gl/y (Stumpf, 1978).

Ethanol is produced by the fermentation of sugars which can be obtained directly from plants such as sugar cane and sugar beet or can be obtained by the hydrolysis of starch or cellulose. In Australia ethanol is produced from the fermentation of sugar contained in the molasses by-products from sugar milling and refining. In Brazil, large scale production of ethanol for vehicle fuel is fermented from sugar juice.

The CSIRO study estimated the possible production levels and production costs of ethanol made from a variety of crops; cereal grains, sugar cane and cassava. With new plantings of suitable crops a net yield of ethanol of 130 PJ/y (6.63 Gl/y) (Stewart et al, 1979) is predicted. This represents about 10% of Australia's total crude oil and condensate consumption in 1976-77 (Table 2 in Energy - overview). The retail cost per litre of motor spirit equivalent, assuming similar excise and distribution costs to current motor spirit, would range from 37 to 54 c/l (1975-76 dollars). It is concluded that such an industry is not likely to develop to a major scale until the economics can be improved considerably. Liquid fuels from coal and natural gas appear to offer significantly cheaper solutions to the shortage of liquid fuels. The fossil fuel raw materials are geographically localised and enable economic large scale plants to be built. Conversion plants using biological fuels are limited in size by the increasing raw material transport costs as the size of plant grows. The raw material costs are estimated to be 55% of the production cost of biomass alcohol.

Notwithstanding these inherent disadvantages of biological fuels, further developments may improve the economies of ethanol production such that it could make a useful contribution to liquid fuel supplies. Selected areas will have better economies than the average situation for large scale production calculated by Stewart et al. Also excess production of crops such as sugar cane could be used if distillery capacity were available. The incremental cost of production should give a lower cost product than that from a newly established processing facility. Developments such as continuous fermentation (Prince & McCann, 1979) and alternative microbial ethanol production processes offer potential savings. They could give higher conversion efficiency and a faster throughput and hence incur smaller operating and capital costs.

The net energy efficiency of ethanol production is low because of the high energy consumption in distillation. The availability of low value fuels for the distillation (e.g. waste biomass not suitable for fermentation) would be a significant factor in the choice of crop or the siting of the plant.

Zero value was given to the by-products of ethanol production in the CSIRO study. The residues remaining are large (1 tonne grain residue and yeast per tonne of ethanol product) (Stewart et al, 1979) and would be difficult to assimilate in the current market. It has been suggested that the ethanol production costs would improve if these products were utilised in an integrated agro-industrial complex (Weiss, 1979).

Oils and hydrocarbons

Anaerobic fermentation of cellulose material can yield volatile fatty acids with a high energy efficiency of conversion. These can then be converted (chemically condensed) to yield a mixture of ketone condensation products e.g. mesityl oxide, phorone and mesitylene (trimethyl benzene) (Weiss, 1979). These products have a lower oxygen content than ethanol (mesitylene is a hydrocarbon) and the product mixture has very similar properties to petrol and would be a more valuable fuel extender than ethanol or methanol. This process is at an early stage, the technology is novel, and comparative costs with other fuels are not available.

There are other alternatives for solar production of liquid fuels but technical and cost factors are not well documented. Several plant species, particularly in the Euphorbiacae family, produce hydrocarbons in reasonable quantities, and many of them will grow on marginal land. Oils from oilseeds could also be used as feedstock for liquid fuel production. An alga, Botrycoccus braunii, grows wild in certain lakes in Australia and other parts of the world, and produces hydrocarbons remarkably similar to those of crude oil. This organism, which gives rise to the oil bearing mineral, Coorongite, could potentially supply a large fraction of Australia's liquid fuel needs. The organism can contain as much as 70% of dry weight hydrocarbons, and could possibly supply all of our present oil needs from a lake area of 800,000 ha. It is however poorly understood, and should not be considered a potential short term solution to Australia's oil needs.

3. Present environment

The OPEC oil cartel has increased the price of crude oil by a factor of 10 in the last 9 years. The price spiral is indicated by the following costs for Arabian light crude (f.o.b.);

date:	9-9-60	1-9-73	1-1-74	1-10-75	1-1-79	12-11-79
$A/bbl	1.601	2.168	7.846	9.168	11.618	16.47
$A/kl	10.07	13.64	49.35	57.66	73.07	103.6

Because Australia imports one third of its crude oil requirements the price escalation represents a growing foreign exchange bill. More importantly perhaps is the strategic vulnerability when foreign oil supplies are withheld for policital bargaining purposes. Recent shortages of avgas, which Australia imports from Iran, highlight the real threat which a cut in supply would bring.

Australia's recoverable reserves of petroleum products (crude oil, condensate, LPG and natural gas) are shown in Table 1. These reserves are total recoverable reserves and include reserves not yet proven economic at current prices. The 13 year "lifetime" (recoverable reserves divided by current consumption rate) of oil reserves emphasizes the scarcity of known domestic supplies. The 109 year "lifetime" of gas is deceptively high because if the NW Shelf is developed the additional projected production rate of about 13 Tl/year of natural gas will more than halve this lifetime. Also a rapid increase in Australian consumption of gas will further reduce the lifetime.

Australia's crude oil production is currently about 25 Gl/y and it is estimated that this level will be maintained to about 1988 before production declines. Production could be raised above this level in the event of a national emergency but a continued higher production rate would lower the total recovery from the reserves. Crude oil requirements are estimated to continue increasing with an increasing population and an increasing per capita consumption.

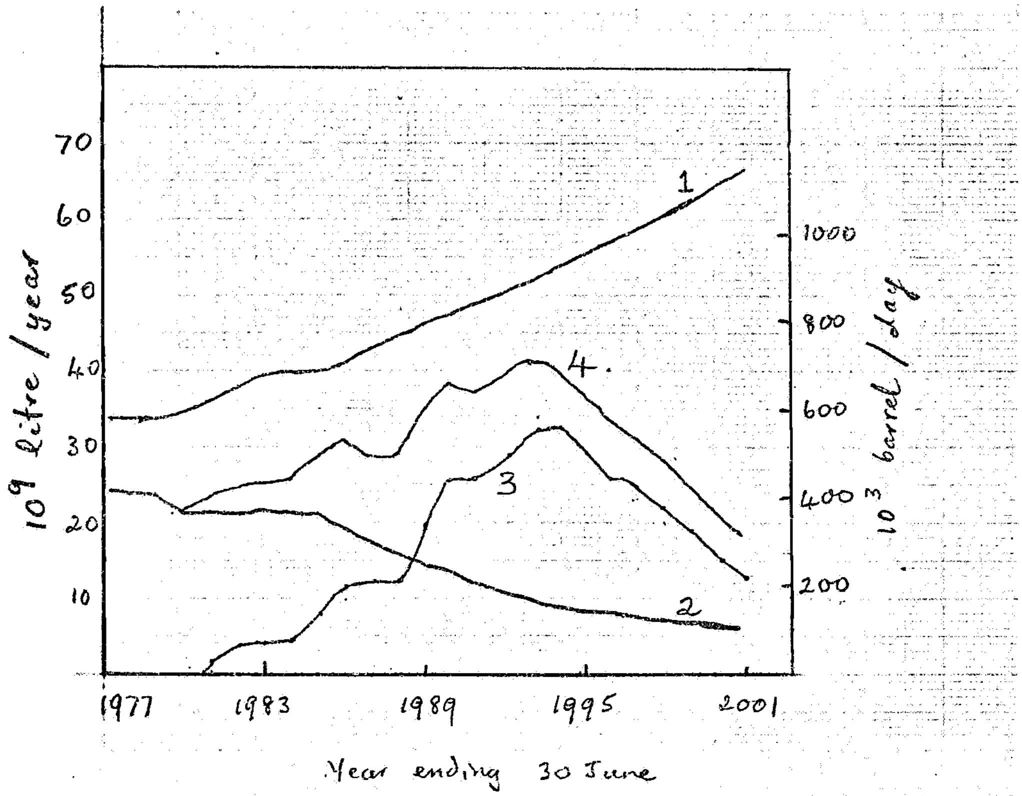
There have been many recent estimates of future oil demand and supply. The Department of National Development estimated in 1978 that

Australia's oil consumption would increase on average at 2.63% annually (based on an annual GDP growth of 4%). Recent events such as the reduction in Iranian supplies and rapidly increasing world prices together with a matching price for local crude led BHP (Foster, 1979) to assume a 2% annual increase in crude consumption in Australia. Folie and Ulph (1979) have also made recent econometric estimates of future demand based on varying oil prices. The most recent and long reaching estimates have been made by the Department of National Development and these are shown in Figure 2. The estimated demand for crude oil (curve 1) is compared with the calculated supply from known reserves (curve 2). Statistical estimates of undiscovered reserves were noted earlier in Table 7. The potential supply from undiscovered reserves and the aggregate supply are shown by curves 3 and 4. 148

The projections in Figure 2 clearly show Australia's continuing dependence on imported oil. If there are no new discoveries there is a shortfall of about 39 Gl/year (670,000 bbl/day) in 1990 which will need to be made up by increased imports or alternative domestic supplies of liquid fuels. At today's oil prices this shortfall would cost $4.6 billion but will be even larger because oil prices are virtually certain to rise in real terms. New discoveries can not be relied upon, and while every effort is made to discover and prove new reserves it will be necessary to plan for the situation where there are no reasonable discoveries. The alternatives are continued high imports, conservation measures or alternative fuels.

Australia is atypical of many western countries because of the large proportion of its crude oil consumption which is devoted to the transport sector (see Table 11). Only the U.S.A. and Canada have such proportionately high petrol use.

FIGURE 2 Crude oil supply and demand with production from new discoveries.



1. Projected demand, (medium GDP, medium energy price)
2. Projected supply from present domestic resources
3. Projected supply from new discoveries (median probability of discovery)
4. Projected aggregate supply, including new discoveries

Source: D. National Development (1979)

TABLE 11 Per capita consumption of oil products by country, 1976

Country	Total petroleum products litre/person	Petrol and aviation gasoline litre/person
U.S.A.	4 722	1 897
Australia	2 589	984
Japan	2 461	266
Britain	1 932	409
West Germany	2 562	452
Sweden	4 189	538

Transport accounts for about 58% of petroleum products used in Australia in 1977-78 and motor gasoline alone, for 37% of total petroleum (Table 2). Liquid hydrocarbon fuels are essential for the greatest part of our current transport system (electric rail and tram being the only exceptions). Because of the large fleet of oil fueled vehicles, it is not easy or cheap to change the usage pattern quickly. Oil fuels are advantageous for a number of reasons: they have a high energy density (30 times that of batteries) and they are quickly refueled (about 1,000 times faster than battery charging).

There is likely to be a continuing demand for a high private use of motor vehicles in Australia. High personal mobility is an accepted and expected part of the Australian lifestyle. Australia's sprawling, low density cities contribute to the need for private vehicles for a variety of reasons.

Eighteen per cent of total oil consumption is as fuel oil (see Table 2) which is mainly used for providing heat (as opposed to mechanical work) in stationary applications. This represents the greatest opportunity for conserving oil by using substitute fuels and is discussed later. Other non-fuel products such as solvents, lubricants and bitumen do not have cheap and available substitutes and there is little prospect of substitution in these areas. Even with substantial substitution and conservation it is apparent that there is most likely to be a continuing decline in liquid fuel self-sufficiency if the present domestic production status remains. Also Australia will continue to be dependent upon overseas oil imports to obtain heavy products such as fuel oil, lubricating oils and greases, irrespective of whatever light crude oil discoveries may occur.

Current Government policy provides the environment for many changes and developments in the energy sector. The energy policy objectives of the Government, (Newman, 1979) are:

- to move crude oil prices in the direction of international levels;

- to restrain the average rate of growth of energy consumption, particularly of liquid fuels;

- to achieve the highest degree of self-sufficiency in liquid fuels consistent with the broadly economic use of Australian energy resources;

- to develop economic oil and gas resources;

- to substantially increase energy research and development,

- to encourage individual major projects to meet overseas demand for energy materials where these would provide an adequate return to Australia.

The major initiative flowing from this policy is the pricing of Australian produced crude oil at import parity (OPEC) price. While refineries pay the full OPEC price for all oil, the producers will not receive full parity price on their oil, due to the Government levy. In 1978-79 the levy raised $1189 million but is expected to be $2023 million in the next financial year. For "new oil" discovered after 18 August 1978 producers would receive import parity prices without being subject to a levy.

Realistic pricing of oil is designed to:

- provide a major incentive for the search and development of new oil fields;

- encourage the conservation of scarce liquid fuels;

- encourage substitution of less scarce fuels for oil;

- encourage the development of alternative liquid fuels.

Taxation concessions have recently been introduced to encourage the conversion of industrial oil fired equipment to use other fuel. There are also incentives for the conversion of vehicles to run on LPG.

Australia's oil refining capacity and gas distribution network are fixed capital items which affect future fuel usage patterns. Australia's 11 refinery installations had a capacity of 35.6 Mt/y at December 1978. This is little more than the total demand and there is very little margin for plant maintenance and refitting or for disruption from industrial disputes. Refinery capacity in N.S.W. in particular is below reasonable levels, and the NSW Government is involved in a joint development to build a new refinery which will raise the State's petrol refining capacity by 20%.

The 169 seaboard bulk storage installations had a capacity of 11.0 Gl at 30 June 1978. This represents 29% of the total annual consumption of petroleum products in 1977. The NSW Government is promoting the establishment of strategic stockpiles of liquid fuels.

The Government has recently announced incentives to encourage greater use of LPG. These include removal of the sales tax on conversion equipment and removal of the road tax on LPG. This fuel costs about 1/2 that of petrol on a distance travelled basis. It costs about $700 to convert vehicles to enable them to run on either LPG or petrol. The Government is encouraging vehicle makers to sell factory produced duel fuel vehicles so that the conversion cost is reduced. At say $700 per vehicle, converting 500,000 vehicles (about 10% of Australia's passenger car fleet) represents an investment of $350 M. Manufacturers have expressed reluctance to produce LPG fitted vehicles in the factory until standards and safety regulations are finalised.

A wider distribution network for LPG is needed if LPG is to be an acceptable alternative. Again a large capital investment is involved.

LPG fuelled vehicles are an economically attractive option for fleet vehicles, taxis, etc. because the savings over large distances quickly pay back the conversion cost. The private motorist however, is less likely to use this fuel at present because of the conversion cost, and also because of the loss of luggage space in the boot of the vehicle.

Australian LPG production in 1977 came mainly from Bass Strait (1,437 kt) and from refineries (358 kt). Australian consumption was only 427 kt, the rest being exported. LPG is currently sold for both export and domestic use at world parity prices of about $110/t to $120/t and earns about $190 million in foreign exchange. LPG sold for vehicle fuel totalled 20 kt in 1978 but very rapid growth is likely. The total Australian production of over

2.0 Mt (about 3.8 Gl), if used only as a motor fuel and ignoring other commitments, would satisfy about 25% of current motor spirit consumption.

4. Factors affecting change

Reliance on overseas supplies of oil is risky from a strategic point of view and is undesirable because of the growing drain on foreign reserves.

Clearly, the greater the dependence on imports, the greater the costs of any arbitrary interruption to supplies. Alternatively, dependence on imports can be reduced;

- by increasing domestic production, which implies higher national expenditure on energy
- by consuming less energy and reducing waste of energy with some consequent indirect economic and social costs.

An important decision facing Australia concerns the degree of reduced dependence on imports which is to be sought in the light of the added costs that greater energy independence implies.

It has been argued recently by Folie and Ulph (1979) that the strategic risk can be most cheaply countered by a government funded stockpiling plan, rather than by encouraging the development of more expensive indigenous supplies. These authors also argue that the future balance of payments situation is not overly serious and that a structural readjustment of the economy is preferred to a government policy of increased self-sufficiency.

Further discoveries of commercial oil fields offer the simplest and cheapest solution to Australia's liquid fuels shortage. Generous government incentives have recently been announced and the main issue is whether these incentives will be retained. The policy mentioned earlier sets the selling price of oil from new discoveries at the import parity price. Very large profits could flow from new oil discoveries and the Government would not obtain such high returns as it now gets from the crude oil levy. Other incentives inculding tax concessions, investment allowances and increased rates of depreciation apply to the industry and these could be varied in light of perceived needs. Other policies and regulations which affect developments include the restrictions on foreign ownership for new developments (50% Australian equity required unless the company is classified as a "nationalising" company), export controls, and state and federal government policies with regard to provision of infrastructure. Export controls in particular can be used to conserve scarce resources for Australian consumption. For example, if export approval had not been granted for part of the gas from the N.W. Shelf there would be a greater incentive to use the gas locally either for methanol production or in direct use. Lease granting regulations and the rate of relinquishment can affect the rate of exploration. The withholding of permits can also be used as a further control. An example is the Government decision to stop exploration and not to renew petroleum permits in the Great Barrier Reef region until the results of research are known.

The nature of any new refinery or extension to current refineries will be important in determining the degree and speed at which Australia can conserve liquid fuels by using alternative fuels in stationary applications. A large scale hydrocracking refinery, with consequent economies of scale, has been suggested by Saluzinsky (1979). Such a refinery would convert heavy fractions, currently consumed where other fuels could be substituted, into valuable transport fuels. This would require the exchange of dissimilar products between different refineries, which in turn would require co-operation and agreement at a greater level than is current. Because such a technical option is dependent to a degree on the rate of interfuel substitution careful planning and co-ordination is called for. Once large investments have been made whether in refineries or in gas or coal facilities an extra segment of long term fuel mix and fuel use is committed. The future requirements of the different types of transport fuels also effects the nature of future refinery developments.

There are several refinery and vehicle related options for obtaining better crude oil economy in transport use. These include:

diesel fuel
broad cut fuel
lead in petrol
octane levels

emission control
vehicle and engine changes

The production of diesel fuel or broad cut motor fuels (Anderson, 1977) give better fuel efficiency both in the refinery and in the vehicle than conventional motor spirit. The former fuel requires the use of diesel engines the second requires fuel injection in a conventional Otto engine but preferably a hybrid Otto-diesel engine. Both can only be introduced with new vehicles. Further details are given in the Transport chapter.

Diésel available

Tetraethyl lead ("lead") is added to motor spirits to increase the octane number. High octane fuels can be made directly in refineries without the addition of lead but at the expense of increased crude oil consumption. The addition of lead tetraethyl is a cheaper means of producing high octane petrols particularly as oil prices rise. High octane fuels can be used in high compression engine vehicles which give greater fuel economy than low compression engines. Concern that adverse health effects could result from lead emissions from vehicles has lead to regulations for a programmed reduction in the lead content of motor spirit (NEAC 1978a). This action however runs counter to the aim of minimising crude oil consumption. Lead filters can be fitted to vehicle exhaust systems as an alternative means to reduce lead emissions, but their practical use is not proven. Current measures to decrease motor vehicle exhaust emissions are generally acknowledged to have raised specific fuel consumption. If more stringent regulations relating to unburnt hydrocarbons and nitrogen oxides are invoked than catalytic convertors or stratified charge engines (with lean burn) may be required. Completely lead free petrol is required if catalytic converters are used. It was noted earlier that methanol could be used to raise the octane level of petrol to which it is blended.

Fuel consumption of motor vehicles can be reduced by various means discussed more fully in the chapter on transport. These means include smaller, lighter cars, computerised fuel injection and ignition, radial ply tyres, etc. Recommended targets for fuel economy have been made by NEAC (1979). These recommendations are for weighted fleet average consumption for new passenger cars to be 9.0 l/100 km by 1983 and 8.0 l/100 km by 1987. The consequent savings in motor spirit are expected to be about 5% and 12% in 1983 and 1987 respectively. In 1977 the fuel consumption for new vehicles was about 11 l/100 km but for the existing fleet was 12.2 l/100 km. The Federal Government has endorsed NEAC's recommended levels in a voluntary programme of national fuel economy goals. It is not certain that a voluntary programme alone would achieve such savings. Further options include making the programme obligatory on the vehicle manufacturers or increasing market pressures for more economic vehicles by e.g., placing differential sales taxes on vehicles according to consumption or by further increasing petrol prices or by rationing of petrol.

Patterns of transport use can be altered by a host of means and could contribute to a reduction in liquid fuel requirements. Such changes include, increased electrification of railways and public transport, extension and improvement of public transport systems, improved traffic management, roads and traffic rules, and legal changes to allow car pools and private vehicles charging fares. These issues are covered in more detail in the chapter on Transport.

Conservation measures for liquid fuels have been detailed in preceding material and in other sections. There are already financial incentives to encourage conversion of current oil fired installations. The availability of gas is a limiting factor in many situations. Federal and State Government policies can affect developments relating to gas distribution e.g. the speed and degree to which the Pipeline Authority expand the grid. State laws and regulations, particularly with respect to coal fired boilers (see Coal section), are at present inhibiting a wider use of coal for industrial heating purposes.

Publicity and education can improve public understanding of the energy situation and lead to better direct use of energy and a more favourable climate for introducing energy saving measures which may be considered unpopular (e.g. high sales taxes on inefficient vehicles). A $2 million publicity campaign is currently being directed at public awareness for motor fuel conversion. In industrial situations further promotion, education and incentives could speed up conversions from oil.

Pricing policy on alternative fuels is a major determinant in setting and changing usage patterns. The use of LPG has been strongly encouraged by the removal of the road tax on LPG for vehicle use. The Federal

Government can directly affect the prices of petroleum products and other energy products through its taxation powers. These are currently applied to crude oil but not to naturally occurring LPG or natural gas. Gas prices are determined between gas producers and distributors. Prices vary widely between different consumers.

The better the long term perspective of Australia's future energy needs and likely directions of development, the better will be the planning for future modifications, changes and new industries. For example, an indication of the probability and timing of alcohol extenders to motor spirit would allow modifications to be made to new vehicles now so that the new fuel could be used without any problem. Research and development planning in areas with long lead times like liquid fuel substitutes is aided by the best possible future outlook.

Surges in demand for skilled people could lead to serious shortages if prior action is not appropriate. Conventional programmes for educating tradesmen and graduates need to keep pace with the expected long term demands. Special training programmes and relocation incentives (including low cost housing) are measures which can help to provide the required manpower at the right time, and at the same time increase and broaden the skills of the workforce. Training programmes are already being planned in W.A. for the expected high demand for labour on the N.W. Shelf project highlighted in a recent report. The report suggests that overseas guest workers may be needed in times of extreme labour shortages.

5. Implications and consequences

There will be a growing dependence on imported crude oil if there are no further discoveries or if no alternative liquid fuels are produced. This growing shortfall is shown in Figure 3 (curve 1) in the Energy-Overview section. Also shown is the growing cost of the oil priced at the late 1979 price of $117.5/kl ($18-68/bbl). This shortfall is derived from the predictions given earlier in Figure 2. If the median probability oil discoveries are assumed, the outlook is far less sombre (curve 2, Figure 3, Energy and Overview). High import charges and strategic vulnerability are never the less still indicated.

Estimates for the cost of alternative liquid fuels vary from $60 to $600/kl (6 to 60 c/l). Prices are not directly comparable because some fuels require further processing before they can be used in vehicles and also the fuel economies of different fuels differ significantly (e.g. about 1.4 litre of methanol used in a 15% blend is required to give the same range as 1.0 litre of motor spirit). Nevertheless, the following tabulation gives a broad indication of possible costs for alternative liquid fuels. Also shown are estimates, based on G.M.H. (1979) forecasts, of the minimum lead times required before a reasonable commercial level of production could be achieved.

TABLE 12. Estimated costs and lead times for liquid fuel alternatives

Fuel	Price range, cents/litre	Lead time, years	Reference for prices
1 from shale[1]	9.4 - 15.7	5 - 15	Folie & Ulph (1979)
1 from coal[1]			
- synthesis	18.9 - 25.2	7 - 10	ibid
- pyrolysis	11.3 - 25.2	7 - 10	ibid
- hydrogenation	12.6 - 13.8	10 - 15	ibid
thanol[2]	6 - 8	3 - 5	Bradley & Robinson (1978)
hanol[2]	14 - 60	3 - 5	Milkens (1979)
G[2]	13 - 14 (retail)	0	

1. Comparable product to crude oil which costs to refinery (1-7-79) 11.75 c/l ($18.68/bbl).
2. Comparable product to petrol which costs ex refinery about 20 c/l (late 1979).

It appears that the price to the refiner of alternative fuels for transport is unlikely to be more than about twice that of the cost of present crude oil. If other costs (excise and distribution) remained constant then future motor spirit costs would be no more than double present prices. This is most significant in terms of the direct impact on the private motorist and in terms of added costs and inflationary effects in other fuel dependent areas. The analysis of the costs of alternative fuels is most useful in that it provides an upper ceiling to the apparently infinite price spiral of recent years. Further refinement of cost estimates in the next few years will give a more exact idea as to which are the cheapest options and what the "price ceiling" is. The "price ceiling" will not be an infallable prophylactic to rapacious OPEC prices in the short term. Because of the long lead times in developing alternative supplies it will remain a sellers market until alternatives are being produced in substantial quantities.

The perceived need for alternative fuels and the lead time in developing alternative supplies will be as important as the price of alternative fuels in deciding what choice is made. Short term solutions using current proven technology include LPG (already rapidly growing use) methanol and ethanol. The alcohol fuels could probably be in commercial production in 3 to 5 years if crash programmes were started now. New Zealand is likely to make methanol from natural gas and is considering further processing to petrol via the yet to be commercialised Mobile process. Optimistic estimates for oil shale suggest small levels of commercial production in 5 years but larger development time of at least 10 years would seem more likely. The least efficient but proven synthesis route for coal liquefaction could possibly be operating in 6-8 years. The complexity and non-commercial status of hydrogenation processes indicate a lead time of at least 10 to 15 years.

An intense development effort on all forms of liquid fuels will be followed by very large investments in energy producing plant. The North West Shelf venture alone will cost over $4000 million and this will contribute only marginally to our transport needs (unless methanol is produced). A major oil find on the Exmouth Plateau would lead to another project like the N.W. Shelf. Capital costs for the other options discussed earlier range from $200 million (methanol) to over $2000 million for large scale oil shale or coal conversion projects. These investments are much larger than those previously made for equivalent fuel production levels. The higher costs of the products emphasise this aspect. The increasing capital cost per unit of energy clearly implies a greater proportion of the country's capital and productive effort being devoted to liquid fuel production. It is noteworthy that the future high costs of energy will be real costs to the nation and will represent a real deployment of capital in this sector. The present high liquid fuel costs do not reflect the real costs to the nation for this energy because they include high government charges as well as the real but relatively smaller costs of local production and imported oil. The high government charges (about 83% of the final price) becomes revenue uncommitted to the sector from which it was derived. Australia will have large capital requirements for these developments and, while in the past Australia has readily obtained foreign capital, in the future many countries will be facing similar large investments and a widespread scarcity of capital can be expected as the world increases its productive effort in energy production.

Employment effects due to these new energy projects can only be roughly estimated. The North West Shelf project is expected to require 3000 to 4000 people during the five year construction phase and continuing direct employment for about 500 people (Harrison, 1979). Annual government revenue is estimated at $743 million (Bambrick, 1978). With the increasing value of this sector of the economy there will be increasing employment despite the capital intensive nature of the industry. The capital investment will create demands and raise production and employment levels in a large number of supporting industries. Only a full input-output analysis can reasonably estimate the flow-on effects and Bambrick (1978) estimates that a multiplier factor of 2.5 is appropriate for this project. Large secondary employment effects are therefore indicated for these new liquid fuels projects.

It is difficult to make any quantitative predictions about employment trends in the established industries of oil exploration, oil refining, oil marketing and distribution, and gas transportation and distribution (for recent employment see Tables 3, 4, 5, 6). Oil exploration activity (and employment) is volatile and dependent on government policy. The recent upsurge in activity (see Exploration) will undoubtedly increase employment in the short term. Statistics for oil refining and gas distribution are not sufficient to draw any historical lessons. Rapid growth of gas use in the short term probably indicates a transient increase of employment for further reticulation. In the high labour area of oil marketing and distribution there are current examples of labour reduction features. The number of outlets is reducing and there is significant labour saving in self-serve operations with a single computerised sale terminal monitoring all pumps. A continuation of this trend will give large reductions in employment in this industry. The growing use of LPG will provide some compensating new employment in this industry. With the present technology, the filling operation will be done by the retailer and not the driver.

The continually increasing cost of motor spirit will be the most direct and obvious impact that the energy situation has on the ordinary citizen. In 1977 the average passenger car used 1900 litre of motor spirit (NEAC, 1979), At current prices of 30 c/l this costs $570. With a significant price rise in real terms (increasing by say a factor of 2 as indicated earlier) the fuel costs for the average 1977 passenger car will be $1140. Conservation measures and changing patterns of use will reduce this figure a little but the effect is still very substantial. The likely impact is better appreciated when it is realised that petrol prices have remained effectively constant in real terms since 1967 (Department National Development, 1979). This is illustrated in the Overview section.

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Expansion of the electricity supply system will require further commitments of water which could lead to environmental conflict in some areas.

Photochemical air pollution from motor vehicles reaches unhealthy levels at numerous times in both Sydney and Melbourne. Continued lead emissions are also considered a possible health hazard. Vehicle pollutants are related to engine and fuel types and the overall efficiency of fuel utilisation.

4. Factors affecting energy production

A variety of issues are discussed in other sections. These are briefly tabulated here.

- what level of liquid fuel self-sufficiency should Australia have?
- what oil stockpiling arrangements should be made?
- is the oil levy (which raises domestic oil prices to import parity prices) the best pricing policy?
- should domestic oil production or consumption be rationed?
- is the current and planned level of oil exploration sufficient?
- should legislation foreshadow requirements that vehicles attain specified fuel efficiencies at specified dates?
- should legislation foreshadow vehicle compatibility with alternative fuels, e.g. LPG or methanol or ethanol blends.
- is the pricing of natural gas satisfactory?
- is the gas supply system adequate?
- should LNG be exported from the North West Shelf or should it be used in Australia for, e.g. making methanol for use in petrol?

- should the price for electricity reflect the opportunity cost of the coal used for its production?

- what is the best pricing scheme for selling electricity to both large and small consumers at differential rates?

- what price should private producers of electricity be paid for electricity supplied to the grid?

- is it feasible, safe and desirable to amend the legislation regarding coal fired boilers in order to encourage their use?

- are there situations where low grade coal wastes can be used advantageously to provide electricity?

- should off-peak electricity rates be available more widely for solar hot water heaters?

General factors affecting energy developments

There are a number of general factors and issues which apply to most aspects of technological change and developments in the energy area. These matters include the availability of capital, foreign ownership, distribution of wealth, provision of infrastructure, and technological capability and research and development.

Planned expenditure on mining projects was recently estimated to be $9100 million (D. Industry and Commerce, 1979). Much of this expenditure is to be in energy projects such as the large North West Shelf project and numerous coal mine developments. The availability of capital could be a limiting factor, even with up to 50% foreign equity as presently allowed.

If there is a domestic capital shortage there could be pressure to lower the Foreign Investment Guidelines to less than 50% Australian equity for these new ventures. An alternative is to obtain foreign loans rather than equity investment. In this case foreign control can be minimised but debt servicing commitments have to be met irrespective of the profitability of the operation.

Large foreign earnings from energy exports (coal and uranium) will put upward pressure on the exchange rate which in turn will disadvantage other export industries and import competing industries. McColl (1979) suggests that appropriate tariff, taxation and other measures need to be devised so that the benefit from energy exports is not confined to small select groups and so that structural adjustment allows a reasonably smooth flow of resources into appropriate areas of production.

Responsibility for the provision of infrastructure is a major factor which influences the profitability of a venture. Infrastructure for major mining projects in the past has often been provided by the developing companies. Such infrastructure included towns and some municipal services. There is a growing tendency for greater government provision of infrastructure which if continued will further assist new projects.

Research, development and commercialisation

The options for technological change in energy supply are generally technically feasible, but are not well developed and product costs have yet to be determined. Proven processes developed in one country will be used worldwide but because each country has its own energy priorities and each primary energy source has different properties, development work will always be needed for new energy projects, more so when the technology is new and complex. Major technological changes and developments such as coal liquifaction or shale retorting take a long time to come into full scale operation and to create a significant impact. Processes require development, adaptation and evaluation, raw materials have to be evaluated and delineated, pilot plants need to be built, tested and run, and products need to be evaluated. Even the building of a new power station using conventional technology takes a minimum of five years (including coal mine and water supplies). With such long lead-times to bring new processes into production, effective long term policies and planning are required to ensure that development effort is directed in the right direction at the right time.

Energy research, and more importantly development work, will be vitally important in deciding what options to follow and in bringing these options into production. Australia's energy R and D effort can be only a small part of the world effort but it will be necessary to maintain a comprehensive understanding of all relevant technologies in order to support the substantial development effort. ASTEC (1978) reports that in 1976-77 total government funding for energy R and D was about $30 million representing about $2-20 per capita. This compares with $12-90 and $6-35 per capita respectively in the United States and Britain.

Continued public funding of energy R and D will be required but, with increasing emphasis on development and demonstration, the method of funding may need to change. Demonstration projects will not have such a high probability of failure as initial research but the funds invested will be far greater and the overall risk will be large. Government support could be direct, or through development allowances in approved fields. During the development and demonstration phase the market situation may change unexpectedly and render the process uneconomic. A guarantee of a base price may therefore be required in certain instances.

Comments and recommendations

In preparing the Energy section of this report, there was difficulty in obtaining comprehensive, up-to-date, and consistent information on energy matters in Australia. It was even more difficult trying to obtain a comprehensive, broad and balanced outline of possible and probable energy options for Australia. Government departments and instrumentalities as well as industry organisations and companies were most helpful in providing data. Much of the data was publicly available, some of it was not. A lot of the data is several years old. Taken in aggregate, there was a lot of internal inconsistency in the data. Other comments have been made regarding the long lead times in development, the increasing seriousness of a liquid fuels shortfall and the need for a general outline of the possible and probable energy options for Australia so that people generally, and leaders in government, business and unions are prepared for, and can plan wisely for, the likely changes. These factors suggest that a much greater public sector effort is required to provide better, up-to-date, readily available information. An Annual Energy Review is suggested as a regular government publication to satisify the needs noted above.

It is suggested that an Annual Energy Review would include comprehensive data outlining the historical and present situation. Up-to-date information with speedy publication should take strong precedence over accuracy in the more recent figures. The future energy options, liklihoods and preferred directions would also be presented. Changes and shifts of emphasis will always be necessary, and the predictions would be given in this light. Any major changes from one year to the next would be highlighted. The Review should also indicate the likely resources required including labour (and skills), research development and demonstration, and capital. In providing the data, further effort would be needed in energy modelling and problems regarding industrial confidentiality of energy consumption data would need to be overcome.

An increasing Australia wide effort in energy developments is called for. To increase and speed up this effort, increases in resources in Government bodies such as AMEC, NEAC, NERDDC and relevant government departments are called for. R & D on energy matters is low by comparison with other countries and should be increased in the relevant areas.

5. Implications for the future

Self-sufficiency in liquid fuels

Total self-sufficiency in liquid fuels would not appear to be an achievable goal in the short to medium term. Various measures have been discussed which could reduce the demand for oil or could provide alternative transport fuel. Unless substantial new Australian oil discoveries are made it seems that a number of the measures will each contribute to meeting our transport fuel requirements. Although there may be one or two large volume fuel extenders or alternatives, the smaller, more unusual, options can be expected to contribute in special cases, and in aggregate to make a worthwhile contribution to transport fuels. Modal patterns of use of fuels and vehicles will become more complicated and with it increasing complexity in administration and difficulty in deciding appropriate fuel pricing policies.

A major growth area

The energy sector will be an area of rapid growth, technical developments and high activity. In the next decade there will be rapid growth in the export of steaming coal and uranium for foreign consumers. Domestic coal and electricity production will also grow faster than before. Planned expenditure on coal is $2.1 billion and on electricity production $5 billion (Lynch, 1979). Uranium enrichment could add significant value to the raw yellowcake exports. Beyond ten years, substantial investment in alternative liquid fuels can be expected to give further impetus to this sector and the economy in general.

Directly related to this growth in export of primary fuels will be a growth in export oriented energy intensive industries in Australia. The aluminium smelter developments best exemplify this trend with planned expenditure of $4.6 billion (Lynch, 1979). Soda/chlorine production is another energy intensive industry with expansion plans to satisfy domestic requirements of soda for bauxite refining.

Large increases in foreign earnings will flow from both direct energy exports and exports of products such as aluminium based on energy intensive processes. This may cause problems for low productivity sectors of the economy but as Bambrick (1978a) points out it is "not valid to argue from this that profitable mining ventures should be discouraged. Increased foreign exchange earnings can be used either for investment or for imports. To refuse them is to lower economic growth. To accept them may mean some structural readjustment for other industries". Increased foreign earnings for energy exports will be most valuable in offsetting increases in the import bill for crude oil. employment

Most major new energy projects tend to be capital intensive with relatively low levels of direct employment. The large expenditure in these projects flows on to other supporting industries and secondary employment and industrial expansion results. The maximum flow-on and multiplier effects occur when project expenditure is within Australia but even with the N.W. Shelf venture where there are special high technology items (e.g. LNG carriers and offshore facilities) about half of the expenditure will be in Australia (Bambrick, 1978).

Rapid growth in profitable energy industries also brings growth in government revenues from taxes on profits, royalties and levies. In the case of new oil discoveries the current pricing policy allows the local producer to receive the full import parity price. While the government foregoes the oil levy directly it will still receive a large return through taxes on any "windfall" profit.

Effects of increasing cost and scarcity of liquid fuels

Increases in the price of Australia's imported crude oil has undesirable social and economic effects. Australia imports one third of its crude oil requirements and in 1976-77 net petroleum imports cost almost $800 million. The total value of primary energy consumed in Australia in 1976-77 was roughly $2 billion compared with the gross domestic product of $73 billion. An increase in the cost of imported oil means an increased capital outflow from Australia and the added cost flows onto the domestic cost of all other oil dependent commodities. If there are no compensating changes in the economy then undesirable effects which result are claimed to include increased unemployment, an increased trading deficit, an increase in the consumer price index, contraction in GNP growth and a reduction in exports (Vincent et al, 1979).

If instead of importing oil, expensive alternative liquid fuel processes are developed then a large redeployment of domestic and possibly borrowed foreign capital into the energy sector is indicated. A larger fraction of the country's resources will be devoted to producing a given amount of liquid fuels. Many of the undesirable results will be the same as those occurring when oil is purchased from overseas at ever increasing prices. In contrast however, domestic production of liquid fuels would give security of supply and would provide both direct and indirect employment and economic flow-ons. A major issue is whether resources are more profitably employed in local liquid fuels production or whether the same resources applied elsewhere would earn more foreign exchange to pay for oil imports.

A most important point of debate is whether the economic benefits flowing from large energy exports will outweigh the disadvantages of higher costs and greater deployment of resources for producing liquid fuels in Australia. This is a difficult question to answer without having a more detailed idea of what specific developments will occur but it emphasises the advantage to be made in the short term from exporting those energy materials with which we are well endowed.

On its own, the increasing cost and scarcity of liquid fuels is shown above to be a constraint on economic growth. As both total GDP and energy consumption are a product of the population size and per capita consumption it is possible to maintain an expected increase in per capita GDP by having a lower population growth rate. Changes in population growth can be affected directly by government immigration policy or may occur indirectly by people choosing smaller families in order to maintain their expectations of per capita income. In the face of a decreasing growth in GDP, a decrease in per capita GDP growth is the other alternative to a decrease in the population growth rate.

The rapid price rise and scarcity of liquid fuels which is giving rise to large scale changes in the energy industry itself will have impacts in all areas of the economy and society. Energy intensive industries will be most directly affected but the increased prices will be passed on through their products to other industries and ultimately to consumers.

The use of oil and petroleum products by industry sectors was as follows (1976-77, energy basis, see also Figure 2)

transport	56%
manufacturing	25%
domestic, commercial	8%
agriculture, mining	8%
electricity, gas water	3%

The transport sector will be strongly affected by petroleum price rises and scarcity, and many changes will occur - in the technologies used in transport, in the way people use transport, in the cost of goods with a high transport component. Technological change in the transport and materials handling sector is discussed in another section of this report.

The most direct effect will be seen in price rises in liquid fuels. In real terms, petrol prices have fallen since 1967 although not as much as other energy prices (see Figure 3). Recently, motor spirit prices have been rising in real terms. Assuming that oil prices rise faster than inflation and that Government levies and excises increase in step, then there will continue to be price rises in real terms in petroleum fuels.

The proportion of fuel costs in the total costs of various forms of transportation is not great. The Australian Transport Advisory Council (1978) claim that with petrol costs of ca 16¢/l in 1977 fuel costs for running a private motor vehicle were of the order of 10-15%. Fuel costs in other forms of transport are generally cheaper than those for private cars. For government buses fuel costs are claimed to be 3% of total, for private buses, 10%, and for air transport about 20%. Therefore, although liquid fuels are an important and, in many instances, an essential part of our society, their current cost is not a major part nor generally a significant part of the cost of particular operation. ATAC (1978) estimated that, if petrol prices rose from 16.9 c/l to 25.5 c/l, the use of private vehicles in urban areas would drop by 10% and rail travel would increase by 27%. Other modal shifts would be insignificant particularly in non-urban areas.

With further increases in fuel prices in real terms these shifts will continue. Further effects will be that people will wish to live closer to work and public transport, and higher living densities can be expected. There will be more car sharing for regular commuting. With the increased use of public transport the frequency of service will increase, thus making the service more attractive. These changes will require some degree of government interaction and planning.

In industry generally, the effect of increased liquid fuel prices and changes in relative costs of fuels will lead to more efficient use of energy and substitution of cheaper more abundant fuels for more expensive fuels. Some of these changes can be accomplished by good industrial housekeeping, others will require process changes and capital investment. Inevitably the increased prices for energy must lead to increased costs of products to the consumer (all other things being equal).

It is important to note that although liquid fuel prices will continue to rise in real terms, the ultimate cost of liquid fuels is effectively limited by the cost of the next cheapest readily produced alternative. This upper price limit will not be impenetratable however, because of the delay in producing alternative fuels.

Social and environmental effects

New developments of energy fuels will lead to increasing urban and industrial development in the energy rich areas. In the Latrobe Valley, Victoria, there will be increasing development of the brown coal deposits for electricity, and also the liklihood of a solvent refined coal plant. In NSW's Hunter Valley there will be large increases in coal production for export and electricity generating facilities and possibly a coal hydrogenation plant. In Queensland's Bowen Basin there will be large coal developments and again the possibility of coal hydrogenation. The N.W. Shelf venture will require a large township and supporting industry near Dampier. In areas such as the Hunter and Latrobe Valleys, which are rural areas with some urbanisation, the increasing development will markedly increase the degree of urbanisation and reduce the rural nature of the areas. These areas already have substantial populations and the coming changes are likely to be favoured by some of the inhabitants and disliked by others. On the positive side there will be greater wealth in the area, with greater employment opportunities. There will be better shopping, municipal and social facilities. On the negative side there will be increased demands on reduced open space, and more industries with associated heavy traffic and pollution.

The loneliness and remoteness of mining towns in remote and harsh environments is decreased as the size and self-sufficiency of the township and region is increased. For the scattered inland towns servicing the Bowen Basin coal fields the future developments in this area will lead to a better serviced and more social environment. Similarly the N.W. Shelf project will improve the social amenity of the iron ore towns of Dampier and Karratha.

The working environment in most areas is likely to improve continuously, in both comfort and safety. Underground coal mining is an area of high discomfort and hazard and while the former factor is an inevitable aspect of the job, further improvements in safety measures would be most desirable. Coal liquifaction processes can produce carcinogenic materials and careful control and containment will be required in this area.

The general effects of increased liquid fuel costs on transport and urban structure have already been noted briefly. The implications are that greater attention in regional and urban planning will need to be given to transport and fuel factors.

Environmental conflicts are likely to increase with an increasing number of developments. Such conflicts will be more probable, closer to large centres of population where further alienation of natural, scenic or recreational areas has a more pronounced effect in increasing the pressures on the remaining undeveloped land. It can also be expected that there will be increasingly higher pollution standards to be met in the future. Conflicts over development will cause delays in approval and further lengthen the lead time of large projects. Improved long term planning may help to avoid such conflicts.

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COAL AND ELECTRICITY

COAL AND ELECTRICITY

1. Perspective

Coal
Electricity

2. Technologies

2.1 Coal

- Mining and beneficiation
- Waste disposal and utilisation
- Pipeline transport
- Coking coal
- Coal for heating-interfuel substitution

2.2 Electricity

- Emission control
- New generating, transmission and control technology
- Cooling water

3. Present environment

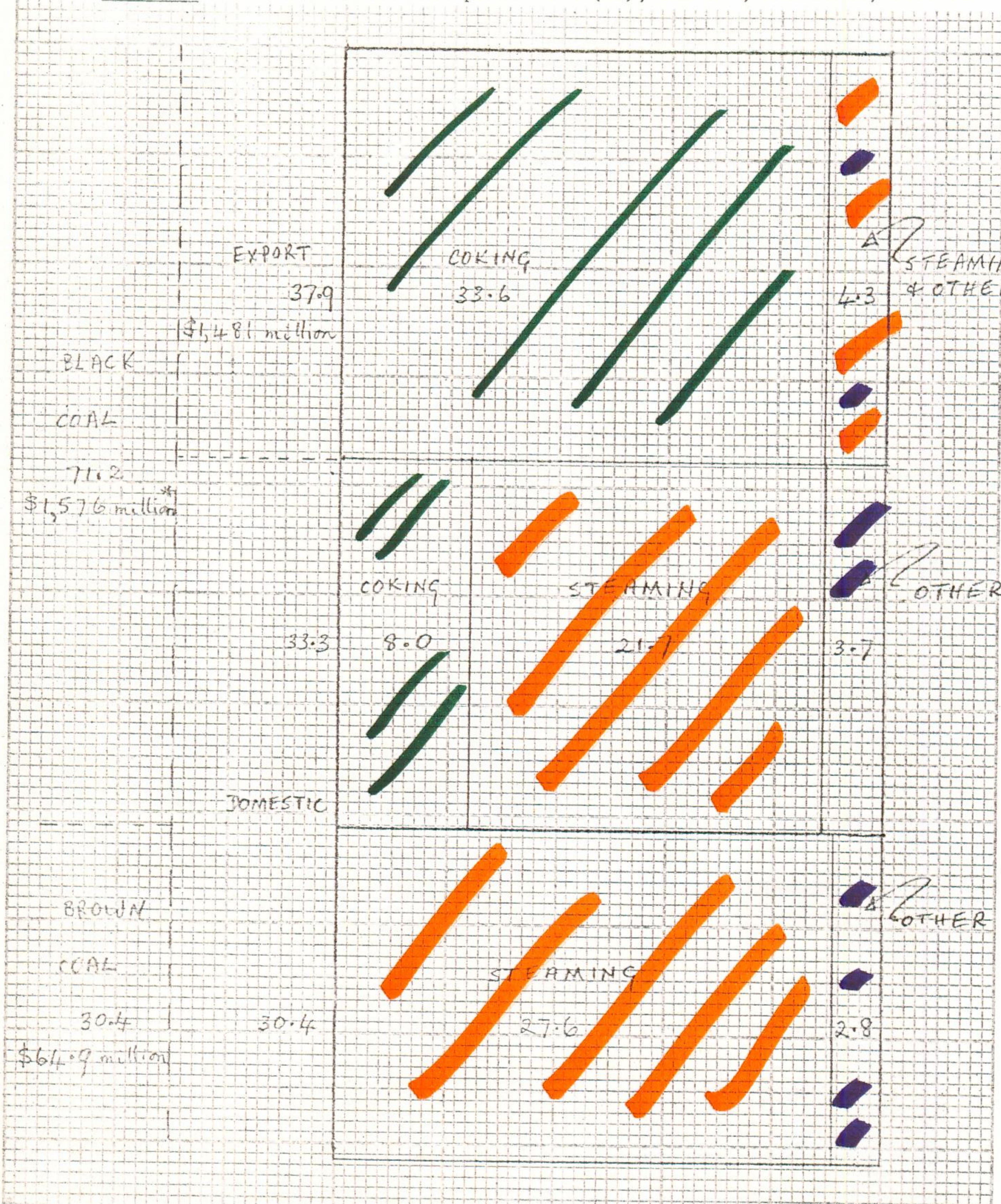
4. Factors affecting change

5. Implications for the future

COAL AND ELECTRICITY

1. Perspective

FIGURE 1 : Australian coal production (Mt), end use, and value, 1977-78



Source: Joint Coal Board, 1979, ABS, 1979.

* This product value from ABS was for a production of 79.3 Mt.

FIGURE 2 Production, employment and productivity in black coal mining in Australia.
(Joint Coal Board, 1979)

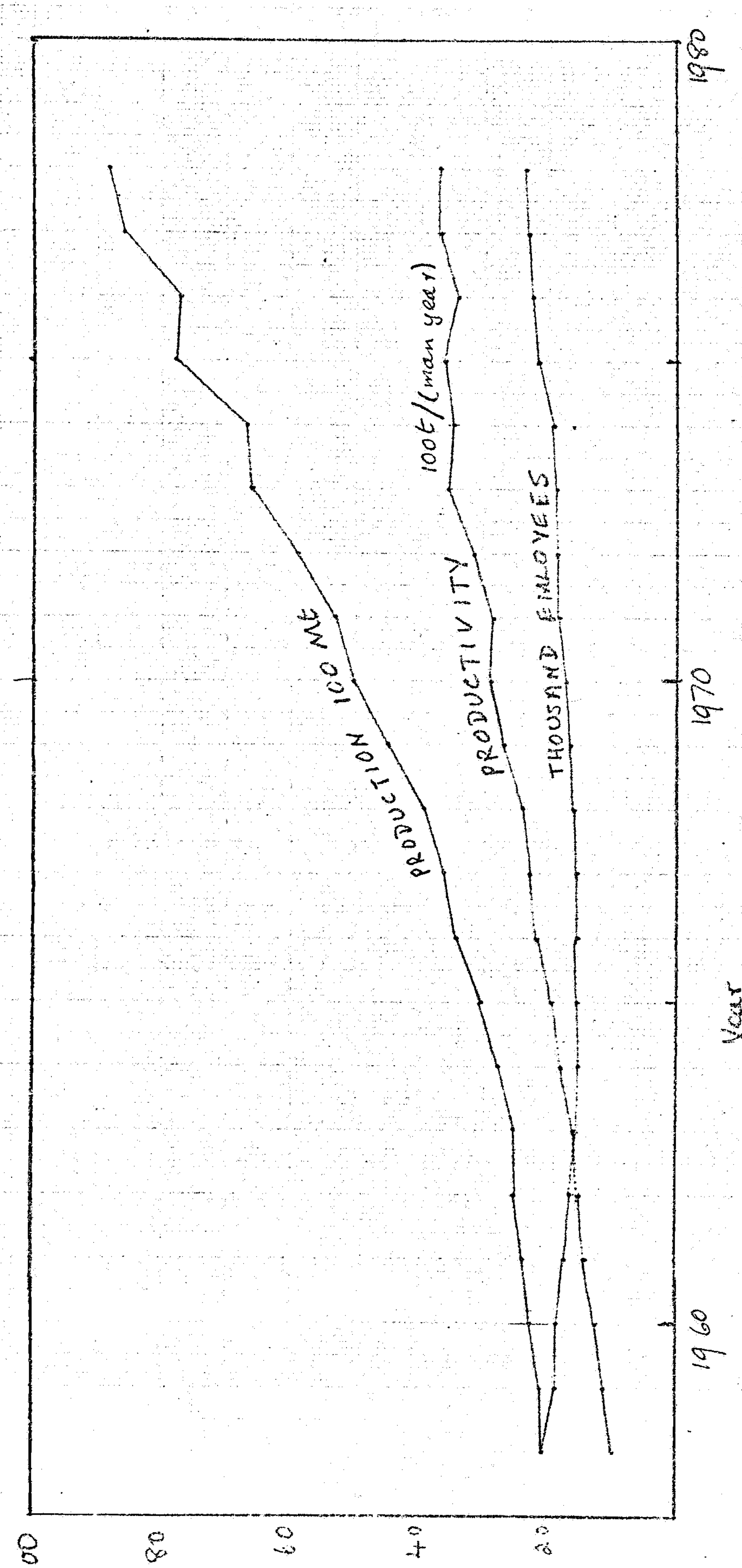


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TABLE 1, Coal reserves and production rates

	Production 1977/78, Mt	Demonstrated economic resources, Mt	Inferred economic reserves, Mt	Total reserves/ production, years
NSW	41.7	16,150	+58,000	+1,770
Queensland	25.0	17,360	+100,000	+4,680
South Australia	1.8	*720	2,300	1,680
Western Australia	2.4	1,950	0	813
Tasmania	0.2	120	0	600
Australia black coal	71.0	36,300	+160,000	+2,760
Victoria (brown coal)	29.4	39,000	0	1,330

TABLE 2 Primary fuel consumption used in electricity, 1976-77

Primary Fuel	Energy, PJ	Share, %	Predicted growth rate, to 1987 %
Black coal	495	54	6.34
Brown coal	279	30	4.27
Oil	25	4	6#
Natural gas	45	6	10.65
Hydroelectricity	49*	5*	1.07
Renewable	1.3	0.1	-5.76
TOTAL	895	100	5.61

* Hydroelectricity represents about 18% of the total electricity produced but only 5% of the primary fuel. The reason is the low efficiency of converting heat to electricity.

\# Estimate.

TABLE 3 Black coal in Australia (ASIC 1201). ABS Census of Mining Establishments

Year	Establishments at 30 June No.	Total employment at end of June No.	Turnover $M	Value Added $M	Fixed capital expenditure $M
1968-69	138	16860	254.2	146.5	38.8
1969-70	133	17526	205.2	186.2	49.8
1970-71	134	18784	358.8	219.3	85.4
1971-72	131	19169	408.4	254.2	116.6
1972-73	124	19025	487.8	310.3	85.4
1973-74	127	19412	571.3	357.0	76.7
1974-75	127	21720	1047.5	733.6	104.1
1975-76	118	22619	1381.6	986.5	159.6
1976-77	117	23454	1659.1	1165.8	177.5
1977-78	115	23638	1944.7	1344.3	193.1

TABLE 3A Electricity generation and distribution in Australia (ASIC 3610) ABS Census of Manufacturing Establishments

Year	Establishments at 30 June No.	Total employment at end of June No.	Turnover $M	Value Added $M	Fixed capital expenditure $M
1968-69	171	60166	1122.9	677.3	373.9
1969-70	167	60195	1213.5	740.4	383.4
1971-72	153	62480	1444.4	860.9	452.4
1974-75	115	62591	2091.1	1235.0	465.2

Coal

In 1977/78 the total value of the black coal produced in Australia on an "at mine" basis was $1576 million and the export of black coal earned $1481 million (Joint Coal Board, 1977). The value of raw brown coal produced was approximately $65 million (Pratt, 1978). Tonnages and values are shown diagrammatically in Figure 1.

Direct employment in black coal mining in Australia (see Fig. 2) has not varied dramatically over the last 20 years and now stands at 23,500. The 25% decline in the early sixties was due to the introduction of mechanical miners but the continual growth in production boosted employment again. Labour productivity has increased by a factor of 2.7 in the last 20 years in both underground and open pit mining due to mechanisation (see Fig. 2 and Table 4). In underground mining the use of continuous miners has made a significant impact. In open pit mining the use of ever bigger draglines and trucks has been a major factor. The overall labour productivity has increased by a factor of 3.7 because of the increasing proportion of highly productive open cut coal mining.

TABLE 4, Black coal output per manshift* worked

Year	Output per manshift worked, tonnes			Open cut Coal
	Underground	Open-Cut	Total	in Total %
1948-49	2.8	7.4	3.1	
1957-58	3.8	11.2	4.1	10.4
1967-68	8.9	23.0	10.1	19.4
1977/78	10.1	30.2	15.2	51.0
Increase 1967/78 to 1977/78	+13%	+31%	+51%	

About half the coal mined is used in Australia the other half is exported, mainly as coking coal for steelmaking. Of the domestically consumed coal almost 68% (on an energy basis) is used for electricity generation (steaming coal). Production of steaming coal is from both government and company operated mines.

Most of the growth in coal production in the last 10 years has been in exports of coking coal. Steaming coal exports are now starting to rise rapidly as overseas countries substitute coal for oil.

Coal use by industry sector in 1976-77 was as follows:

agriculture and mining	2.4%
manufacturing industry	29.3%
electricity gas & water	67.9%
domestic commercial	0.4%
TOTAL	100.0% equal to 1146 PJ

Electricity

Total electricity generation in 1978/79 was 90,883 GWh giving an average annual per capita consumption of 6330 kWh or an average continuous consumption of 723 W/head. Coal (black & brown) accounted for about 3/4 of the total electricity produced. Hydroelectricity contributed 16,174 GWh of the total (representing 18% of total) mainly from Tasmania (8.5%) and the Snowy Mountains Scheme (5.6%).

Most electricity is supplied by public authorities which had a total capacity of about 22,000 MW in 1978. Large private installations in remote mining towns and others for metallurgical processing totalled about 850 MW. Wall (1977) estimates that the minimum total private electricity generation capacity was 1,576 MW and that the degree of utilisation was 45% compared with 38% for public supplies.

Tasmania, because of the relative cheapness of electricity from hydro sources and the presence of several large electrochemical industries, has an exceptionally high consumption per capita, about four times the Australian average and about the same as Norway, the world's highest per capita consumer.

Electricity from the public supply systems is sold in about the following proportions:

41%	industrial
40%	residential
17%	commercial
2%	traction and public lighting

For the financial year to June 1978 the industry was characterised by

production of 86,000 GWh of electricity,	
with total sales of	$2156 million
an increase in total fixed capital of	$ 850 million
to give an approximate total fixed capital of	$9400 million .
Costs of	$2097 million
included capital charges of	$ 664 million .

At 30 June 1978 employment figures were:

56,891 on power station and transmission production operations
12,895 on construction of new works.

A substantial amount of work is done by contract workers not included in these figures. The figures do not include those employed in associated industries such as coal mining, transport and manufacture of equipment.

An analysis of skills in the industry is given by the following classification applying to the Electricity Commission of NSW (about 8,700 employees).

Classification	Proportion %
Professional	10
Administrative, clerical and all female staff	16
Technicians and operators	22
Tradesmen	12
Semi-skilled	19

Unskilled	14
Cadets, trainees and apprentices	7

There has been a trend in recent years to employ more private contractors for construction work for economic reasons.

2. Technologies

Coal

Mining and beneficiation

In underground mining continuous miners have contributed significantly to increased productivity. Although about 4 longwall miners are currently installed in NSW mines their rate of introduction has not been rapid. They do not offer as much increased productivity over conventional continuous miners as continuous miners themselves did over handwinning. Productivity increases in open pit mining have been largely due to the availability of larger capacity machines - larger draglines, trucks etc. This trend is likely to continue. Short run belt conveyors, and pipelines, carrying coal slurries will be increasingly used to transport coal from the mine face to the washery. In underground mines in particular this will desirably replace rail haulage which is a common source of accidents.

Open cut mining itself can be either strip mining or open pit mining. In future open cut mining there will be increasing use of open pit techniques. Both methods require that the overburden to coal ratio be sufficiently low (depending on coal price). Open pit mining offers the advantage of giving higher recoveries when there are multiple seams to be extracted. In strip mining only a narrow strip of mined ground is exposed at any time - mined out areas are covered with fresh spoil. Open pit mines become larger with the age of the mine and require large areas for the storage of spoil taken from the pit.

The beneficiation of black coal by coal washing will increase rapidly in the next 20 years. Washed (beneficiated) coal has a higher at-mine value because its lower ash content reduces maintenance and waste disposal costs in steaming operations and because low levels of gangue in coking coal give reduced consumption of expensive metallurgical coke. Present coal washing capacity is in the order of 40 Mt/y, this being mainly for coking coals, both export and domestic. At present little of the domestic steaming coal is washed, but it is expected that washeries will be installed in most of the current steaming coal operations. An expansion of the black coal industry to almost 300 Mt/y by the year 2000 (discussed later) implies additional washing capacity of about 6 times the present capacity, on the assumption that most coal will be washed in the future.

Most coal for power gen not washed

Waste disposal and utilisation

The amount of refuse for a given output of coal will continue to increase. In 1967-68 coal recovery was 82% of washery input but declined to 72% in 1977-78. By the year 2000, washing refuse could be in the region of 120 Mt/y (assuming 30 t waste for 70 t product and 285 Mt/y washed coal production). This will require extra land suitable for the dumping of these sometimes troublesome wastes. Coarse waste material is dumped and these dumps may ignite spontaneously. The fine muds and sludges from washeries are disposed of in tailing ponds which take a long time to dry out and become safe: these fine wastes can also pollute local streams. In many areas the disposal of washery wastes is easy and safe but in NSW's southern coalfields the disposal of washery wastes pose serious problems. In open pit mining such as the large export coking coal mines in the Bowen Basin in Queensland or in the new steaming coal mines in the Hunter Valley, waste can be readily disposed of by blending with the overburden being put in the mined-out areas.

Washery wastes typically contain about 30% to 40% coal and as such are both a low grade fuel and a mineral resource. The waste can be used as a self fuelling ingredient in brick making. Burnt washery waste can be used as a cement diluent, as an admixture in cementious mine backfill, as a road base, etc.

Fluidised bed combustion is a developing technology which offers advantages for the combustion of low grade fuels such as washery wastes (La Nauze, 1979). Small commercial units are available and development models up to 100 MW (thermal) are being tested. The Joint Coal Board and CSIRO have been operating a 2 t/h (3.0 MW thermal) combustor at the Glenlee washery (NSW). It can burn both coarse and fine washing reject. Such a development offers the hope of solving an environmental problem while at the same time obtaining either (or both) energy and a usable product from an otherwise waste material (Waters, 1977). The use of the heat for electricity generation would be most efficiently done by centrally burning the waste material to benefit from the economies of scale in power generation. Transport costs would necessitate that a fluid bed combustor be centrally and closely located to the waste sources. It is conceivable that up to half of the total waste material available would be used, representing an 8% increase of energy utilised.

In-situ gasification

In-situ gasification of coal seams is an infant technology which could be of great value in tapping Australia's deep and thicker coal seams. Coal seams are ignited underground and air or oxygen blown into the combustion zone gives a gas product. When air is used, a low energy gas of low value is produced which needs to be used locally. Heat contents range from 2 to 5.4 MJ/m^3 (Stewart, 1979). Coal (and energy) extraction is better than 70%. High pressure gasification at 30 atmospheres or more, is possible with coal seams deeper than 600 m and in this instance higher energy substitute natural gas can be produced. This technology is of particular significance in light of Australia's present gas reserves which are unlikely to last more than 25 years. In-situ gasification of unmineable seams would provide a long term gas resource.

Pipeline transport

The use of pipelines for transporting coal slurries could be used for a variety of end uses. It was noted that coal can be transported in slurry form from the mine face to the washery, obviating the need for underground rail haulage. Long distance pipelines could be used to transport coal to power stations sited on the coast or to ships for export. In the latter case the slurry pumped into a ship would be settled prior to transport and reslurried for removal at its destination. The oil agglomeration technique being developed by BHP provides a convenient means of dewatering the product prior to use. The size distribution of coal required for fluidised transport in a pipe is fortunately similar to the preferred size distribution for coking coal. Oil used for agglomerating the coal is distilled off and recovered from the coking oven. Pipeline transport is claimed to be economically advantageous in many instances. A reliable water supply and rights of way are required.

Coal for Coking

Coking coal for domestic requirements is likely to expand with the economy in general. No significant export oriented growth in the steel industry is likely since the industry already has a reasonable proportion of export production and expansion in this area would leave it more vulnerable to the fortunes of foreign economies. The Department of National Development forecast that the average annual growth rate in domestic coking coal will be 1.5% (1978).

Only a small proportion of Australia's coal is high quality hard coking coal. However several developments in coking technology will broaden the range and reserves of coals suitable for coking. This might be considered advantageous in terms of future export growth but competing exporting countries will similarly benefit from the changing technology. Formed coal processes allow coals to be used in coke making which would not normally be used in conventional coking. Formed coke processes similarly allow the use of lower grade coals but these processes require large new capital equipment to replace conventional coking overseas. Preheating of the charge to a coke oven and also stamp charging of coke ovens are techniques which also allow the use of non-coking coals, especially soft high volatile coals. With these developments, the price differential between coking and non-coking coals will be reduced.

Solvent refined coal is made by hydrogenating a slurry of coal and a coal derived solvent. A tarry product is obtained which can be used as a boiler fuel, or after hydrogenation as a petroleum feedstock. Solvent refined coal is also advantageously used in coke making. When very small amounts are mixed with soft coal the mixture can replace expensive American hard coking coals which are an almost obligatory part of a coking mixture. The Kominic group of three Japanese companies is investigating the feasibility of the process using Victorian brown coal and plan to build a pilot plant.

Coal for heating - interfuel substitution

It was noted in the discussion on Liquid Fuels that much of the heavy end petroleum products used for industrial heating purposes could be replaced with alternative fuels. The heavy oil displaced from this role could then be cracked to lighter white products which are least easily substituted for and for which we have the greatest need. Total fuel oil consumption in industry was 5.67 Mt in 1976/77 and of this 4.83 Mt was used by large consumers in boilers, kilns and metallurgical processes all of which could use coal instead of oil (Joint Coal Board, 1978). The technology is available for the use of coal although there is much scope for improved ease of operation: the economics mainly determine which fuel will be used.

Australian produced coal is a cheaper source of heat than oil fuels which coal replaces. However, it is not likely that it is worth converting small boilers from oil to coal firing. However when installing new equipment (or replacing outmoded equipment) calculations show that a boiler producing 25 t steam/hour running for 6000 h/y produces steam at a total cost (operating & capital) of $5/t when coal fired and $5.75/t when oil fired (assuming coal costs $25/t and oil cost $70/t) (Joint Coal Board, 1978). Above this level of production the lower price of coal maintains its advantage over oil firing despite the higher capital cost of the coal unit.

Some problems with coal installations include:

- room for coal and ash handling may not be available;
- grit emissions can pose environmental problems;
- a full time boiler attendant is required for coal fired boilers working above a pressure of 172 kPa.

The latter two problems could be overcome by technical and legal changes.

Fluidised bed combustion is a newly developing means of burning coal. It has several advantages over stoker fed burners:

- NO_x emission levels are lower
- it can readily handle high ash coal

- clinkering and fouling properties are eliminated
- unmanned operation would be more easily obtained.

The potential for the use of fluidised bed combustion for generating electricity using coal washery waste was noted earlier.

Coal can be used for firing cement kilns where the ash is an acceptable component of the clinker. Otherwise gas firing would need to replace oil. Similarly, most reverberatory and open hearth furnaces can be converted to coal use.

Where direct use of coal is not feasible, producer gas can be made from coal to provide a cleaner fuel if natural gas or LPG are not readily available. However, producer gas units are expensive and it is suggested that the price of these units could be lowered.

The use of coal slurried in fuel oil is another potential fuel designed to give improved handling and convenience to coal. However oil is still the predominant fuel and it is doubtful whether much is gained by the use of this fuel.

Electricity

Emission control

Coal burning for electricity is coming under increasingly stringent environmental controls and control measures are an increasingly expensive component of electricity generation costs. Dust removal equipment at the Eraring power station now being constructed at Lake Macquarie, N.S.W. will cost $50 million and will be the third most expensive segment of the project. In the future, emission control on older equipment will be improved and new equipment will be of a high standard.

A testing facility jointly funded by the Joint Coal Board and the CSIRO enables coal to be burnt and the characteristics of the fly ash to be determined. This is of great value in designing emission control equipment for power stations being built on new coal fields and also for characterising export steaming coals so that the customer can be informed as to the best means of reducing the emissions. Australia's lead in this field is evidenced by the fact that American, Japanese and other foreign technologists have visited this testing facility to use and learn how to build such units.

New Generating, transmission and control, technology

Improved technology in steam generated electricity has resulted in an increasing efficiency of conversion of thermal energy into electricity from below 30% for old units, up to 34% for modern installations. Greater thermodynamic efficiency is being achieved through higher temperatures (up to 540°C) being used in new plants. Because of the construction lead times and even longer development lead times, the present technology will still be installed for at least 10 years.

Magnetohydrodynamics (MHD) is the most promising development in new generating technology (Messerle, 1977). By using the energy of combustion at higher temperatures (up to 3300 K) it may operate with a greater conversion efficiency (over 50% is possible).

MHD is technically feasible and the main need is for the development of an economically operating plant. Russia has been operating a 350 MW (thermal) plant generating up to 20 MW electrical. A 500 MW MHD plant (equal to a large module in a modern installation) is being developed for operation in the mid 80's (Engineers Australia, 1979). Current plants use gas or oil firing but coal fired plants, although more difficult to develop, would be of more interest to Australia. However low energy gas from in-situ gasification of uneconomically extractable coal (Stewart, 1979) (e.g. deep or multiple thin seams) might prove to be a satisfactory fuel as well as a means of utilising an other otherwise untappable resource. Electrode development work for MHD is being carried out in Australia to test the possibility of using coal (Messerle, 1979).

New automatic link-up controls are being installed to improve the reliability of switching and load matching operations. The current upgrading will improve operations in the event of catastrophic breakdowns such as lightening strikes, or sudden generator shutdowns. This is of increasing

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importance in N.S.W. and Victoria which are becoming increasingly short of base capacity. This shortage of capacity is resulting in increasing interstate transmission between Victoria and N.S.W. Connection between Victoria and Soth Australia and also between N.S.W. and Queensland are likely developments in the future. The use of a D.C. line connecting Tasmania to the mainland has been suggested as a means for Victoria to make use of Tasmanis's hydroelectricity. Larger more complex grids will require more elaborate control equipment to maintain a stable system.

SE Study.

Cooling Water

Satisfactory efficiency of conventional Rankine cycle steam powered electricity stations is achieved by using a low temperature heat sink which is generally direct water cooling or evaporative cooling. Cooling water requirements for new power stations are large (about 15 l/y per installed watt) and becoming increasingly more difficult to satisfy. In N.S.W. for instance, plans for future plants have saturated the cooling potential of the major lake systems, Macquarie and Tuggerah. Water for the Bayswater plant will require regulation of the Hunter River to guarantee sufficient cooling water. Much future potential cooling water in the Hunter region occurs in natural areas and environmental conflicts are likely to intensify.

Private generation of electricity and total energy systems

When electricity is generated using a heat engine about 2/3 of the fuel energy is rejected as low grade waste heat. There is little prospect of utilising the waste heat associated with the major generating plants because they do not have adjacent residences or industries where the heat could be used. In industrial situations where both electricity and heat (steam) is required, on site generation of electricity and subsequent use of the waste heat is a much more efficient way of using primary fuel. For instance 70 kW electricity plus 1 GJ(heat)/hour can be produced with an overall efficiency of about 80% (Wall, 1977). Wall estimates that maximum possible use of this approach could produce 26% of Australia's electrical requirements.

For the scheme to be attractive a better scale of prices would have to be developed so that electricity could be bought and sold at fair prices by private generating units. This would allow private producers to install units to match their heat requirements and to buy or sell electricity to balance their needs. Combined private generation of electricity and utilisation of waste heat can be used in a variety of situations from shopping and office complexes to large industrial plants.

Private generation of electricity would have two benefits; better fuel utilisation and lower water requirements. The cooling water which is needed in large amounts for the current large public units would not be a significant requirement in private plants where the waste heat would be used in the same manner that it was prior to installation of a generator. The disadvantages are higher fuel costs and poor economies of scale.

3. Present Environment

Coal

The main uses for black coal in Australia are for steelmaking and other metallurgical processes (coking coal) and for electricity generation (steaming coal). It is also used for direct heating applications, often as "pulverised fuel". Brown coal, produced in Victoria, is used almost solely for electricity generation. Black coal is readily converted to coke and gas, the latter being a more convenient fuel in many situations. Virtually all coke made in Australia is for metallurgical purposes, and over 95% of this is for steelmaking. Coal can also be converted to liquid hydrocarbon fuels (for motor transport) although the process is expensive and only operates commercially in South Africa (for strategic reasons).

The demonstrated and economic reserves of black coal are given by NEAC's Report No. 2 (1977) as 36,300 Mt (in situ) although the inferred economic reserves are at least an additional 160,000 Mt.

The populous states of NSW and Victoria have large coal resources which are close to the centres of population and use. Table 1 gives the state distribution of economically recoverably coal resources. There are other very large resources of coal which are not economically recoverable at present. In the Pedirka and Cooper Basins in South Australia there is an estimated 3 x 10^{12} t of coal at depths of 400-1200 m (S.A. State Energy Committee, 1976). This amount of coal is 20 times greater than the rest of Australia's inferred economic reserves and will present a great technological challenge to exploit this vast resource when needed.

The quality of Australian coal varies from anthracitic coals (low volatility) through sub-bituminous to bituminous coals and brown coals (solely in Victoria). By world standards the ash levels tend to be high but the almost universally low sulphur content is a very desirable property from both a steelmaking point of view and in terms of low air pollution problems when burnt for electricity generation. However, the nitrogen content may sometimes be a negative feature for export steaming coals. The energy content of black coals on average is 27.9 GJ/t whereas brown coal is only 9.76 GJ/t (D. National Development, 1978).

The rapid rise in oil prices has encouraged countries to reduce their oil consumption and to switch to cheaper alternatives. In Australia there is potential for saving oil by switching to coal or gas in some instances. The techniques and problems in using coal for steam raising are discussed above. Overseas however, there is a much greater potential for substitution because a large proportion of electricity is generated with oil and a large amount of oil is used for space heating. The figures in Table 5 shows Australia's high coal usage compared with other western countries (Urie & Meldrum, 1977).

TABLE 5 Consumption of Primary Energy 1974
% of Total

	Solid Fuels	Liquid Fuels	Nat Gas	Hydro & Nuclear Elec.	Total
Australia	44.5	46.1	7.4	2.0	100.0
Japan	20.4	74.4	2.6	2.6	100.0
USA	20.6	43.9	33.3	2.2	100.0
W Europe	24.3	56.8	15.1	3.8	100.0
World	31.8	44.7	20.9	2.6	100.0

It is now generally more favourable for countries to import coal rather than oil for generating electricity.

Electricity

Electricity is an integral part of our modern life: it is essential for powering industrial machines, lights, domestic appliances, sound and video equipment, communications equipment, computers, control equipment, electrochemical processes, refrigerators and air conditioners. It also provides a substantial proportion of space heating requirements.

Current electricity production is predominantly from coal fired stations (about 70%) and based on large reserves in the eastern states this is likely to be the case in the future. Availability of water for cooling is often a more serious limiting constraint.

Potential hydroelectricity sites are estimated to be about 70% utilised and even if fully utilised immediately would not satisfy the growing electricity demand for long. The maximum continuous hydro supply on the mainland is estimated to be about 3200 MW (NEAC, 1977). Pumped water storage capacity in the populous states of N.S.W. and Victoria is satisfactory at present but future capacity will be needed beyond 1990.

Additional hydro potential in Tasmania is estimated at about 3600 MW. However efforts to realise this potential will involve further environmental disputes such as occurred over the flooding of Lake Pedder, and is at present occurring over the Gordon-Franklin wilderness rivers national park proposal. There are currently no large economic coal deposits in Tasmania, but deposits at Fingal are now being proven by the Mines Department in the hope of obtaining sufficient reserves to fire a thermal station. An established railway could take coal to the standby power station (for times of drought) at Bell Bay which would need to be converted from its present oil fired design.

In Western Australia, which has limited coal supplies the possible use of a nuclear power station has been foreshadowed by the W.A. Government. If gas from the NW Shelf were available this could also be used in Perth for electricity generation.

Two oil fired electricity generators in W.A. have recently been converted to dual oil or coal fired operation. It is believed to be the first such conversion carried out in the world (Treadgold, 1979). Two 200 MW units were converted at a cost of $2 M and it is estimated that fuel savings will equal this cost in less than four years. The conversion will cut the State's oil consumption by 1% and reduce the annual oil bill by $10-12 M.

4. Factors affecting change

Substitution of coal for oil for heating purposes in Australia could be significant, given the appropriate climate. Major factors include the relative prices of fuel oil, gas and coal as well as the availability and ease of conversion and use of these fuels. Oil prices are basically determined through the Federal Governments oil pricing policy. Laws and regulations which discriminate against the use of coal fired boilers were noted in the discussion on interfuel substitution. Tax deduction concessions have recently been introduced by the Federal Government to encourage conversion away from oil fired equipment to alternative fuels.

Australia's reserves of high quality coking coal are not large in spite of the large coal deposits. A policy to reserve adequate supplies for domestic requirements appears prudent and has been recommended in the past (Endersbee, 1977). Such a policy may limit coking coal exports.

Incentives to improve mining methods to obtain higher recovery of coal during mining could lead to an extended life of the current reserves which are the easiest and cheapest to extract. Recoveries in underground mining are as low as 50%.

The development of a coal conversion industry (producing liquid fuels) in Australia would significantly increase the size of the coal industry. Such a development is discussed in the Liquid Fuels section but is primarily dependent on the perceived need for alternative fuels and the relative economies and practicalities of the competing liquid fuel alternatives.

Predictions of very large future exports of steaming coal, discussed in the next section, will be dependent on various external and internal factors. To maintain a satisfactory competitive advantage with respect to other coal suppliers will require timely provision of supporting infrastructure for the major investments in mines, railways and ports. Such supporting infrastructure includes towns, roads, water, power and industrial services. Royalties and levies on coal are policy instruments already in use which can affect the competitive advantage of Australian coals overseas and applied differentially to the type or source of the coal can selectively conserve coals (e.g. coking) or affect the proportions of underground to open cut coal and hence the manning levels in the industry.

The price of electricity affects the amount used particularly for electricity intensive operations such as alumina smelting or soda and chlorine production. The price also affects its competitive situation with alternative sources of heat. In instances such as alumina smelting where the product is exported, it has been suggested that electricity is being sold too cheaply in order to attract overseas investments and generate spin-off prosperity for the economy at large (Financial Review, 1979). Different prices for different types of consumers can be justified to a degree but if taken to excess the benefits generated from the industrial growth and export earnings is at the expense of burdens and disincentives in other areas of the economy.

It has been suggested (Thomas, 1977) that the price of coal to the electricity supply authorities should be at an opportunity cost rather than an extraction cost with no profit (as at present). Rough estimates indicate that the opportunity cost of washed steaming coal at a power station would be $15 to $20/t ($25/t export price less $5 to $10/t freight and port costs). This compares with an estimated at-mine cost of $10 to $15/t (washed). Fuel costs are only a minor cost in electricity supply costs, for example 24% in NSW in 1978/79. On this basis electricity costs would not rise more than 25% if the coal were priced at its opportunity cost.

The pricing policy for electricity bought and sold by plants which install their own electricity and steam raising facility would be a major factor in determining the viability of co-generation schemes. Electricity supply authorities have the responsibility for producing power at the lowest possible price and the purchase of electricity from small private producers would run counter to this charter. A policy to maximise the economical use of energy from non-renewable resource would dictate that greater use be made of integrated electricity and heat producing systems. Positive government action would be needed to facilitate such a development, because of the changes required in institutional goals.

The greenhouse effect is a factor which could eventually discourage the growing use of fossil fuels and thus promote the use of solar, nuclear and biological sources of energy. It is postulated that the atmospheric build up of carbon dioxide could increase the earth's overall absorbance of solar energy causing a temperature rise with subsequent climatic changes and even a significant rise in ocean levels due to melting of the polar ice caps. The large use of fossil fuels is undoubtedly raising the atmospheric level of carbon dioxide but the long term climatic effects are far from certain because there are other major factors involved which are not well understood. If it could be reasonably proven that the use of fossil fuels was seriously threatening the world's climate it would still take time to reach international agreement to limit fossil fuel use. It is most unlikely that any country would unilaterally decide to change to a more expensive fuel alternative for the benefit of the rest of the world.

5. Implications for the future

Australia's very large coal reserves can be expected to play an increasingly important role in providing domestic energy requirements as well as overseas needs through greatly increased exports. The International Energy Authority (IEA) 1979 and the World Coal Study (ERT, 1979) have estimated Australia's likely coal production in the year 2000. These are shown in Table 6 together with figures obtained by simply extrapolating National Development's 1978 estimates for the year 1986/87 through to 2000 (using the same average compound growth rates as were used in the projections to 1986/87).

TABLE 6
Estimates of Australia's Black Coal Production in Year 2000

	Domestic		Export		Total
	Steaming	All Other	Steaming	Coking	
IEA estimate	70 Mt	20 Mt	120 Mt	75 Mt	285 Mt
World Coal Study			160 Mt	70 Mt	
Extrapolation of D.N.D. figures	82 Mt	19 Mt			
Growth rate for extrapolation	6.28%	1.69%			

The IEA estimates for all classes of coal agree fairly well with the other respective estimates for the domestic and export levels. The estimated total production (IEA) of 285 Mt is four times current production levels of black coal and represents an average annual compound growth rate of 6.5%. In addition to the growth in coal consumption for current uses assumed in the two estimates for domestic consumption in Table 6, there is a liklihood of increased coal consumption for interfuel substitution and coal conversion. Rough estimates would indicate that these developments could each require an additional 10 to 15 Mt/y for today's energy mix, but this would be escalated in proportion to the overall growth in energy consumption at later dates.

If such a high growth is to be attained it will require a simultaneously large growth in infrastructure, particularly railways and ports, and in support industries.

The foreign earnings from exported coal will be very large. Based on the IEA estimates for year 2000, coking coal exports would be worth $3750 million (current value) if the coal cost $50/t. Similarly steaming coal would earn $3,000 million at a price of $25/t. Total earnings therefore of $6750 million (current value) are greatly in excess of the calculated future costs of importing oil at that time, again at current values and current costs of oil. Of course a rise in the oil price relative to the coal price would reduce the margin.

Growth in direct employment in coal mining will be lower than the production growth rate due to further improvements in labour productivity.

Making the assumption that productivity in both underground and open cut mining will double by the year 2000, estimates can be made of employment levels for various proportions of underground and open cut mining. Calculations on this basis (Table 7) indicate that if the proportion of open cut production remains the same (Scenario 1) the labour force will be 38,000 (c.f. 23,500 in 1977-78) but with a rise in open cut production to 75% of total (Scenario 2) then the employment is 28,800. These estimates are necessarily very approximate because of the various assumptions about future production levels, productivity and the proportion of open cut mining.

TABLE 7

Estimates of employment in black coal mining in the year 2000 based on an expected production of 285 Mt/y

	1977-78				2000						
						Scenario 1			Scenario 2		
	Production		Productivity	men	Productivity	Production		men	Production		men
	%	Mt	t/(man year)	'000	t/(man year)	%	Mt	'000	%	Mt	'000
Underground	49	43	2,480	17.4	4,960	49	140	28.2	25	71	14.4
Open cut	51	45	7,420	6.1	14,840	51	145	9.8	75	214	14.4
TOTAL	100	88	3,736	23.5		100	285	38.0		285	28.8

As well as growth in direct employment, commensurate expansion will occur in the major supporting industries and services.

The continuous rapid growth in coal exports will be concentrated in the Hunter region of NSW and the Bowen Basin in Queensland. Large coal to oil conversion plants may also be developed in these regions. It will lead to strong regional growth and economic prosperity in these areas. The Hunter region will be additionally boosted by the growth in electricity production for Sydney. Queensland developments will be centred on the coastal towns of Mackay, Rockhampton and Gladstone. In Victoria electricity development in the Latrobe valley as well as the possibility of a solvent refined coal plant also point to strong regional development. Such regional growth will not however be without its penalties and restraints. The development of major towns and the spread of urbanisation will bring social stresses to those who prefer their present rural environment.

Development proposals, particularly for water requirements in the Hunter Valley, can be expected to lead to increased environmental concern and conflict over diminishing natural areas as the cities get larger. Air and water pollution from developments will also be matters of concern. Increasing public scrutiny and assessment of impact will add to the cost and development time of new projects. The simplest and cheapest development concept will not always be the successful one. Governments will continue to maintain and preserve intangible social and environmental values which public opinion demands. The price paid is the incremental cost of the next cheapest acceptable option. Increasing attention to public opinion and long term co-ordination and planning will help to avoid wasteful effort being put into new developments which get blocked.

From a strategic and resource point of view, the likely technological changes associated with an increasing use of coal should lead to a reduced dependence on imported oil. Improvements in mining and electricity generation as well as conservation measures will lead to slower depletion rates than would otherwise be the case. National Development forecast an annual growth of 5.44% for the electricity gas and water sector which is dominated by electricity. Increased use of electricity instead of oil, for example in space heating, together with new large electricity consuming projects (e.g. aluminium smelting) should result in higher than predicted growth in electricity production. Increased direct employment (currently about 70,000) together with beneficial flow-on effects to other sectors can be expected.

Alternative sources of electricity - private generation and plants fuelled with coal wastes - would add diversity and complexity to the generating industry. These developments however would lead to reduced requirements for coal and water but possibly increased requirements for gas. There would also be an increased defence strategic value in such schemes.

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NUCLEAR FUELS AND ENERGY

NUCLEAR FUELS AND ENERGY

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1. Perspective

Australian reserves of demonstrated economic reserves are given as 346 000 tonnes uranium metal (extractable at a cost of less than $US 80/kg) (NEAC, 1977). World resources (at the same extraction cost) are given as 1,655,000 tonnes (Barnett 1979). Thorium, another less common nuclear fuel, has demonstrated economic resources of 25,627 tonnes thorium (NEAC, 1977).

From 1954 to 1971 Australia produced about 9200 t of yellowcake (uranium oxide concentrate) from five mines; Radium Hill in S.A., Rum Jungle, United Uranium and South Alligator in the Northern Territory, and Mary Kathleen in Queensland. Gross revenue in historical values was about $170 million.

The Mary Kathleen mine recommenced operations in 1976, and in 1978 produced 608 t of uranium oxide. About 460 people are employed at the mine. The Nabarlek and Ranger mines are in an active construction stage and production is planned for 1980 and 1981 respectively.

The Australian Atomic Energy Commission operates a research nuclear reactor at Lucas Heights, Sydney. Medical isotypes are produced but no useful electricity is generated. In 1969 the Jervis Bay reactor project commenced. A 500 MW electricity generating unit was envisaged. The project was abandoned in 1972.

2. Technologies

2.1 Mining and processing

Mining of the Northern Territory uranium deposits is planned to be by conventional open-cut mining except the Jabiluka deposit. Also the deep Olympic Dam deposit at Roxby Downs, S.A., may need to be mined underground. Radioactive hazards in mining uranium include the gas radon and the low activity dusts. In open cut operation the Fox Report (1976) concluded that the normal control of dust in mining today "generally reduces radiation exposure to well below the prescribed levels". Control of these hazards in underground mining would at least require very effective ventilation measures.

Uranium oxide ("yellowcake" U_3O_8) is obtained from the ore by acid leaching and chemical processing.

Heavy metal leaching can occur from both stockpiled ore and tailings remaining after extraction. The leached material can escape into the local environment with deleterious effects. In the past, when controls were lax, heavy metal pollution caused serious local damage downstream from the Rum Jungle (N.T.) uranium mine and also below the Captains Flat (A.C.T.) base metal mine. Recent plans envisage total indefinite retention of all tailings, ultimately under vegetative cover. Given the monsoonal climate of Arnhem land and the finely divided and reactive nature of the material it is clear that considerable planning and designing is needed for each individual operation. Given such planning, stringent and diligent monitoring and control should enable pollution levels and risks to be kept low.

In Australia the uranium industry has produced only yellowcake. There has been no commercial downstream processing.

2.2 Nuclear fuels and enrichment

Crude uranium oxide is converted into nuclear fuel elements in three stages, conversion to uranium hexafluoride, isotopic uranium enrichment and fuel rod fabrication.

Conversion of uranium oxide to uranium hexafluoride is a realtively simple chemical engineering process. The AAEC already have the necessary proven technology to build a commercial plant for this purpose.

Isotopic uranium enrichment is the production of two streams of uranium, one enriched in the uranium isotope U^{235} (up to about 3%) and the other depleted in this isotope. The enriched uranium is used for fuel in thermal nuclear reactors but the depleted uranium can generally only be used in fast breeder reactors which are new and for which present fuel requirements are negligible. The enrichment process can be achieved by several means of which the main features of the two major processes are briefly discussed, gas diffusion and ultracentrifuge. The capacity of enrichment processes is measured in separative work units (SWU). It takes about 4.3 SWU to produce 1 kg of uranium enriched from 0.72% to 3% U^{235}. Gas diffusion plants are the major source of present enriched fuel. They have higher power requirements and economies of scale necessitate large plants. Centrifuge plants, on the other hand, are almost reaching commercialisation and have about 5% of the specific power consumption of diffusion plants, and they can be economically built with smaller capacities. The table summarises the major features.

TABLE 1 Comparison of power requirements of diffusion and centrifuge plants

	Plant Capacity		Power requirement	
	million SWU/y	3% enriched product t/y	specific power kWh/SWU	continuous plant power MW
Centrifuge plant	1.0	290	130	15
Diffusion plant	10.0	2900	2500	2900

The capital costs are approximately $300-400/annual SWU for both processes but these unit costs depend amongst other things on the scale of operation. Enrichment plants in the USA will enrich a customers fuel on a toll basis and the current cost is given as $US 85/SWU (Holy and Thompson, 1979).

The technology for centrifuge production is not particularly sophisticated and could be easily transferred and the complete production industry developed within Australia.

Fuel rod fabrication is the third and final stage in producing fuel for nuclear reactors and in the case of thermal reactors this process is carried out routinely in a number of countries. The making of mixed fuel pellets of uranium and plutonium as might be used in a breeder reactor, is much more difficult and hazardous (Butler et al, 1977).

2.3 Nuclear reactors

There are two basic types of nuclear fission reactors, (a) thermal reactors (having slow or "thermal" neutrons) or (b) fast breeder reactors (having higher energy or fast neutrons).

Thermal reactors

The thermal reactors use uranium fuel, either with natural or enriched concentrations of U^{235}. During operation some of the non-fissile U^{238} is converted to plutonium, which is fissile, and which then contributes to the reactors thermal output. The controlled fission processes generate heat which is then utilised by a variety of coolants to drive conventional turbines, and thence to produce electricity.

There are five basic types of commercial nuclear reactors as described by Butler et al (1977).

- the most common is the U.S. pressurised water reactor (PWR). This reactor uses ordinary pressurised water as a coolant. It uses enriched 3% U^{235} fuel.

- the U.S. boiling water reactor (BWR) also uses ordinary water as coolant but at a lower pressure. Enriched fuel is also used.

- the British graphite/gas cooled (G/GC) reactor uses a graphite moderator. It uses natural unenriched uranium.

- the advanced gas cooled reactor (AGR) uses enriched fuel

- the Canadian CANDU reactor uses natural uranium and heavy water for both coolant and moderator.

The reactors which can use natural uranium give independence from the few suppliers of enriched uranium. The pressurised water reactors by their very nature are more prone to failure and leakage of radioactive materials but they have been widely accepted in most major countries. The reactor accident at Three Mile Island near Harrisburg, Pennsylvania (in March, 1979) was in such a high pressure water reactor.

Nuclear reactor safety was studied and reported in detail in the Rassmussen report (U.S.A.E.C., 1974). It concluded that for every year that a large nuclear power plant operated there was a one in a million chance that an accident at the reactor could result in 70 people being killed and a 1 in 10^9

chance that 2300 people would be killed. Thermal reactor breakdowns can not give rise to atom bomb type nuclear explosions but could give rise to serious radioactive leaks.

Fast breeder reactors

Fast breeder reactors are fueled with at least 20% plutonium together with U^{238}. Within the reactor the U^{238} is converted to plutonium and more is produced than originally fuelled the reactor. Hence this system allows the abundent, non-fissile U^{238} to be utilised (the depleted U^{238} from enrichment processes is currently stockpiled). By using breeder reactors between 50 and 100 times as much energy can be obtained from natural uranium as would have been obtained if it were used in a thermal reactor. This is an enticing feature of the breeder reactor.

The breeder reactor itself is potentially more hazardous than thermal reactors. It operates at high temperatures with liquid sodium and could go super-critical. The major concerns with the breeder programme are the problems created by the widescale use, and handling of plutonium which is a dangerous material suitable for use in nuclear weapons. Widespread use of breeder reactors would lead to a wider distribution of fissile material with less control on it. Proliferation of plutonium increases the opportunities for countries to arm with nuclear weapons and even terrorists (with non-government resources) could make a crude nuclear device with plutonium. Butler et al (1977) therefore advised against the development of breeder reactors but concur with mining of Australian uranium and the extended use of thermal reactors around the world.

To avoid the problems of the "plutonium economy" an alternative breeding cycle has been proposed. This uses thorium 232 which breeds to uranium 233, a fissile, energy producing material. Mixed with U^{238} the illicit bomb use problem is overcome. It is thought that this process might work in a modified thermal system (CANDU) but considerable development would be required.

2.4 Nuclear Fusion

The sun's vast energy is from nuclear fusion but despite considerable effort no man-made sustained and controllable fusion reaction has yet produced a net energy yield. Considerable effort is being expended on this very low pollution form of nuclear energy but it is considered unlikely that a workable process will be developed within 20 years if at all (Butler et al, 1977).

2.5 Reprocessing and waste disposal

The ultimate safe disposal of radioactive wastes is a necessary requirement for the continued use of nuclear energy.

The spent fuel from nuclear reactors contains a variety of radioactive wastes which are obtained in the reprocessing of the reactor fuel (plutonium and uranium is recovered for further use). The high level wastes contain long-lived low activity elements as well as short-lived high activity elements. These concentrated wastes are presently stored in stainless steel tanks. After some years when the activity is substantially decreased they will be disposed of in a manner which requires no further attention from man and which will be safe and non-polluting for the long life of the active materials. A variety of disposal methods have been suggested (see Stewart et al, 1977). The most promising method at the moment appears to be by incorporating the wastes in a vitreous material. The vitrified wastes then have to be disposed of in geological safe or stable situations - sunk in deep holes on the surface or on the ocean bed. Although the waste disposal methods have not yet been fully tested and proven safe in the long-term it is generally considered that given sufficient effort satisfactory processes will shortly be available.

Other low and medium level wastes are already disposed of by burial or by depositing in deep ocean areas. Obsolete reactors also have to be made safe because of their radioactivity. In the U.S.A. they plan to seal an old unit in a massive tomb of concrete.

3. Present environment

3.1 World energy requirements - coal versus nuclear

The higher use of oil in other Western countries and in particular the use of oil and gas for electricity generation, was noted in the Coal and Electricity section. The recent oil price rises have caused a shift to the next cheapest energy alternatives for producing electricity. These alternatives are principally coal and nuclear energy. In the absence of cheap domestic sources of coal, many countries have been expanding their nuclear generating capacity.

An economic comparison of the two fuels is simply summed up in the following table from (Barnett, 1979, Table 5.8).

TABLE 2 Cost of electricity from nuclear and coal-fired power stations

Fuel	Price	Capital charge	Fuel charge (US cents/kWh)	Operating charge	Total charge
Coal	\$10 per tonne	2.23	0.37	0.07	2.67
	\$40 per tonne	2.23	1.50	0.07	3.80
Uranium	\$77 per kilogram U_3O_8	2.76	0.87	0.10	3.73

Note: Costs are in U.S. currency, interest rate is 18 per cent (this is high and favours the lower cost plant) and the plants operate for 70 per cent of the year.

In summary, nuclear power stations have higher capital and operating charges than coal-fired stations with the same capacity. When coal is cheap, the overall cost of power from the coal-fired station is cheaper than nuclear power, but for high coal costs the nuclear plants is cheaper.

Numerous other factors affect a decision between coal or nuclear energy. Relative safety of the plants (nuclear with a low risk of pollution but high damage versus coal with high risk of pollution with a low level of damage), guarantee of supply, disposal of waste products, reliability of plants etc.

Thus there is no generalised preference which applies world wide. Growth of both forms of electricity production is certain in the short to medium term. Consequently there is a growing demand for both nuclear fuels and coal (see Coal and Electricity re coal demands).

A quantitative assessment of the futue world market for uranium is beyond the scope of this report, however, production rates for various Australian deposits are shown in the table together with the sales value at \$78/kg U metal (\$66/kg U_3O_8).

TABLE 3 Production, sales and employment from Australian uranium

Mine and reference	Reserves	Production t of U/y	Production Value at \$78/t U \$M	Capital* cost \$M	Operators
Jabiluka (1977)	207	2540	198	230	660
Ranger (1979)	100	2540	198	288	340
Koongarra (1978)	13	850	66	70	150
Nabarlek (1979)	12	920	72	75	100
Yeelirrie (1979)	47	2120	165	300	650
Aggregate	379	8970	627	963	1900

* 1978 dollars.

Source: AAEC compiled this data from the references indicated.

While not all these projects will operate simultaneously significant export earnings are indicated. Barnett (1979) also notes the very high return on investment with these ventures, in the range of 13% to 39%.

3.2 Ranger Inquiry - Fox Report

In July 1975 a Commission of Inquiry was constituted under the Environment Protection Act to consider and made recommendations regarding uranium mining in Australia. The Report of the Commission (Fox, 1977) made recommendations for safe mining procedures at the Ranger deposit, environmental safeguards, the granting of Aboriginal land rights, the establishment of a major National Park, sequential development of the Arnhem land uranium deposits and siting of a regional centre for the mining operations.

3.3 Government decisions on mining and enrichment

The Commonwealth Government decided to support the mining and export of uranium. A series of statements in August 1977 (Uranium, 1977) detailed the Government's arguments. Many of the recommendations of the Fox Report have been adopted by the Government and some of those that haven't include the proposal for sequential development of deposits and the alternative siting of a regional centre.

Safeguard agreements to be applied by the Government require that uranium can only be sold to approved countries. Non-nuclear weapons states supplied with Australian uranium must be parties to the Non-Proliferation Treaty (NPT), and supplies to nuclear weapons countries must not be used for explosive or military purposes. All states must allow International Atomic Energy Agency (IAEA) inspection of Australian uranium.

The Government's Foreign Investment Guidelines for the development of uranium resources requires that all new developments should have at least 75% Australian equity. In recent approvals for the Yeelirrie deposit in W.A. and the Olympic Dam deposit at Roxby Downs, the Government has waived these requirements and allowed development on a 50% Australian equity basis.

The Government is investigating the possibility of building a uranium enrichment plant in Australia. It envisages participation of private industry and possibly overseas customer countries. There is currently sufficient world enrichment capacity but because of the long lead times it is necessary to start planning now so that if a plant were to be built it would be available in the late 1980's when further capacity is likely to be required. At present there are no formal standards, criteria, codes or regulations under which a nuclear fuel cycle industry would be controlled. Such requirements would be needed for this industry.

The Aboriginal people

The effect of uranium mining in Arnhem land on the local Aboriginal communities is a complex issue. In Barnett's words (1979) "the Aborigines have an intimate metaphysical relationship to the land which cannot be easily translated into western concepts of ownership and land use". One example of the socially disruptive effect which mining can bring is the employment of young Aboriginals who are better educated by western standards than others in their community. The young men of the community earn good money and hold prestigious jobs. This leads to a breakdown in the tribal heirarchy where the older men are reverred and respected. Many other disruptions occur, due to the mixing of cultures generally, and few are specifically related to mining itself.

The Aboriginal Land Rights (Northern Territory) Act 1976 provides for Aboriginal freehold title to certain land and provides that exploration and mining on Aboriginal land requires the consent of the Aboriginal owners. Payments are made in lieu of royalty for uranium mined on Aboriginal land. Agreements currently provide for an effective royalty rate of 4¼% of the production value for the Ranger mine and 4½% of the value for the Nabarlek project. These funds will be deposited in the Aboriginals Benefit Trust Account which is used by communities and not individuals. Government approval on 9 January 1979 for Ranger to export 3000 t/y of yellowcake implies that annual payments of about $6 million would be involved from this project alone.

Kakadu National Park

The Government has decided to declare the Kakadu National Park in stages thereby allowing mining at Jabiluka and Ranger to take place outside the first stage of the Park. Stage 1 of the Park was declared in April 1979.

Plans of management will be designed to allow for, and control any deleterious effects, from mining enclaves, or high numbers of visitors.

Nuclear Energy in Australia

Cheap electricity prices on the east coast of Australia due to abundant coal deposits, make it unlikely that nuclear power would be installed there in the medium term.

In States such as S.A., W.A. and even Tasmania, where there are insufficient economic coal deposits of satisfactory quality, nuclear energy can be considered an option.

The Western Australian Government has announced this year, two potential sites for a nuclear power station. It would not be operating before 1990.

4. Factors affecting change

Public acceptance of nuclear energy generally and uranium mining in Australia specifically, could influence the domestic uranium industry. Growth in nuclear energy overseas while significant has not been as rapid as had been predicted several years earlier. Environmental and safety enquiries have caused delays which, along with a reduced demand for electricity, have contributed to this slowdown.

Within Australia, public opposition to uranium mining and export, and union bans, could lead to delays and stoppages.

If breeder reactors become commercially established then the demand for uranium will level off. Only thermal reactors will require fresh uranium to obtain U^{235}, while breeders will use the stockpiles of depleted uranium. The U.S.A. has curtailed its breeder reactor programme because of the greater potential hazards compared with thermal reactors. France and West Germany however, maintain active programmes, which if continued, could lead to substantial installations by 1990.

Similarly, in the longer term, if photovoltaic electricity generation became substantially cheaper this would also limit the further demand for uranium.

Planning and licensing arrangements take a long time in this area of complex and sensitive technology. Hence government policies need to lay down stable, consistent guidelines that provide a conducive environment for rational and enterprising private venture operations.

The possible use of nuclear power in S.A., W.A. and Tasmania will be affected by any discoveries of alternative energy sources and by any developments which would enable the poor quality coals to be more economically used. Further discoveries of gas for example would provide an alternative fuel.

If a decision is made to proceed with uranium enrichment a further option of major significance is raised. Should Australia provide nuclear fuel elements, reprocess spent elements and provide long term waste storage? Butler (1979) suggests that by this action, Australia would be doing its best to satisfy a moral responsibility to oversee the final disposal of radioactive materials, while at the same time retaining control of what happens to the spent fuel emanating from our uranium.

5. Implications and Consequences

The potential economic benefits from uranium mining and enrichment in Australia are very large. Approximate estimates only can be put on the possible developments. These are tabulated.

TABLE 4 Features of uranium development possibilities

	Date	Production t/y	Production $M/y	Capital cost $M	Employment	Reference
Uranium mining (U)	1985	10000	780[2]	-	up to 2300	1
	1990[4]	8970	700	963	1900	3
Uranium Hexafluoride	1985-90	5000(U)	6[5]	40	200	1
Uranium enrichment (centrifuge)	1985-90	1 M SWU (1,300 t/y U feed, 230 t/y 3% U^{235} product)	100	400-500	300	1

1. Holy and Thompson (1979)

2. This value is based on a value of $78/kg (U)
3. AAEC figures - See Table 3
4. These figures are the aggregate of all 5 deposits in Table 3.
5. Estimated.

While these figures protray high economic benefits in the form of high foreign earnings as well as the previously noted high profitability, the ultimate economic determinant will be the future market for uranium and particularly enriched uranium.

Unlike mine development with relatively short lead times, enrichment facilities take a long time to bring into production during which time the market situation would have changed significantly due to the several factors mentioned previously. This strengthens the argument for including foreign contract customers in the enrichment project. This should be the only reason for permitting a relaxation of foreign investment guidelines for such a profitable Australian resource venture.

Not withstanding the best attempts to minimise any adverse affects on the Aboriginal people it would seem that changes, possibly detrimental, will occur to their lifestyle. An example was noted earlier. It is to be hoped that the generous royalty payment can be used in a manner which will help overcome the difficulties faced by the intermixing of two cultures which have almost immiscible outlooks and values.

The quality of the Kakadu National Park could be threatened by unsatisfactory mining practice or from excessive visitation brought about by the local developments. Modern mining practice can be made so that the environment outside the mine perimeter is not despoiled. The new Woodlawn mine near Goulburn provides such an example. Immediate and complete dedication of the Kakadu Park, with mining excluded, will continue to be sought from bodies such as the Australian Conservation Foundation. Particular pressure can be expected to stop mining enclaves such as Koongarra in the Stage 1 area of the Park or other prospects in Stage 2.

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SOLAR AND OTHER SOURCES OF ENERGY

SOLAR AND OTHER SOURCES OF ENERGY

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- Solar space heating
- Solar heat for electricity and fuels
- Photovoltaic conversion
- Wind energy
- Batteries, fuel cells and energy storage
- Thermal storage
- Methane from biomass
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SOLAR AND OTHER SOURCES OF ENERGY

1. Perspective

Solar energy and other technologies included here (batteries, energy storage, hydrogen fuel) are at present a very small part of the total energy picture. Most of the developments are at an embryonic state (some are only conceptual) and hence there are a lot of possible combinations for a future energy scenario, which includes some of these developments.

The largest present direct use of solar energy is in water heating which it is estimated contributes about 1 part in 3000 of Australia's total energy needs. Comprehensive statistics for the solar water heating industry are not available. Total production of solar absorbed units was 108,000 m^2 in 1978-79. Assuming a 4 m^2 domestic unit costs $800 the annual production value was about $22 million. Employment for all types of water heating systems was 1800 persons in 1977-78. Solar heating units represent about 8% of the total water heating market.

Electricity generation from solar energy is relatively expensive but is being used for small isolated applications in remote areas where other sources are more expensive.

2. Technologies

Water heating

Sales of solar hot water systems are growing rapidly (from 28,000m^2 of collector area in 1975/76 to 108,000m^2 in 1978/79). Sales of other domestic heaters remained virtually constant in the same period. Assuming an average of 4 m^2 for a domestic unit, the 1978/79 figures indicate that sales of solar water heaters have risen rapidly to about 8% of the total of new domestic hot water systems.

If it is assumed that the total installed capacity is 400,000m^2 and usable energy obtained in 2.76 GJ/(m^2y) then the annual contribution of solar energy to water heating is 1.1 PJ/y. This present use of solar energy is a minor contribution to even the domestic/commercial primary energy consumption of about 190 PJ/y in 1978/79.

The economics of solar water heaters have been estimated by the CSIRO (1977) who give the size of system and the value of solar energy collected at various localities for a family of four (Table 1).

Domestic solar hot water systems will be attractive as a major supplement for those existing heaters which use more expensive fuels e.g. gas and peak rated electricity.

Solar collectors were estimated to cost $125/m^2 (including installation) in 1977 (Morse, 1977). This can be considered as the approximate additional costs above the cost of a conventional off-peak electric water system, and the savings incurred should pay back this investment in a reasonable time if the expenditure is to be justified on economic grounds.

TABLE 1. Size of system and value of solar energy collected at various localities for a family of four

Locality	Area of collector (m^2)	Tank capacity (litre)	Value ($) of solar energy collected in a year, related to power cost at 2¢ per kilowatt-hour
Alice Springs Coober Pedy Darwin Townsville	3	270	51.10
Adelaide Brisbane Canberra Perth Sydney	4	315	58.40
Hobart Melbourne	5	360	60.84

A large use of solar hot water heaters occurs in the northern and more remote areas where electricity costs are high (5.35c/kWh increment in Darwin, Nov. 79) and the saving quickly pays for the capital cost. There is the added national benefit that oil consumption for electricity generation is reduced in these areas. In other cities coal fired off-peak electricity is cheap (1.7 c/kWh in Brisbane to 2.43 c/kWh in Perth) and solar heating savings are not so great. However the competing wholly electric off-peak systems fitted to existing houses require expensive roof installation or occupy valuable house space.

Much of the cost in solar water heaters is in the basic materials, copper and glass. Developments in conventional flat plate collectors including large scale manufacture can be expected to reduce costs but not dramatically.

Higher temperature solar hot water heaters are being developed using a selectively absorbing surface inside a glass evacuated tube. Operating temperatures of 150°C and possibly up to 200°C can be achieved. The cost of such collectors if mass produced is predicted to be 3/4 that of flat collectors (Burck, 1979). This is a more valuable temperature for industrial use than the 60° - 80°C currently available from flat plate collectors.

<u>Space Heating</u>

Space heating requirements in the cooler parts of Australia are larger than domestic water heating needs, (e.g. from 15 GJ to 40 GJ/y for space heating in Melbourne compared with a total maximum water heating requirement of about 20 GJ). The CSIRO (1978a) estimate that a collector area of 15 m^2 with a heat store of either 4 m^3 of gravel or 1 m^3 (1 kl) of water could provide 80% of the required heat load of 16 GJ/y in Melbourne. The cost of this heat, if provided directly by electricity at 3c/kWh would be $107. However the cost of the system would cost around $3000. Clearly this is not economically attractive. Developments in air heating collectors might reduce this cost significantly particularly if integrated with the roof construction. Because of the large volumes and areas involved in these systems they will be most readily installed during building construction. The CSIRO is designing and building a house for Australian conditions with built-in active solar air heating and rock bed storage (CSIRO 1978 b).

Low grade solar heat can also drive heat pumps which can be used for both space heating and cooling. The heat can be used either for absorption type heat pumps or to drive a generator and compressor for a liquefaction type heat pump. Unlike many other solar uses this system has the advantage of maximum power availability when most needed. Although the cost of these systems is high it is estimated that in areas where expensive electricity is generated locally (such as mining towns in the north of Australia), the pay back period would be 7 to 8 years (Leigh, 1979).

Passive solar heating can contribute significantly to the heating of domestic dwellings. Because it involves the correct orientation of a building and appropriate design of windows and eaves it is only appropriate for new buildings and renovations. Even recently built domestic dwellings exhibit little awareness of the principles of passive solar utilisation and greater consideration of the principles of passive solar utilisation would contribute significantly to a reduction in space heating requirements.

Solar heat for electricity and fuels

A variety of methods have been proposed for generating electricity or chemical fuels from solar thermal energy.

Most processes use some means of focusing for obtaining high temperatures of a working medium. Focusing can be fixed or tracking, the latter giving higher temperatures and hence higher conversion efficiencies but it is more complex. High pressure steam can be produced for driving a conventional generator. Such a system is being developed by the Department of Engineering Physics at the ANU. The first 25 kW plant is to be installed in a N.S.W. country town. It is estimated that electricity from this process could cost as little as 7 c/kWh when it is well established. This is cheaper than non-grid electricity in country areas. Another popular method being developed uses even higher temperature to thermochemically "crack" chemicals. The same group at ANU is designing a system which heats ammonia causing it to decompose into nitrogen and hydrogen. The mixed gases can be recombined to provide thermal and thence electrical energy but because the gases can be stored before use, this type of process provides its own storage which is a deficiency of direct conversion processes. Many similar processes are being developed around the world, particularly by countries less favourable placed than Australia for conventional electricity generation.

Use can be made of the temperature difference in upper and lower levels of the ocean in tropical regions to drive a heat engine for generating electricity. This method can be used for continuous base load generation. However because of the remoteness of plants from centres of use it is probable that a chemical intermediate such as hydrogen would have to be produced to transfer the energy. This method is only in the preliminary stages of development. A variation on this principle is proposed by Israeli scientists who use solar radiation on a large pond to generate temperature differences for driving an electricity generating heat engine (Durst, 1979).

Photovoltaic conversion

Solar cells are solid state devices which convert high energy solar radiation directly into direct current electricity. Energy storage is required if electricity is required when there is no radiation.

These devices are currently an expensive means of providing electricity but find valuable use in remote and unattended installations where fuel provision and maintenance is expensive. They are used in satellites, drifting ocean bouys and in communications networks in remote areas, for example the Tennant Creek to Alice Springs microwave radio link. This large system will have a peak supply of 11 kW linked to storage batteries.

The most common photovoltaic cells are made from silicon and while silica is a very common material, high purity requirements and the manufacture of large single crystals give a high cost to the products. There is a major development effort to reduce the costs of these and other photovoltaic devices. Costs have fallen dramatically with increasing production levels. Current costs are about $10-$30 per peak watt of electricity; but a recent 350 kW contract cost $6 peak watt (Lyons, 1978). United States Department of Energy targets are for 15c to 50c per peak watt by 1990 (Javetski, 1979). By comparison the capital cost of new fossil fueled power stations is 20c-$1/watt).

As solar cell costs drop energy storage becomes the major cost component in solar electricity. Lead acid batteries cost \$10-\$20/MJ (\$36-\$72/kWh) of stored electricity (Ecos, 1978). The potential for cheaper and better energy storage is discussed in another section.

Godfrey (1978) has calculated that isolated rural electricity can be provided for 3.0c/MJ (10.8c/kWh) using a diesel system, and for 11.8c/MJ for a photovoltaic solar system. However the solar system with a small supplementary diesel generator would half the solar cost. In the near future as oil prices rise and solar cell prices drop, the hybrid system will soon become economically attractive for isolated uses.

Photovoltaic conversion of solar radiation on a geosynchronous satellite has the advantage of having a continuous output with only one brief predictable black out per day. Four times more energy is available to the satellite than the most favourable terrestial location (Glaser et al 1979). The solar derived electricity would be beamed to a terrestial antenna by microwave. The massive costs (total R&D would cost \$43 billion) limit the development effort to the major powers. Plans envisage that production could start by 2000.

Solar radiation shining on suitable electrodes immersed in an electrolyte solution can produce hydrogen from decomposition of water. However the process is not likely to achieve a high efficiency (Ecos, 1978) and conventional electrolysis or thermochemical means are likely to remain a preferred way of producing hydrogen.

Wind energy

The use of wind energy for mechanically pumping water is a well established feature in the Australian rural scene. Wind energy can also be used for electricity generation. Variable production and the need for storage are common problems shared with photovoltaic conversion. The location is a more important factor in wind power than in direct solar use. In favourably windy locations wind power may be an option for domestic or unattended installations where electricity costs are very high.

The Western Australian Government is investigating feasible applications for wind power. Two units are to be installed on Rottnest Island - one a 50 kW vertical axis machine, the other a 22 kW horizontal axis (propellor type) machine. Similar developments are being considered for King and Flinders Islands in Bass Strait.

Batteries, fuel cells and energy storage

Batteries are an efficient means of chemically storing electrical energy. Rechargeable batteries can be charged and discharged with high cycle efficiency up to about 70%. Conventional lead-acid batteries are used for both small vehicle propulsion and as a storage medium for intermittently produced electricity such as solarvoltaic and wind power. Batteries need improvement in many aspects to increase their potential and value in these applications. Batteries need to be cheaper, have high cycle lives, deep charging and for transport applications it is desirable that they can be charged more rapidly and that they have higher energy and power densities. The sodium/sulphur electrochemical couple has a high energy and power density but the battery operates at 350°C. Lithium/chloride is another high performance battery also operating at high temperature. The hot and dangerous nature of these reagents makes their potential use in vehicles doubtful. However their use for storage of intermittently produced electricity, especially larger scale solar sources would appear potentially promising.

A novel approach for increasing the charging rate of batteries is being pursued at Flinders University. The electrochemical reagents of the battery are in a slurry which is rapidly exchanged for a fresh charge when the battery is depleted. The spent charge can be regenerated away from the vehicle.

The National Energy Advisory Committee give estimates (NEAC, 1978) of future electric vehicle growth. By year 2000 electric cars would constitute 18.5% to 42% of all cars and stations waggons in Australia. It is estimated that the increased load on the electricity supply would be 1½% to 7% of all other electricity generated.

Fuel cells consume chemical reagents to produce electrical energy with a high thermodynamic efficiency (40-50% compared with internal combustion heat engines of only 25-30%). Present fuel cells are small and expensive and are used where fuel efficiency and reliability are important (e.g. spacecraft, and remote, unattended electrically powered installations). Fuel cells need clean, chemically simple fuels such as hydrogen, methanol or methane (natural gas). A natural gas system using 26 MW units is being developed for commercial use (Messerle, 1977). If hydrogen becomes the fuel of the future, fuel cells would provide a likely means of converting it into electricity, either in large scale units or in smaller domestic and commercial applications where use could be made of the waste heat for space heating.

Other energy storage methods include pumped water storage, compressed air storage, heat storage, and flywheel storage. Chemical storage is discussed under hydrogen and other synthesised fuels. Pumped water storage is an established part of the electricity supply system and is used for providing peak power requirements.

Compressed air and flywheel storage systems would be used by major electricity authorities in the same way as water storage. They may be of use when water storage or other peak supply methods are not available.

Thermal storage

Thermal storage methods for all scales of use are being developed. Rock piles, water storage and eutectic salts may be used for low temperature storage for space heating. High temperature storage is also being considered for "peak shaving" in electricity generation - i.e. using excess base load capacity steam to heat a thermal store which can be drawn on in peak demand.

Methane

Methane is the predominant component of natural gas obtained from oil fields but it can also be produced from biological materials by anaerobic fermentation. As a gas it is less useful as a transport fuel (see section on LPG and Natural gas). Its major use will be as an energy resource for local use.

Methane is already produced in sewage treatment plants and other large organic waste disposal systems. There are many agricultural and food processing industries which produce biological wastes which pose environmental disposal problems; e.g. abattoirs, distilleries, starch plants, canning factories and piggeries. Methane production from the wastes offers a worthwhile reduction in the disposal problem together with the production of a useful fuel which, being a gas, is most readily used on site for e.g. process heat, or even lighting and cooking in remote communities (Ecos, 1977).

Hydrogen and other synthesised fuels

Hydrogen is a high energy chemical fuel which can be produced in a variety of ways. Its many useful properties has led to the concept of the "hydrogen economy" which uses hydrogen as the energy transporting medium (like electricity) and as a chemical fuel (like oil). It is envisaged as an alternative to oil when oil runs out. Apart from the enormous capital investment in our present energy systems the main drawback with hydrogen at present is its cost of production.

Hydrogen is produced by steam reforming of methane (giving hydrogen and carbon monoxide) and is also produced in oil refinery operations. Hydrogen can also be produced from gasification of coal. In the long term when fossil fuels run out, hydrogen could be produced from other sources. It can be produced by conventional electrolysis of water at ambient temperatures but developments are aiming at high temperature electrolysis of steam in which case less electrical energy is required. High temperature thermochemical splitting reactions are also being investigated for hydrogen production. Of the methods which do not use fossil fuels this currently appears the most attractive. Heat from solar furnaces or nuclear power stations could be used to drive this process. It is thought that nuclear powered thermochemically produced hydrogen could be produced for about \$9/GJ compared with the costs from natural gas and coal gasification of \$3/GJ and \$5/GJ respectively (Business Week, 1978).

Hydrogen can be readily transmitted by natural gas pipelines although it is not certain whether steel embrittlement problems can be overcome. For distances in excess of 500 km hydrogen transmission is more efficient than high voltage electricity transmission. Hydrogen can also be stored more readily than electricity. Hydrogen can be used to generate electricity with high efficiency using fuel cells or possibly with advanced generating technologies (discussed elsewhere).

Liquid hydrogen is considered to be an attractive potential aircraft fuel which will inevitably be used. It is expected to permit smaller wings, larger fuselages and reduced gross weights. The engines would be quieter and produce very little pollution.

For vehicle use hydrogen would have to be stored as a gas under pressure or in metal hydrides such as iron-titanium hydride. Both containers have a weight problem. Daimler-Benz have converted conventional petrol engines to dual fuel hydrogen/petrol operation. The fuel supply needs significant modification. Hydrogen fueled engines emit virtually no pollutants except nitrogen oxides which can be kept very low.

Reticulated hydrogen to dwellings could be used for recharging hydride tanks on vehicles (they are not as quickly refuelled as petrol vehicles) or for running fuel cells for domestic electrical needs, utilising the waste heat from the fuel cell for space heating. In this way hydrogen could totally replace reticulated electricity.

Hydrogen is a highly explosive gas but with adequate precautions it should be possible to use it safely.

Hydrazine and ammonia are other potential vehicle fuels which like hydrogen can be produced from other energy sources. They can be stored in relatively low pressure containers.

Wave, tidal and geothermal

There are regions on the Australian coast (principally the low population north west area) with tidal ranges of 12 m which could be used for electricity generation. However, the price would be well in excess of alternative electricity costs.

Wave power for generating electricity is being investigated seriously in England but again it does not look like a serious option in Australia because of the cheaper cost of alternative sources.

Geothermal electricity generation is a well established method in some countries but there are no known suitable sites in Australia.

3. Present environment

It was noted earlier that the general energy environment in Australia was characterised by rising world oil prices but more stable coal and electricity prices based on large and easily won coal deposits in the eastern states. The greatest need in Australia's energy supply is for liquid fuels for transport and the potential solar contribution in this area is through the use of biomass, or taking a longer term view, through the generation of hydrogen using solar heat or electricity. However at the present time the costs for large scale development of these options appear unattractive. Alternative means of powering vehicles are desirable in order to reduce our dependence on imported oil.

Solar energy is a freely available renewable energy resource, but it is difficult and costly to collect, store, and transform into useful heat, electricity or work because of the inherent characteristics of low intensity, and geographic, seasonal and daily variations.

Solar energy striking the earth's surface has a density of 1.35 kW/m^2 but at the earth's surface the density normal to the beam is about 1.0 kW/m^2. The wavelength of the radiation at the ground is limited to wavelengths between 0.3 um (near ultra violet) and 2.5 um (middle infrared). On a 24 hour averaged basis the radiation on a horizontal plane in Australia varies from 100 W/m^2 in winter in Melbourne or Hobart to a value of 280 W/m^2 in summer in some southern Australian regions. Australia is not greatly better off (nor worse off) in terms of available global solar energy than is any other country in the latitude range 50^{o}N to 50^{o}S. The yearly mean input to the United States for instance is perhaps only 10% lower than that of

Australia and the yearly mean input into the centre of the Sahara Desert is perhaps only 10% higher than that of Australia (Thomas, 1977).

The overall efficiency of utilisation of solar energy (ratio of annual quantity of energy harnessed to total radiation incident on the collecting area) varies dramatically with the nature of the collecting method: a flat plate water collector (heating to 55°C) has an efficiency of 40-50%, a silicon cell has an efficiency of 10-14%, but photosynthetic conversion by plants is only about 0.5% efficient. One of the reasons for these differing efficiencies is the different bandwidths of the spectrum which the different collecting methods can utilise and which are essentially inflexible and not subject to technical improvement.

There is a strong subjective element in the community's general interest and advocacy of solar energy (e.g. car sticker slogan "SOLAR NOT NUCLEAR"). This could be based on a combination of factors including a belief (probably false) that there is a nexus between the domestic price of oil and coal generated electricity (i.e. they see electricity heating costs continuing to rise in line with oil prices). A belief that solar energy is free or a desire to be independent of a large technological industry could be other factors.

The potential for the use of low grade solar heat in Australia was estimated by Chin (1977) to be a maximum of 7% of total energy used, being composed of 5.5% in domestic and commercial heating and 1.5% in industrial heating. The low potential for industrial applications is due to the substantial reuse of low grade heat which is a by-product of higher temperature usage (steam raising).

The infant state of solar energy and other associated developments and the current development effort suggest that there is scope for innovative utilisation and substantial cost reductions in the new areas.

4. Factors affecting change

Probably the most significant yet intangible factor affecting the use of solar energy and these other sources of energy will be the rate and success of research and development. Other countries, worse affected by the oil price rise than Australia, are putting a substantial effort into this area. The Australian contribution would be of value where our technological competence is high or where we have a special need different to other countries (e.g. the remoteness of outback properties).

More specific factors affecting solar energy utilisation include:

- the degree of extension of the electricity grid
- the price of electricity, particularly the pricing policy for off-peak electricity used for boosting solar water heaters
- the price of fuel oil, gas and coal to industrial consumers
- incentives and subsidies
- legislation defining rights to sunshine

The rate and degree to which photovoltaic electricity prices drop should be a key factor in determining the timing and extent of expansion of the electricity grid to low population areas. Reticulation costs are expensive in the country and solar energy could soon be cheaper overall.

At the present time electricity pricing policies in some areas can inhibit the installation of solar water heaters. Cheap off-peak rates should be universally available from coal based electricity supplies.

Clearly the price of alternative fuels, affects the market penetration of solar energy. Gas is significantly cheaper than oil (oil costs approximately $3/GJ) in Melbourne and is still competitive in Sydney and Adelaide. Coal at $25/t (about $1/GJ) is cheaper again but is inconvenient to handle. At the moment solar heating is only likely to supplement oil heating.

Further incentives or subsidies if provided for solar energy would hasten its use. In particular, encouragement for better passive utilisation of solar energy at the construction stage would lead to significant fuel savings accumulating over the life of the building.

In city areas solar energy can not always be used by those wishing to, due to shading from adjacent buildings and trees. Legislation providing rights to sunshine would stop new occurences of this problem.

It was noted in the coal section that international agreement could possibly limit the use of fossil fuels in order to avoid climatic changes from the greenhouse effect. This would greatly increase the need for alternative energy sources such as solar, nuclear and biomass.

5. Implications for the future

The growth of solar water heating is likely to continue, but in some areas where pay back periods are 10 years or more the growth will be slow.

The industry is not dissimilar to conventional water heating manufacturing with respect to labour intensiveness. The higher sale price of solar water heaters may therefore represent a growth in employment in this industry as the market structure changes.

A crude estimate can be made of the potential national energy saving using solar energy for domestic water heating. If all households (4.16 million in 1975-76) had a solar water heater with an area of 4 m^2 and the collectors produced 2.76 $GJ/(m^2y)$ then the energy saved is 46 PJ/y. A 50% share of the market might be achieved if off-peak electricity were universally available for off-peak boosting. In this instance 23 PJ/y is saved representing about 3.5 Mt/y of coal which would have been burnt in a power station. To make this saving would cost at least $800 million invested in flat plate collectors.

The use of photovoltaic devices for remote household applications is likely to be widespread if costs fall as dramatically as predicted. The Australian market would still be relatively small and Australian production would seem unlikely. These installations would advantageously make use of auxilliary diesel power with either smaller replacement machines or existing units.

The use of small electric vehicles for local commuting is likely over the next 20 years and predictions of 15% to 40% of domestic type vehicles were noted earlier. This will be a very significant factor in reducing our needs of liquid fuels for transport, but will require massive investments and developments in battery manufacturing as well as the new vehicles themselves. Battery charging facilities will be needed both in households and in public places. It is possible that the use of small, low powered battery vehicles will provide a less hectic traffic environment which will encourage the use of other small powered units such as 2 seater cars and motor bikes.

Substantial changes will occur if photovoltaic power generation and storage can be developed to provide cheaper electricity than coal fired stations either in Australia or overseas. It is confidently predicted that coal exports from Australia will grow quickly to large volumes (greater than 100 Mt/y by 2000) to be used for electricity generation. If photovoltaic power were cheaper than coal generated power this trade would stop. Similarly in Australia, mines and power stations would not be developed or replaced once the newer technology was introduced. Photovoltaic power generation and storage could be in small units and widely distributed, and would be of defence strategic value. Such developments are problematic in light of the long time scales involved.

Again far into the future, if hydrogen was the storage method for cheap photovoltaic power then many facets of the hydrogen economy (discussed earlier) could develop e.g. reticulation of hydrogen rather than electricity.

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GLOSSARY OF UNITS AND VALUES

SI Units

Abbreviations

k	kilo	10^{3}	m	milli	10^{-3}
M	mega	10^{6}	u	micro	10^{-6}
G	giga	10^{9}	n	nano	10^{-9}
T	tera	10^{12}	p	pico	10^{-12}
P	peta	10^{15}			
E	exa	10^{18}			

Symbols and equivalents

1 t = 1 tonne = 0.984 ton

1 kl = 1 kilolitre = 6.29 barrel

1 J = 1 joule = 0.948×10^{-3} BTU

1 kW = 1 kilowatt = 1.34 horsepower

1 kWh = 1 kilowatt hour = 3.6×10^{6} J

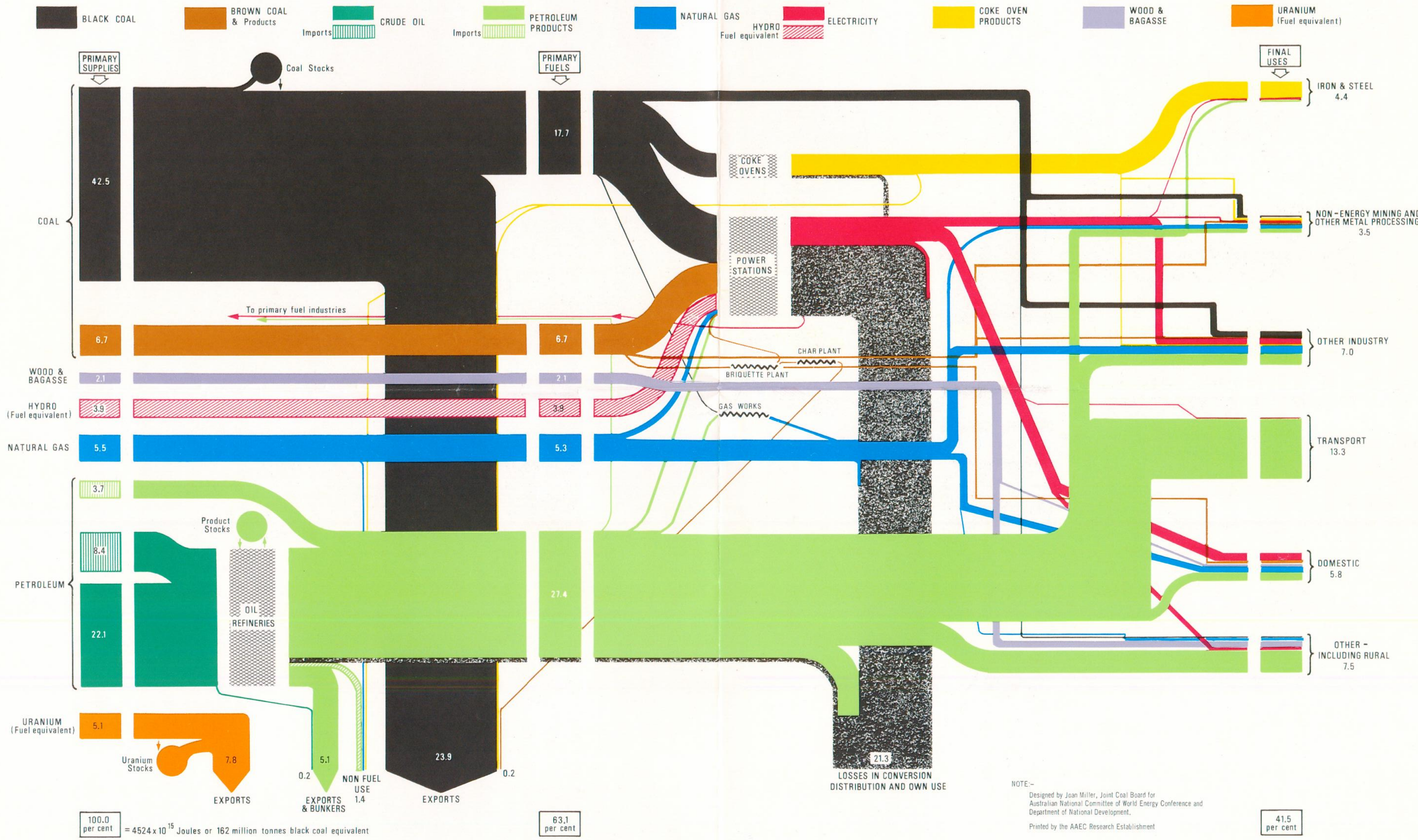
Energy and density values

These values are "typical" values which can vary with the composition of the materials.

	Density kg/l	Energy MJ/kg
Natural gas	0.83×10^{-3}	47
LPG	0.55	49.8
Motor spirit premium	0.737	46.5
Fuel oil (average sulphur)	0.939	43.3
Crude oil - Australian	0.816	46
Coking coal		27
Steaming coal		22
Brown coal Victoria		9.76
Wood		16
Bagasse		9.6

AUSTRALIA ENERGY FLOWS 1976-77

PERCENTAGE OF PRIMARY SUPPLIES (Specific Energy Content Basis)



NOTE:-
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AUSTRALIA
ENERGY RESOURCES
DEPARTMENT OF NATIONAL DEVELOPMENT
MAY 1979
NATMAP
SCALE 1:12 000 000 (189·4 Miles to 1 Inch)
Kilometres 100 0 100 200 300 400 Kilometres
FUELS
Mineral Name
Mine, Field or Area.
Undeveloped
Being Developed
Producing
Refinery or Processing Plant
Coal, Black
Coal, Brown
Natural Gas
Oil
Oil and Natural Gas
Oil Shale
Uranium
OTHER ENERGY SOURCES
Potential Site
Under Construction
Operating
Hydro-electric power
Tidal power
FUEL MOVEMENTS
Railway
Road
Pipeline
Oil
Natural Gas
NMP 79/042
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Troubadour-Sunrise
Puffin
Tern
Scott Reef
Jabiluka
Nabarlek
Ranger
Koongarra
Rum Jungle
Secure Bay-Walcott Inlet
Ord River
Egret-Eaglehawk
Angel
North Rankin
Dockrell-Tidepole
Rankin-Goodwyn
West Tryal Rocks
Spar
Barrow Island
Pasco Island
Westmoreland
Barron Gorge - Kareeya
Maureen
Ben Lomond
Mary Kathleen
Julia Creek
Bowen
Burdekin Falls
Collinsville
Newlands
Hail Creek
Hay Point
Nebo
Goonyella
Peak Downs
Daunia
Saraji
Blair Athol
Norwich Park
German Creek
Oaky Creek
Gregory
Yarrabee
Blackwater
Leichhardt
Cook
Sth Blackwater
Rundle
Gladstone
Callide
Rolleston area
Moura-Kianga
Theodore
Gilmore
Taroom
Roma area
Kincora
Tarong
Brigalow
Bennett
Cabawin
Brisbane
Bulwer Island
Lytton
West Moreton area
Boxleigh-Silver Springs
Moonie
Alton
Millmerran
Ashby
COOPER
Moomba-Gidgealpa-Big Lake
BASIN
Bigrlyi
Mereenie
Palm Valley
Lake Way
Yeelirrie
Lake Phillipson
Mount Painter
Leigh Creek
Beverley
Roxby Downs
Honeymoon
Radium Hill
Port Augusta
Adelaide
Hallett Cove
Dongara
Mondarra
Yardarino
Kwinana
Pinjarra
Collie
NORTHERN TERRITORY
WESTERN AUSTRALIA
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
VICTORIA
TASMANIA
INDIAN OCEAN
CORAL SEA
TASMAN SEA
NORTH WEST SHELF
GIPPSLAND SHELF
Boggabri
Gunnedah
Singleton-Muswellbrook area
Ulan
Warkworth area
South Maitland area
Newcastle
Newcastle area
Lithgow-Wallerawang area
Clarence
Burragorang Valley area
Tahmoor area
Bargo
Wattagamba
Clyde
Kurnell
Matraville
Sydney
South Coast area
Shoalhaven
Port Kembla
Oaklands
Tumut 1, 2, 3
Murray 1, 2
Blowering, Guthega
Albury
Hume
Snowy Mountains
Dartmouth
Kiewa
Eildon
Bendigo
Ballarat
Altona
Melbourne
Yallourn
Morwell
Longford
Geelong
Westernport
Anglesea
Loy Yang
Snapper-Flounder
Marlin
Tuna
Mackerel
Kingfish-Halibut
Barracouta
Golden Beach
Cobia
Turrum
Pelican
Mersey River
Fingal
Pieman River
Central Highlands
Gordon River
Derwent River


AUSTRALIA
COAL RESOURCES
OCTOBER 1979
NATMAP
SCALE 1:12 500 000
INDONESIA
TIMOR SEA
ARAFURA SEA
PAPUA NEW GUINEA
CORAL SEA
INDIAN OCEAN
SOUTHERN OCEAN
SOUTH PACIFIC OCEAN
TASMAN SEA
GULF OF CARPENTARIA
GREAT AUSTRALIAN BIGHT
BASS STRAIT
NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
TASMANIA
BONAPARTE GULF BASIN
CANNING BASIN
CARNARVON BASIN
PERTH BASIN
ARCKARINGA BASIN
CARPENTARIA BASIN
LAURA BASIN
GALILEE BASIN
BOWEN BASIN
SURAT BASIN
CLARENCE-MORETON BASIN
SYDNEY BASIN
MURRAY BASIN
ST VINCENT BASIN
OAKLANDS BASIN
LATROBE VALLEY
TASMANIA BASIN
Collie
Lake Phillipson
Leigh Creek
Port Augusta
Anglesea
Yallourn-Morwell
Loy Yang
Fingal
Laura
ABBOTT POINT
Bowen
Collinsville
Newlands
Hail Creek
HAY POINT
Riverside
Goonyella
Isaac River
Peak Downs
Daunia
Blair Athol
German Creek
Saraji
Norwich Park
Gregory
Oaky Creek
Yarrabee
Blackwater
Leichhardt
Cook
Sth Blackwater
GLADSTONE
Callide
Moura-Kianga
Theodore
Taroom
Brigalow
Tarong
Millmerran
BRISBANE
West Moreton area
Boggabri
Gunnedah
Ulan
Singleton-Muswellbrook area
Warkworth area
South Maitland area
NEWCASTLE
Newcastle area
Lithgow-Wallerawang area
Clarence
Burragorang Valley area
Tahmoor area
Bargo
SYDNEY
South Coast area
PORT KEMBLA
Oaklands
Coorabin
COAL RESOURCES
Major black coal-bearing area with large economic resources
Black coal-bearing area with mainly sub-economic resources
Major brown coal-bearing area
Brown coal-bearing area with mainly sub-economic resources
COAL DEVELOPMENT
Coal Type
Mine or Area
Undeveloped
Being Developed
Operating
Black
Brown (lignite)
COAL TRANSPORT
Proposed
Under Construction
Operating
Railway
Road
Loader
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