Energy in Question

Report of a Working Party on the future sources of energy for Ireland

An Taisce 1979

ACKNOWLEDGEMENTS

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Foreword

1. Man has constantly sought to adapt the natural environment to his own use and benefit. In European terms Ireland has been a slow starter but is now changing faster than at any time in her history. The availability of energy in various forms is essential to effect change and to maintain and increase economic activity. It is important therefore that many people understand the issues involved and take part in the decision making process.

2. For those reasons and in response to the Government's declared intention of stimulating public debate in issuing its document "Energy-Ireland", An Taisce, the National Trust for Ireland, set up a broadly based Energy Study Group with wide terms of reference.

3. It is only in the very recent past that we have had to face an economic limitation in the availability of hydro-carbon fuels - with the consequent possibility of a reduction in available energy - if we do not plan ahead. It is perhaps not a bad thing that we have now to examine the assumption that steadily increasing energy usage is necessary to increase wealth and the general well-being of the country.

4. An Taisce is concerned with the possibility of nuclear fuel generation of electricity and has attempted to put this aspect in the broad context of energy generation and usage.

5. The availability of cheap sources of energy is fundamental to the generation of wealth and consequent economic well-being. It is probable that good conservation practices will only emerge in such an atmosphere - where we can afford time and money to consider long term advantages and avoid the expedient of short term gain and unnecessary environmental damage.

6. Energy is required to effect all physical environmental change. The issues are therefore not simply minimising pollution and ecological damage. We are hopeful that this report will contribute significantly to this important debate ; a debate from which, if properly conducted, will emerge a consensus opinion on the best road forward to deal with Ireland's future energy requirements.

Philip A.Mullally, B.E., C.Eng., M.I.C.E., M.I.E.I.,
Chairman of Council,
An Taisce - the National Trust for Ireland.

List of Members of The Energy Study Group of An Taisce.

Chairman: +* Mr.F.A.Julian, M.Inst.P., M.R.I. (Technologist)
Ex-Chief Experimental Officer Culham Laboratory, Research Group, U.K. Atomic Energy Authority. Formerly, Chief Experimental Officer, Nuclear Research Division, Atomic Weapons Research Establishment, Aldermaston.

Members: * Dr.D.Conlon, B.Sc., Ph.D.
Senior Executive, Dublin Gas Co., Former Chief Executive, An Taisce.

* Mr. M.J.G.Minch, B.Sc. Chairman
Minch, Norton & Co.Ltd. (Maltsters).

Dr.A.Sagarra, Ph.D. (Chemist) Ex-Lecturer in Fuel Technology, Chemical Engineering Department, University of Manchester (UMIST).

+* Ms.S.Scott, B.A., M.Litt.(Economist)
Economic and Social Research Institute.

+ Mr.B.Nolan, B.E., M.I.C.E., M.Inst.Pet.
(Industrialist) Managing Director, Irish Shell Ltd.

* Mrs.B.Sweetman-FitzGerald (Member of An Taisce Council) Ex member of Board of Electricity Supply Board.

Mr.S.Tinney, B.E.,B.Sc., M.I.E.E. (Engineer)
Director of Generation and Transmission, Electricity Supply Board.

Mr.J.Owen Lewis, B.Arch., M.Sc., M.R.I.A.I., M.R.I.B.A., M.C.I.B.S. (Architect), Lecturer in Architecture, University College Dublin.

Dr.T.C.O'Connor, M.Sc., Ph.D., F.R.Met.S.
(Physicist), Lecturer in Physics, University College Galway.

+* Dr.D.W.Jeffrey, B.Sc., M.A., Ph.D. (Ecologist)
Senior Lecturer in Biology, Director Environmental Sciences Unit, Trinity College Dublin.

Members: Mr.B.Dowling, M.Phil. (Economist)
Research officer, Economic and Social Research Institute.

* Mr.L.Clohessy, B.E. (Electrical Engineer)
Executive Secretary An Taisce.

Meetings Secretary:-

Mrs.M.Courtney.

* Signifies Member of An Taisce

\+ Signifies Member of Editorial Panel.

Editors' Note

The individual members on our Study Group feel strongly about the issues involved in the present energy debate. Discussions were carried out in a cool and reasonable atmosphere and a serious effort to separate fact from fiction was sustained throughout. We differ with "Energy-Ireland" and with each other on some facets but each with his own reservations supports the presentation of this report to An Taisce's Council and through it to the Minister for Industry, Commerce and Energy as an informed and thoughtful response to "Energy-Ireland".

The concept of energy is sophisticated and difficult to understand fully. None of us claims to have a deep philosophical knowledge of the nature of energy. But several of us have a better than average knowledge of modern methods of energy exploitation. We feel that a large majority of the general public do not really know what energy is; and so we strongly recommend the interested layman to the works by M.King Hubbert, and by J.T.McMullen, (Ref. 4.15 and 5.1) . Every voter should inform himself sufficiently to take part in the national energy debate and to make such decisions as will save him money by avoiding energy waste.

The energy debate is a continuing one; conclusions reached to-day are not permanent and indeed are likely to need amendment at frequent intervals. This report makes no claim to be the last word on the subject; it is just a contribution to the national energy debate, in which it will be difficult, even for the well informed to vote unemotionally.

The Editors: May 1979.

Chapter 1

Introduction & Summary

A glance at the list of participants in this study indicates that all of us have professional connections with some aspect of energy - as consumer or producer, technologist, architect, economist or ecologist. In making our contributions to this discussion of energy in Ireland we have made a number of general assumptions, sometimes tacitly, occasionally in the text. These concern the way of life in Ireland that all of us will pursue now and in the future.

We take it for granted that economic development will continue and that policies designed to increase G.N.P. and reduce levels of unemployment will be followed. We anticipate that improved quality of life in Ireland as measured by health, comfort, environmental quality and material standards will be the aspirations of most individuals. Energy use is connected with all of these things.

Whilst we recognise that membership of the E.E.C. brings national responsibilities and opportunities it must be remembered that several features of Ireland's geography and size render us unique in energy supply terms. (That we consume just 0.7% of all the primary energy in the E.E.C., we are detached from the European electrical grid and have the highest rate of population growth in the Community are but three significant facts).

Finally, we face up to the fact that on a global scale energy resources are close to an adverse balance between consumption and known reserves.

This is specially true of the petroleum fuels which are so convenient a source of heat, motive power and chemical feed stocks. Shortage will ultimately force us into re-considering fuel usage and it is better that we start to plan now rather than await passively.

Thus, our basic attitudes are not far removed from those adopted by government or the ultimate consumers of energy, the people of Ireland.

Sound economics must be the basis for prediction but it is pointed out that there are considerable difficulties in obtaining data and developing a sound mode of predictive analysis. In order to compete successfully in trade terms we must conform to European and other world norms of energy intensity. Our projections for 1990 indicate a band of total energy need ranging from 12 to 16 MTOE.

Conservation of energy is quantitatively of very great importance. Encouragement of investment in energy conservation must surely be the most important pillar of energy policy. We recommend an ambitious but achievable target of a 20% saving of energy for a given purpose by 1990. Such a policy should have general acceptance and bring economic, social and environmental benefits.

Possible changes in fuel sources and uses, some inevitable, some desirable, are indicated. It is likely that coal's share will increase in relation to oil as the main source of heat. Generation of electricity, entailing a high consumption of primary energy and long lead times for capital plant acquisition, must be given special consideration. We applaud the introduction of a dual fired 300 MW station.

Alternative sources of energy have a special place in Ireland's case. We are well placed for utilizing developments in biomass (1990) and wave energy (post 1990) and the existing research and development investment should be encouraged and extended.

Future discoveries of natural gas or oil could radically alter any current view of fuel balance.

Nuclear Power is a special case of an additional energy supply which could provide some 15% of all electricity in 1990 (or less than 3% of energy delivered to the user) and with the advantage of storage capacity for 3 years fuel. That this would provide cheaper electricity is, however, unproved and there are a number of unresolved technical problems in the nuclear fuel cycle. Accidents would present economic and health risks. We, therefore, recommend that An Taisce opposes the installation of a nuclear power plant for operation before 1990.

Environmental effects are associated with all fuel uses, and an increase in air pollution levels is seen as inevitable. This may give rise to potentially serious local situations unless appropriate plans are made. Nuclear energy cannot replace sufficient of the conventional sources of pollution and yet brings environment risks which are different from and additional to those already in existence.

<u>Options</u> are quantified by an example taken from the middle of the total energy trend for 1990. Electricity growth should be closely related to its special uses. Polluting fuels should be consumed by large scale users where there is benefit from economies of scale in pollution control. The required flexibility implies a preparedness to accept a variety of fuels into the system as prices and technologies alter.

Chapter 2

Forecasts & Economic Aspects

INTRODUCTION

"Ireland has just got to have the energy it needs for its increasing levels of population and industrial output". This remark has been heard again and again, yet it is rarely followed by any realistic appraisal of what these energy needs might be.

Energy-Ireland states on page 23:
"The best estimates available at present indicate that total energy consumption is likely to increase from 7.51 MTOE in 1977...to 18 MTOE by 1990".

These estimates accompany a growth in GNP from 1977 to 1990 of 100%. If, however, GNP were to display "low growth" at 70% then by 1990 energy demand will reach 15 MTOE, it says. If economic growth rates were higher and if "a number of energy-intensive industries such as smelters" were included, the energy demand would be far higher. In other words, the "best estimate" official forecasts assume a 'business as usual' setting, though accelerated, but with oil becoming increasingly scarce and expensive over "the next twenty years". (Energy-Ireland page 8).

How reasonable are these official forecasts, given the assumptions? This chapter shows that the forecasts are on the high side without even disputing the assumptions.

At the beginning of this chapter we look at some past history. In the light of this and of foreign experience we analyse the official forecasts and present a more realistic range, with suggestions for improving the forecasts.

IRELAND'S ENERGY CONSUMPTION SINCE 1950

We will describe energy consumption here in terms of final deliveries. Why 'final deliveries', instead of the more usual 'total energy demand' which includes all the energy required to make secondary fuels such as towns gas and electricity? The answer is that final deliveries are what people actually want and buy - they are the raison d'etre of the energy system. Also, expressing energy demand in terms of final deliveries gives an idea of the relative importance of the different fuels from the final consumers' angle.

During the twenty-seven years since 1950, final deliveries of energy have more than doubled as is shown in Figure 2.1. The trend displays three main phases: a static fluctuation from 1950 to 1958, a steep rise from 1958 to 1973, and another fluctuation after 1973. It will be useful to analyse each of these phases in turn with the help of Figure 2.2 giving the path of GDP since 1950, and the path of the real price of fuel, that is the Fuel and Light price index adjusted for inflation.

FIGURE 2.1.

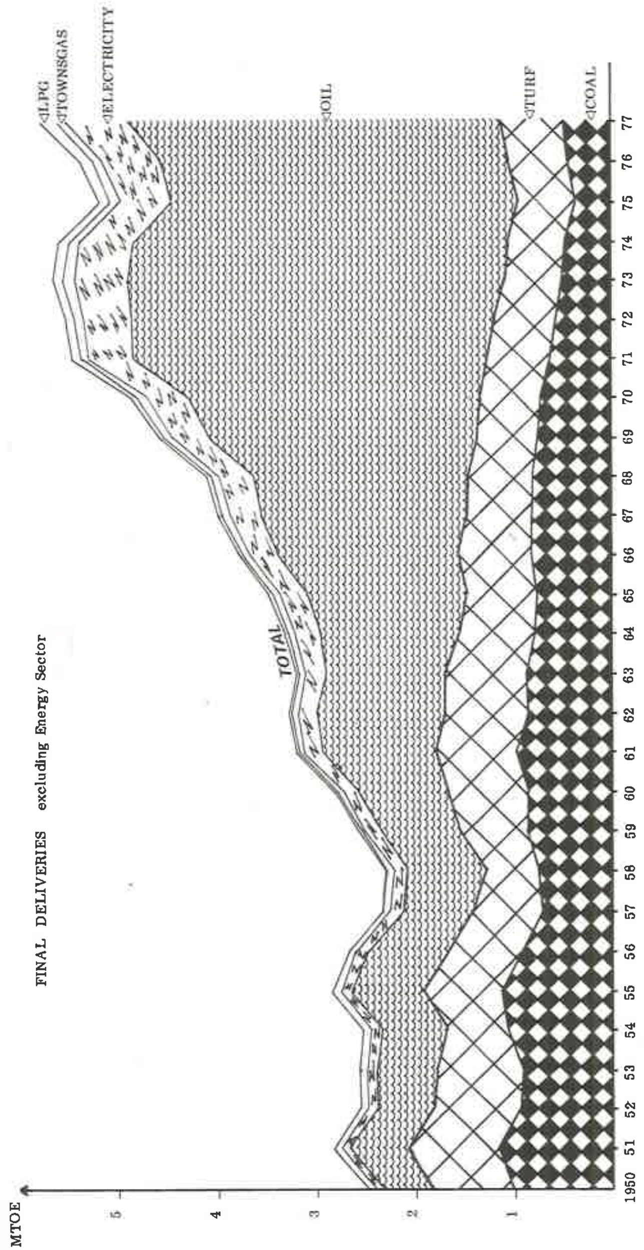
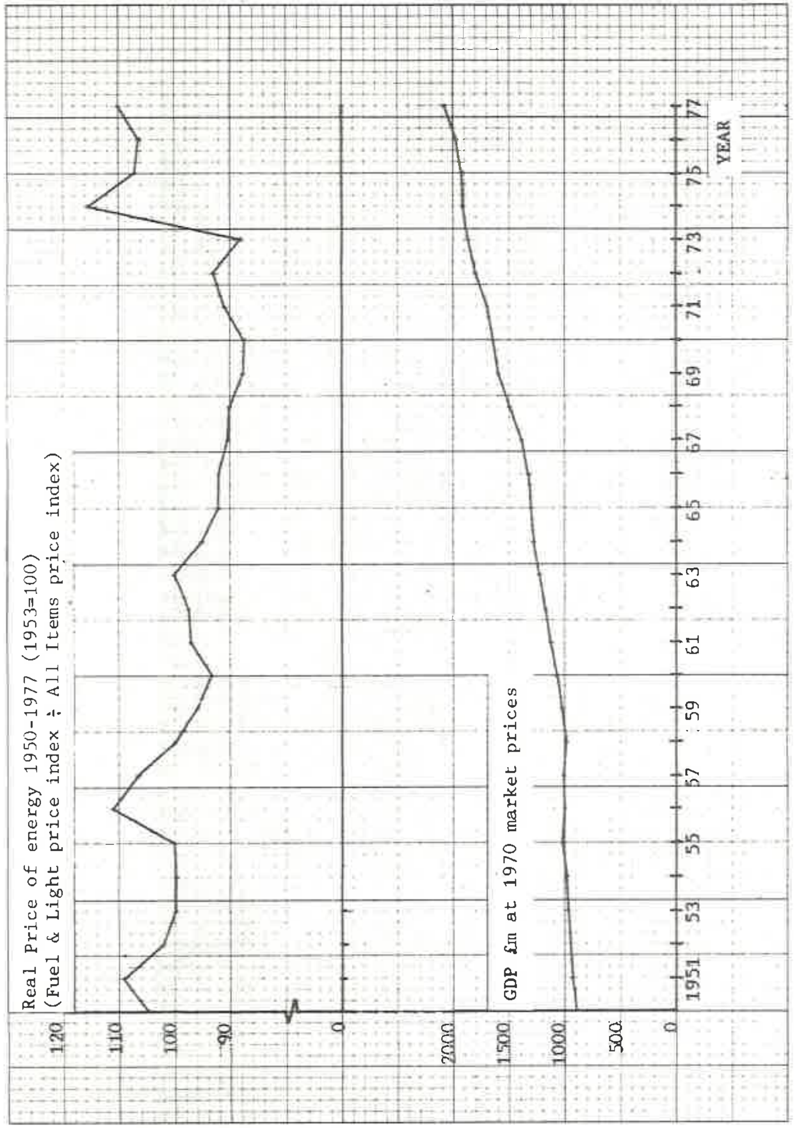


Figure 2.2.



It can be seen that energy growth more or less echoes that of GDP, as is to be expected, though only in the middle phase do final deliveries grow faster than GDP, overall. It is also consistent with the trend in prices, which similarly displays three phases in reverse image: a high phase, followed by a decline, followed by a high phase again. In other words, one can discern a logical relationship between final deliveries of fuels on the one hand and GDP and fuel price on the other. Though not the only factors influencing demand, GDP and price are important factors. The problem facing forecasters is already becoming apparent: we have evidence of what happened to energy demand when GDP growth was low and energy prices high and of what happened when GDP growth was high and energy prices declining. We have not so far had the combination: high GDP growth and high or rising energy prices, so past experience will be limited in its usefulness for forecasting.

INDIVIDUAL FUELS

An analysis of the individual fuel shares, that is, each fuel expressed as a proportion of total final deliveries, suggests that a reasonable degree of substitution between fuels can and does take place. Substitution occurs for a variety of reasons,including price. This applies not only to the prices of the fuels themselves but also to the price of labour, which has risen considerably in quantifiable and unquantifiable ways. On the one hand there is electricity, a labour saving fuel, and on the other there are the solid fuels, coal and turf, requiring a person to stoke and remove ash. Changes in labour costs will alter the relative attractiveness of different fuels.

This raises the next forecasting problem: in the light of this substitution between fuels and the unknown paths of prices in the future, how can one tell what proportion any individual fuel will represent in the future?

We next turn our attention to the official forecasts, which are expressed in terms of total primary energy. Total primary energy is all the energy required by the nation to provide the final deliveries which we have been discussing.

THE OFFICIAL ENERGY FORECASTS FOR 1990

As already mentioned, Energy-Ireland's best estimate of total primary energy demand in 1990, assuming a virtual doubling of GNP (2.1), is 18 MTOE compared with 7.51 MTOE in 1977. Also given are high and low growth (2.2) cases, tabulated here as follows:

TABLE 2.1. Official Projections of Energy Demand in 1990

	GNP growth (% from 1977)	Energy Demand (MTOE)
Low growth	71.36	15.0
Best Estimate	99.55	18.0
High Growth	147.80	24.0

The most noteworthy features are that:

1. The projections reflect past trends

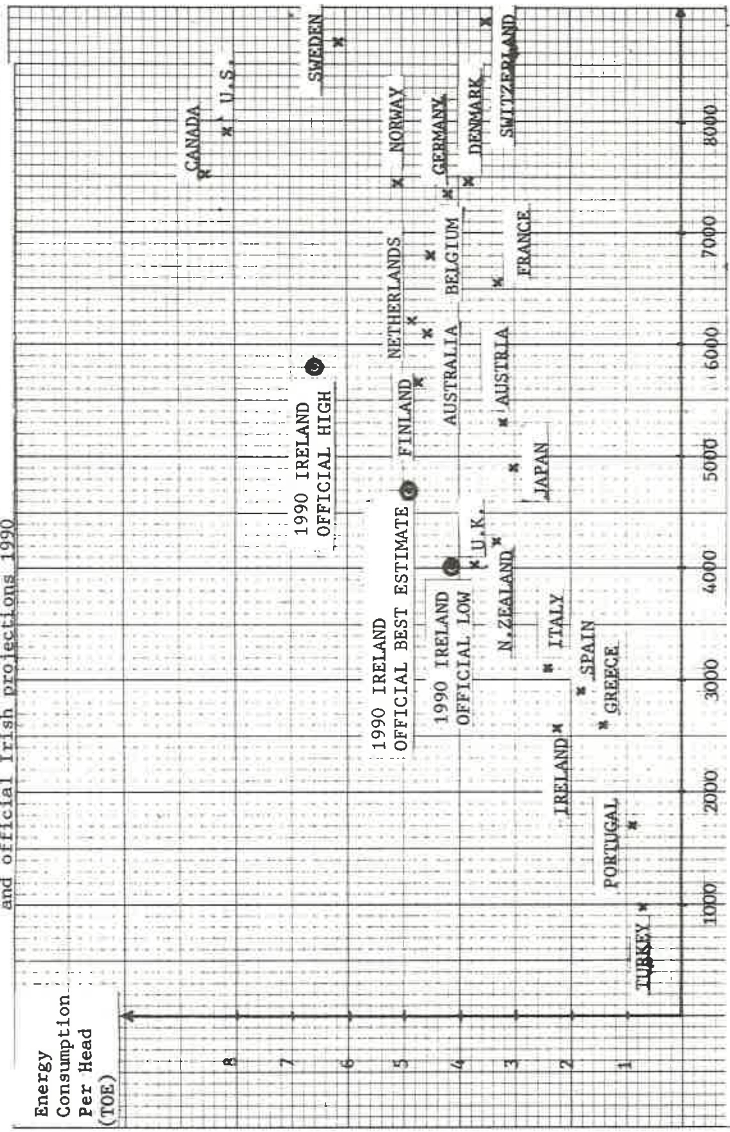
2. The forecasting chapter does not mention price having been taken into account at all.

3. The projections have a built-in assumption of increasing energy intensity over the period: that is the energy required per unit of GNP is rising (2.3).

We will discuss these aspects now: projecting past trends is fine, provided the trends continue. The trouble is that past trends don't always continue so it is preferable only to use them for projecting over a short period especially when significant changes, like price rises, have just occurred. That price, or the unknowns relating to price, are not mentioned in the forecasting chapter, is an extraordinary omission. If the price mechanism has vanished without trace, what explains our bombardment by energy literature such as this document? True, the effects of price rises are difficult to gauge exactly. The full effects of the 1973/74 price rise will not have worked themselves through yet owing to the long life of some energy using capital stock and to the long time required for the impetus to the development of new technology to play itself out. Consequently, there may be a natural tendency to underestimate price effects; not to mention them is a different matter.

To discuss the third point, on the assumed trends in energy intensity, we unfortunately have to resort to international comparisons - unfortunately, because such comparisons suffer from the fact that each country is unique in terms of climate, population density, lifestyle and so on and because the data is distorted by exchange rate fluctuations. At this stage however, there is no alternative (though we recommend one at a later stage). In Figure 2.3. overleaf, we have graphed the positions of 22 OECD countries in 1976, in terms of energy consumption per head on the vertical axis, and GNP per head on the horizontal axis. Superimposed on this graph are Energy-Ireland's low, best estimate and high energy forecasts. These forecasts are clearly above the other countries in 1976. For example.: the high forecast suggests Irish people will consume significantly more energy per head than people in France, Denmark, Germany, Belgium, Australia etc. before Irish people have reached these countries' per capita incomes. Similarly, the best estimate puts us at more energy intensive than New Zealand, Japan and Austria. Granted the problems raised by international comparisons, we should next ask: in which direction will the other countries be moving over the coming years; if one drew a trend line through the international plots, is there any shift in the trend line over time? The answer is that there is indeed a shift; downwards mainly, that is over the period 1970-1976. Even during 1963-73, a period of declining real energy prices, the Nine EEC countries combined showed no change in energy intensity (2.4). Furthermore, as shown in figure 3.1. in the following Chapter on conservation, eleven of these countries are planning to reduce their energy intensity and only Greece, Spain and New Zealand indicate a significant rise (2.5).

Figure 2.3 1976: Total energy consumption per head against GNP per head for OECD countries, and official Irish projections 1990



SOURCES: Energy/hd from OECD Observer March 1978
GNP/hd from World Development Report,1978, (World Bank Aug.1978).

To the extent that countries actually achieve their low energy targets, the official Irish forecasts will be left further out on a limb: a guarantee that Ireland's output will be non-competitive if real energy prices rise.

SUGGESTIONS FOR IMPROVING FORECASTS

Enough has been said to demonstrate that the whole energy forecasting relationship used by the Department is on the high side even if one accepts the GNP projections.

There are fortunately several approaches to forecasting. In particular, one might suggest a detailed analysis of the consuming sectors, especially industry. Industry appears to be treated as one entity and, as stated below (Ch3.note 3.7), the official forecast implies that 40% more energy per unit of industrial output is envisaged. This gives rise to an increase in energy demand of 7.91 MTOE or more than all the energy consumed in Ireland at present. It would be useful to see which individual industries are likely to absorb this increase. Agreed, while Ireland is industrialising, overall, output becomes less labour intensive and more capital intensive, and energy intensity rises. But this must be viewed in the light of foreign evidence for individual industries. In Germany, France and U.K. (2.6) for example, energy intensity in the majority of individual industries declined during 1960-1974, that is even during a period of energy price decline. This suggests that once an industry has "industrialised" its subsequent capital replacement is more energy efficient. Clearly an analysis in more detail is called for.

Finally, in order to forecast the breakdown by fuel, one must have information on what end-use fuels are put to. We have no firm information on this at present, and repeated calls have been made for an analysis backed up possibly by a survey of the big energy using industries. Having combined this information with an outline of the sort of industries which are likely to establish new plants here, and with a range of possible future relative fuel prices, one would be in a position to produce some well-founded estimates of fuel shares. Energy-Ireland's projection that the share of electricity in 1990 will reach 33½% of total energy appears to be based on the fast rise in electricity's share between 1970 to 1976 (2.7) and on the forecast for the EEC of 34.6%. Clearly more analysis is called for.

Where does this leave energy demand in 1990? Pending the execution of a sounder approach to forecasting suggested above, we should here at least try to give some reasonable range for energy demand in 1990. Let us see what figures we get from applying some very crude assumptions.

If the forecast increases in domestic product are not significantly more energy intensive, and if real energy prices do not rise and are not expected to rise, then overall energy intensity will tend to remain near its present level. Thus energy demand in 1990 would be: 15 MTOE for doubling of GNP or 12.8 MTOE for GNP rising 70%.

Now some domestic product might be more energy intensive, (2.8) but also energy prices might rise or be expected to rise. These two factors have an opposite effect on energy demand. Their net effect will depend on their relative strength, in particular, on

- what new industries establish here
- how fast energy prices will rise
- the strength of the price effect on demand, and its time-lag.

Without information on these items we don't feel we can justify taking a narrower range than 12 to 16 MTOE. This is using the same assumptions given in Energy-Ireland, including the assumptions that no significant new energy finds will be made and that there will be no introduction of a number of energy intensive industries.

References - Chapter 2.

2.1. Consistent with Economic Development for Full Employment 1978.

2.2. Details and assumptions are set out in Energy Forecasts 1978-1990, Dept. of Industry, Commerce and Energy, Dublin August 1978. GNP figures here are approximate owing to rounding in the official text.

2.3 Energy Forecasts 1978-1990 op.cit. page 8: "Average overall growth ratio...is likely to be 1.27". This ratio is assumed to decline, but as long as it is greater than unity, energy intensity is rising. (growth ratio = ratio of the percentage change in energy consumption to the percentage change in output, p 6 of Energy Forecasts 1978-1990. Op.cit.

2.4 1970-76 and 1963-73 growth rates for GDP and energy from Basic Statistics of the Community 1973-74 Table 13, Basic Statistics of the Community 1978, Table 16, and OECD Energy Balances 1974/76 p.26. If the energy growth rate exceeds that of GDP, then energy intensity of GDP has grown, and vice-versa. In Figure 2.3 the energy intensity of a country is shown by the slope of the line joining the origin to that country.

2.5. Out of the 17 countries covered and excluding Luxembourg. OECD Observer July 1978: What Progress on Energy?

2.6 Dept of Applied Economics, Univ. of Cambridge. Input-Output and Energy Demand models for the UK. Final Report, Table 6 gives U.K. trends.

2.7 Hardly surprising since the price of electricity rose slowly relative to that of other fuels. Also labour costs rose considerably in quantifiable and unquantifiable ways, and electricity is a labour saving fuel.

2.8 Incidentally, a smelter producing 100,000T Zinc per year would require about 0.09 MTOE.

Chapter 3

Conservation

"Most studies indicate that investments to achieve energy saving yield higher returns and have more positive effect on growth and employment than many of the supply expansion alternatives. This makes conservation, properly carried out, a cheap alternative to increased energy production.... Ireland has committed itself to pursue a vigorous and active energy conservation programme". These very positive statements at the beginning of the Conservation Chapter in Energy-Ireland, render the remainder of the chapter, indeed document, a virtual non-sequitur. Not only is the remainder of the chapter un-enthusiastic to say the least, but the latter part of the document recommends a rather costly "supply expansion alter-native".

However, woolly thinking on energy conservation is pretty widespread, and little wonder: on the one hand there are people claiming that energy conservation can yield substantial savings, (3.1) and on the other there are people roundly criticising conservation proposals as a serious misallocation of resources and an unnecessary lowering of the standard of living. (3.2). And in the middle there are the people who will be hit if changes are undertaken. The confusion arises from the word "saving". Does this mean saving energy? money? or among other things,both? If,as a result of some conserv-ation effort, people achieve energy savings but on balance no gain,financial or otherwise, then they will feel that their

effort has been unrewarded (unless they enjoy being virtuous). Some possible conservation measures sound suspiciously like this, rightly or wrongly. What traveller is going to wait, standing outside with no shelter, for an unknown length of time, a prerequisite of getting to a destination by some public transport, if a less uncomfortable method, in the form of a private car, is within his grasp? The saving in money or the freedom from parking worries do not outweigh the feelings of powerless uncertainty and discomfort caused on so many of our public transport routes.

The issues need clarification immediately. Conservation methods fall into two basic categories: they are either cost effective, or they are not, seen of course from the nation's point of view. Obviously, some cost effective measures are being adopted automatically as a result of the energy price rise, others need a time-lag until people's energy-using equipment requires replacement. Other methods are cost effective but are <u>not</u> being adopted owing to a variety of reasons. For example: until now builders were supplying houses with inadequate insulation, because people were willing to buy them. People were willing to buy them because they couldn't afford to pay more, or because they were not aware of the lifetime of fuel cost savings that could accrue to them. Similarly, not many tenants insulate their landlord's property if each party feels that the benefits will accrue to the other party.

These points are well summarised in a recent UK Department of Energy Green Paper on Energy Policy (3.3).

"there is ample evidence that the response of individual consumers to the price mechanism, even if reinforced by information and advice, will not in practice bring about all the energy conservation investment that is cost-effective by comparison with investment in energy production. Reference has already been made to the division of interest between the developer of a building and the subsequent occupier. Many industrial consumers, when appraising optional investment such as that in energy conservation, require pay-back periods as short as one year or 18 months, equivalent to an internal rate of return perhaps as high as 40 per cent in real terms, and reject investment opportunities with slightly longer pay-back periods even when loans are available to them at rates of interest well below 15 per cent in money terms (equivalent to a much lower real rate, taking account of inflation). These attitudes, which are not necessarily unreasonable from the point of view of the individual firm, having regard to limitations on management and investment resources, and to competing claims for investment, are not confined to the smaller and less energy intensive firms.

"There are also problems of timing. The prospect of higher prices and of energy scarcity 10 or 15 years hence provides only a weak stimulus to the individual to make early investment. His preferred course would be to delay investment until the price increase was imminent, or had actually occurred. But to raise the efficiency of energy use of the whole country is too vast a task to be completed in a few years".

Lack of incentive, in many cases lack of realistic alternative, ignorance, inertia, sectional interests, poverty, these are powerful forces which must be met with imaginative and firm action.

The Henry Report (3.4) gives a thorough inventory of potential conservation methods. These need sifting through, to isolate those which fall into the category discussed above: cost effective, from a national point of view, that is, using a discount rate, values and a pay back period which reflect the national interest rather than sectional interests. Where there are obstacles to their adoption, some careful analysis is needed to find ways of overcoming the obstacles. The sort of instruments to hand include incentives on the one hand; for example: tax reliefs, low interest loans, grants and so on, and sanctions on the other hand. A present example is the new requirement of certain insulation standards before a housing grant is received. A combination of carrot and stick might have the most impact as well as being the most feasible. For example, revenues received from, say, an extra tax on heating fuels or petrol could pay for the grants, subsidies and other incentives deemed necessary.

Finally, there are the conservation methods which are not cost-effective as far as one can tell at present. These methods will become worthwhile, as the price of energy increases and as the methods themselves improve - the latter tending to follow the former. Research on the methods relevant to the Irish context should be pursued at a realistic level.

SOME IMPORTANT CONSERVATION AREAS

The sectoral distribution of net energy consumption in Ireland in 1977 is shown below (3.5).

TABLE 3.1. Per cent of Total Energy Consumed by each Sector.

Domestic	33%
Industry	33%
Transport	22%
Commercial	12%

Consideration of the demand for energy in each sector will show that well over 40% and probably close to 50% of total energy consumption is related to buildings and building occupancy. The potential for conserving energy in buildings ought to be given due consideration. The available evidence would suggest that Irish buildings are, by international standards, wasteful in their use of energy; yet Energy-Ireland makes no reference to the potential for further savings from improved insulation and ventilation control, waste heat recovery, improved heating systems and better design of the built form.

Approximately 70% of the energy used in buildings and building services is used in the domestic sector. According to Minogue (3.6) the following measures have the most significant potential contribution to energy savings in existing housing.

	*
- Improved insulation	3%
- District heating with combined electricity generation	4%
- District heating without combined electricity generation	3%
- Improved heating appliance efficiencies	2.5%
- Heat Pumps	3.5%

* maximum potential saving as percentage of national primary energy consumption.

Allowance was made for a proportion of the savings theoretically achievable not materialising as energy savings but being taken up as improvement in comfort levels. Minogue also sees a significant potential for energy saving (possibly of the order of 3% of primary energy consumption) in buildings other than housing.

The new national building regulations minimum standards of thermal insulation will cover virtually all new housing, when they are enforced. The standards generally represent a significant improvement compared with recent Irish construction. However, while the new required standards for roofs and ground floors are satisfactory, the standards for external walls fall short of what we should be aiming at, and external walls form a significant part of a house. In addition, to improve the walls later on in the life of a house is relatively costly. We would prefer to see a rolling program of increasingly higher standards which enables builders and suppliers to phase in gradually but to increase their awareness of insulation aspects. Not only should this apply to the aspects just mentioned but to many other areas relating to energy use in houses. For example; we welcome the requirement that National Building Agency and local authority housing should have fireplaces built into them, but there are, in addition, numerous simple features which would enhance the efficiency of fuel use. Again, these features, such as underfloor ventilation, back boilers and throat restrictors, in the case of the fireplace, are relatively costly to install later in the life of the house.

As for existing houses with poor insulation, which form the vast bulk of the housing stock, we would like to see the introduction of schemes to encourage local authorities to improve the insulation levels, as part of an employment creation programme. We would also welcome the introduction of insulation grants with an added allowance for old age pensioners or people on supplementary benefits. There is no point in introducing a scheme which still leaves the less well-off with no choice but to heat the sky.

In the case of commercial buildings we notice that architects are still designing glass boxes leading to heavy fuel requirements to combat the heat loss in winter and excessive heat gain in summer. A reduction in glazing along with other minor changes, such as sensible light-switching layout, would bring significant improvements in fuel use.

Industry is of particular importance in the Irish context. Energy-Ireland predicts a 40% rise in the energy intensity of Irish industry (3.7) over the period 1977-1990, and also states:

> 'A good deal of the industrial plant in use in Ireland is new and generally quite efficient, with consequently less scope for improvement'.

Meanwhile, speakers from the Institute for Industrial Research and Standards Industrial Energy Section have, on a number of public occasions, emphasised the potential for energy conservation in industry. A recent report from the UK Department of Industry (3.8) has pointed to the very substantial savings which may be obtained. Though it is necessary to consider

each type of industry on its own because of the diverse circumstances that exist, measures related to space heating and general factory services have general applicability. In non-energy intensive industries a large proportion of energy purchased is used for space heating so that better thermal insulation and reduction of losses through loading bays etc. are of special importance. Pay-back periods for the insulation of existing buildings are about 4 to 5 years at current fuel prices; most other measures, the UK study found, had pay-back periods significantly less than three years. The introduction of new and more energy-efficient processes offers greater scope for conservation in the long term.

These measures may generally be seen as technical/economic responses in that they seek to improve efficiency or reduce waste as a consequence of increased price. Economic mechanisms considered in isolation may fail as mentioned earlier - who would have expected that houses would be built in 1978 to a thermal standard practically as poor as any Irish houses were ever built to in this century? As mentioned above, there is a divergence of interest between the developer trying to minimise capital cost and the user who will have to pay the fuel bill.

In the area of large-scale energy conversion and transmission the co-generation of district heat with electricity deserves particular mention. The Henry report estimated a saving of 19% of total space-heating energy (after the implementation of other conservation methods) if half of existing urban housing used district heating, one third of the theoretical savings going to improve comfort levels. While the feasibility of applying district heat to existing housing may be called into question, between now and 1990 at least $\frac{1}{3}$ million houses are likely to be built (3.9) i.e. more than 30% increase on the current stock. Also between now and 1990 electricity generating capacity is to be doubled with the addition of more than 2500 MW. With this sort of potential combined with substantial experience of those methods in use elsewhere, it is not clear how Energy-Ireland can round off with: "It is not certain at this stage that the district heating concept is necessarily suitable for general application in Ireland".

TRANSPORT

Traffic congestion in the conurbations is causing problems of:

- carbon monoxide emissions (a matter of concern to the Dept. of Health).
- wasted time (responsibility of Dept.of Transport & Tourism).
- damage to building fabric (Dept.of Environment).
- detriment to life of communities (impinges on Depts. of Health and Social Welfare as well as Environment).

Then considering energy, we find that for the private car the energy consumption per passenger km is in the region of four times that for a diesel bus (3.6). The case for a totally new, upgraded, approach to public transport is overwhelming.

At present a sizeable section of the population cannot drive private cars for reasons of finance, health or age, and have to rely on public transport, the bicycle or walking. Public transport, however, is rendered less reliable as the number of private cars increases, which in turn is caused by the unreliability of public transport. To many people, driving a car is a troublesome responsibility (at least for everyday commuting) but they are forced into making a bad situation worse. Taxation of petrol, mentioned in Energy-Ireland as having an effect on conservation, more accurately simply raises the cost of living, since for so many people public transport at the current level of provision (waiting time, lack of shelters, etc.) is not a realistic alternative. For many other people who have no choice but public transport, it is something they put up with. A major upgrading of public transport is needed, as well as of bicycle paths, and maintenance and lighting of pavements.

On public transport on rural routes, the fare should reflect the marginal cost of the route; and where uneconomic routes are maintained because they are felt to be justified on social grounds, then the subsidy for these routes should come from a social or regional fund, not from other public transport users.

Naturally, we would also endorse encouragement of technical options such as good vehicle maintenance - ignition, carburation, smoother driving behaviour and smaller cars.

Finally, there is the question of international comparisons of the efficiency with which different countries use their energy supplies. Energy-Ireland states that comparisons are made "in terms of the number of additional units of energy used for each increment of increased GDP. The International Energy Agency has been publishing such figures for its 19 member countries and in these returns Ireland ranks approximately midways.... Ireland can thus claim to be about average in the efficiency of its energy use...". It is not clear how the rate of change of energy consumption with respect to GDP can be equated with the output per unit of energy. That said, there can't be much cause for self-congratulation if Ireland is only 'better' than Luxembourg (an exceptional case owing to its concentration of heavy industry), Canada, the US, and the U.K. (3.11) (the last four having large or very large indigenous energy supplies). This is illustrated in Table 3.2 below, which ranks OECD countries in order of their efficiency of energy use (GDP per unit of energy).

What explains Ireland being down there? We have no extremes of temperature, no heavy industry, low car ownership per head of population, to name but a few characteristics. True, we have low population density and spreadout cities and the exchange rate might work against us, but these cannot be the sole culprits. One might seek an explanation in our low GDP: we have such a low GDP, therefore GDP per unit of energy is very small - or, perhaps one should reverse the argument: our GDP is so small because our energy consumption (among other things) is so big. Perhaps that is taking it too far, but whatever the cause or its direction there is clearly no room for complacency.

TABLE 3.2: Energy Efficiency in OECD Countries in 1976 (measured in GDP US $ per tonne of oil equivalent).

Country	Energy Efficiency
Switzerland	2536
Denmark	1986
France	1949
Portugal	1852
W.Germany	1712
Austria	1679
Greece	1645
Japan	1589
Spain	1588
Norway	1505
EEC	1504
Sweden	1476
Belgium	1474
Australia	1441
Turkey	1396
Netherlands	1373
Iceland	1318
Italy	1252
Finland	1245
New Zealand	1225
Ireland	1101 ←
U.K.	1061
Canada	990
US	976
Luxembourg	546

Source: GDP: 1976 at current market prices and exchange rates: million US $, OECD Observer March 1978.

Energy: 1976 Total Energy Requirements MTOE, Energy Balances of OECD Countries 1974/1976. Paris 1978.

CONCLUSIONS AND RECOMMENDATIONS

If we do not improve the efficiency of our energy use we will ultimately reduce our rate of economic growth, the more so if energy prices rise a lot. Irish output will become progressively less competitive since other countries are paying much more attention to the need for energy efficiency. Figure 3.1. at the end of this chapter shows proposed energy intensity for 17 countries in 1990. (Intensity = TOE per(1970) US $ 1000 of GDP = 1 ÷ efficiency)

Rigorous analysis is required to isolate those conservation methods which are cost effective in national terms and to get the measure of the obstacles to the implementation.

Serious efforts must be made to establish relevant incentives and sanctions to promote their implementation.

The most obvious immediate area for application is related to energy use in buildings.

Measures will meet with most success if people can see that the losses they have incurred through sanctions (e.g. taxes on energy) are being more than adequately recouped by the incentives (e.g. tax relief, subsidies on insulation), or indeed in the case of transport, by the provision of a level of public transport which makes it a realistic alternative to the private car.

Since economic resources will have to be diverted to employment creation if our job-targets are to be met, how much more useful is such a diversion if it can also conserve energy.

House insulation programmes, which are highly suited to job creation, should be undertaken.

Without adequate information on energy end-use the full scope of conservation can only be guessed at. A survey of energy end-use has been repeatedly suggested and called for.

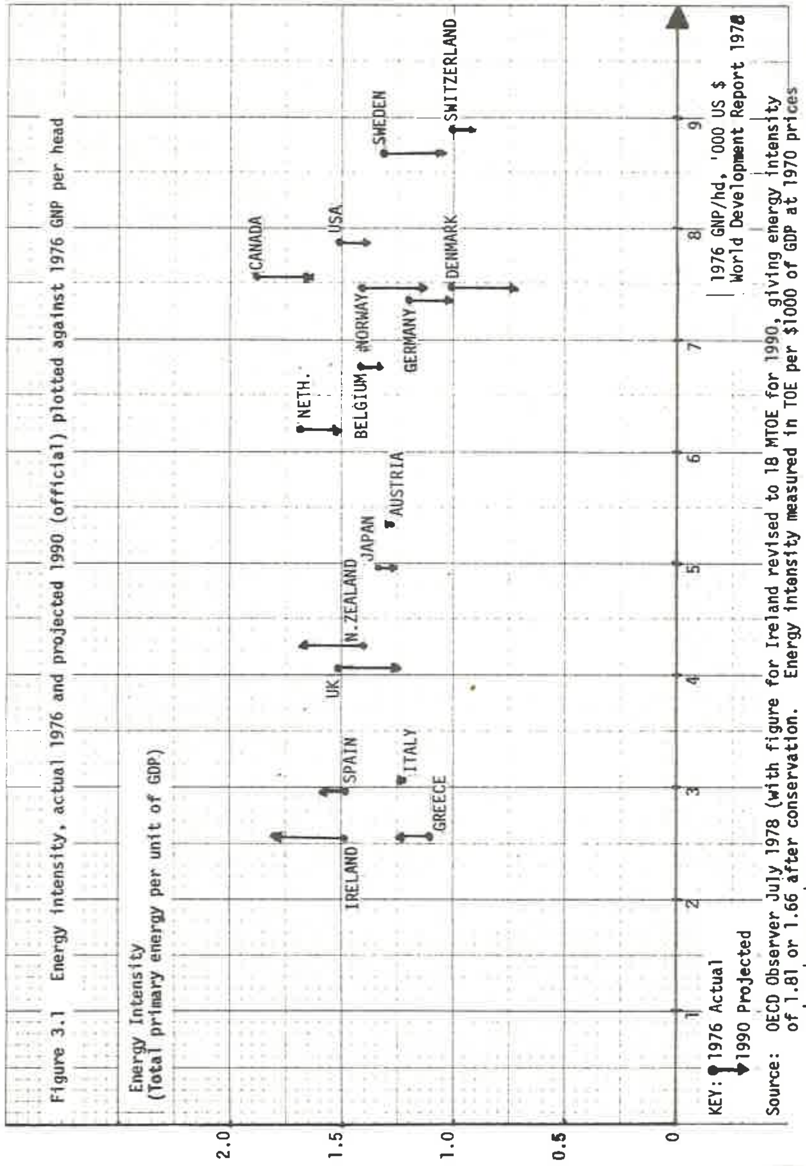


Figure 3.1 Energy intensity, actual 1976 and projected 1990 (official) plotted against 1976 GNP per head

Source: OECD Observer July 1978 (with figure for Ireland revised to 18 MTOE for 1990, giving energy intensity of 1.81 or 1.66 after conservation. Energy intensity measured in TOE per $1000 of GDP at 1970 prices and exchange rates.

References - Chapter 3

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Chapter 4

Energy Sources & Uses

INTRODUCTION

It is assumed that,as we proceed into the future,the mix of fuels consumed in the World, in Europe and in Ireland will gradually change. In the past this has happened in a virtually laissez faire manner, driven mainly by the rate at which technological developments have become economically viable. Fuel availability is now a very important variable, and in future it will be worthwhile making optimum use of diverse resources by planning around their best uses.

Our indigenous (conventional) resources will remain unknown until the results of a decade of exploration are available. Energy-Ireland's figure of 2.04 MTOE in 1990 is clearly the minimum. The future prices of imported energies are also unknown to some extent. This uncertainty calls for great flexibility of the kind afforded by having small incremental units in the fuel sectors which might stand to lose, e.g.in U.K., overcapacity in electricity generation resulted largely from discovery of natural gas. As long as Ireland is "at risk" of discovering natural gas etc., the ESB will need to be careful when embarking on large projects with long lead-times. The extent to which we should substitute indigenous for imported fuels now also needs to be watched in view of the even higher price we might have to pay for imports in the longer term.

IMPORTED SOURCES

Oil and coal will continue to supply the major proportion of our energy in 1990 as now,unless additional finds of natural gas are made. It is widely predicted e.g. 4.1,4.2. that because of its greater natural abundance, and for strategic reasons, coal use will increase substantially.

Western Europe has coal and gas, but is the world's largest oil importer. The Middle -East, North and West Africa are large producers of oil and the world's largest exporting regions. A recent breakdown of the EEC position in 1976 and a forecast for 1985 shows the extent of this dependency. (4.13)

E.E.C. ENERGY	Units Million Tonnes Oil Equivalent			
	1976		1985	
	Production	Imports	Production	Imports
Solid Fuels	184	23	184	36
Oil	22	520	110 - 160	490 - 555
Natural Gas	144	12	153 - 158	79
Hydro/Geothermal	25	1	31	4
Nuclear	21	-	140	-
	396	556	608 - 673	609 - 674
	42%	58%	47% - 53%	47% - 53%

Within the Community significant changes will occur in the dependency of individual countries. England is forecast to improve from a 1975 level of 51% reliance on imported energy to complete self sufficiency by 1985. The Netherlands shows a reverse trend increasing from 6% to 35%. Ireland's dependency is forecast to decline from 82% to 77% due mainly to the introduction of natural gas from Kinsale Field.

OIL

The pattern of international trade in energy - as in any other international trade - depends on the availability of the commodity for export, and the existence of a market for it. Oil, because of its availability, price, convenience, ease of transportation, the extent to which it can substitute for other forms of energy and its unique quality for use as a fuel in transportation has become the largest commodity in world trade. It can be confidently predicted that oil will retain its dominant position in the years ahead. In considering probable sources of future supplies for Europe (incl.Ireland), estimates are available from the "Published Proved" reserves at the end of 1977. (4.12)

World "Published Proved" Reserves 1977.

Units Million Tonnes

	Reserves	1977 Production	1977 Consumption	Surplus (Deficiency)
Total Nth.America	5600	541	953	(412)
Latin America	5700	239	192	47
W.Europe	3700	70	697	(627)
Mid.East	49700	1104	79	1025
Africa	7900	306	57	249
Far East	2700	140	426	(286)
World excl.USSR, E.Europe & China	75300	2404	2404	

Oil prices since the sixfold increase in 1973/1974 have not risen in line with the increased costs of replacing tankers refineries etc.required to bring oil from source to consumer. Following the '73 crisis, world economic growth faltered. A substantial crude oil surplus position resulted. World refining capacity greatly exceeded required capacity (particularly, in Western Europe) and a huge surplus of tankers existed. That position has continued for nearly 5 years and caused such competition that product prices have even failed to cover marginal supply costs in some periods. The economic logic of conservation which should prevail and encourage public and private investment in energy saving has been inhibited.

Prices can be expected to rise sharply in the next few years, probably triggered by producer countries'dissatisfaction with current levels of oil revenues. In some cases these are presently insufficient to fund planned expenditure on industrialisation and military programmes. Other recent actions by producer countries include major construction of new source refineries for product export (rather than Crude Oil), imposition of ceilings on crude production levels and controls on the ratio of "Light" to "Heavy" crude oil produced. Such actions may also contribute to future "spot" shortages and associated sharp price rises.

COAL

World resources of recoverable coal greatly exceed those of oil. Reserves are widespread but production has been mainly confined to the industrial nations of the Northern hemisphere.

Coal has major disadvantages compared to oil and gas, it is more expensive to produce, less convenient to handle and transport, and suffers from social and environmental drawbacks. Free World production has increased by approx. 0.7% p.a. in the 10 year period 1967-1977, but this increase required the imposition of taxes and import controls on imported oil in many coal producing countries to maintain production levels.

In terms of world energy reserves, coal is far ahead of other forms (4.14)

Coal	69%
Oil	15%
Natural Gas	9%
Uranium	7%
	100%

Coal, therefore, has the potential to contribute substantially to future energy supplies and also to provide the time required for future development work to make renewable sources economic. The location of coal deposits are widespread and offer improved security of supply through reducing dependence on the politically sensitive Mid East. (4.14)

USA	29.6% of reserves
USSR	17.3
China	15.6
Western Europe	12.9
Eastern Europe	7.2
Other	17.4

The W.A.E.S. indicated that world coal production could reach three times present level by the year 2000 with 1.8 billion tonnes,56% mined in the USA. However, in these studies potential supply greatly exceeded demand even taking account of conversion of electricity plants from oil and gas to coal, where possible. Coal imports to N.W.Europe are currently competitive with oil imports and should become increasingly so as oil prices rise.

IMPORTED NATURAL GAS

Natural Gas is a clean and convenient fuel with unique characteristics as a fuel and raw material. Known world reserves are large - roughly equivalent in energy terms to about 60% of proven oil reserves. This figure is high when one considers that because of the cost of transportation of LNG much greater effort has gone into the search for oil than for gas. Exploration for gas as a prime objective is still largely concentrated in and around the major consuming areas of the U.S.A., USSR and Western Europe (80% of total consumption). It is therefore considered that future energy from gas may equal or exceed that available from oil.

The basic problem with gas is that,unlike coal or oil, it is expensive to transport across the sea. On land,transport by pipeline is an efficient means of energy transmission. Bunyan (4.3) states that costs per unit of energy transmitted are seven times lower than electricity, with the capacity of transmission ten times greater.

There are technical, political and geographical limits to the expansion of international trade by pipeline. Where reserves are separated from markets by long sea distances, shipment in liquified form is the only currently proven method of transport. Two possibilities exist, low temperature liquefaction, or conversion to methanol. The former requires specially constructed tankers with low temperature insulation built in. Shipping methanol does not require insulated tankers, but there is an overall energy loss of 40% for methanol compared to 25% for liquefied natural gas. Currently trade in L.N.G. is still in its infancy and in 1977 amounted to only 2% of total natural gas supply. Gas has historically been regarded as a cheap fuel or even a waste product frequently associated with oil production and flared off through lack of demand at the well head.

In spite of 1973, attitudes to natural gas pricing still reflect this "cheap" image and are still below the price of imported low sulphur fuel oil. Given this economic climate,gas prices have not risen to oil equivalent levels, or gained the premium over fuel oil which it deserves. As this situation changes, one can anticipate a major expansion in trade in gas. A rise in gas prices will increase the scope for major capital investment in distribution systems which will allow wider use of clean burning low pollutant energy. This will also progressively discourage base load industrial users that gain no specific advantages from the use of gas. Imported natural gas is unlikely to play a significant role in meeting energy needs in this country, but recent finds in the eastern Irish sea or an interconnection via Northern Ireland to the Scottish sources could alter this view. An all Ireland market would make the cost of an undersea pipeline more viable.

ELECTRICITY

Electricity generation consumes some 30 per cent of our total primary energy to produce for the user about 10 per cent of energy supply. The industrialised world has accepted the trade-off between fundamental losses of energy for the enormous convenience of a readily controllable source of power and light, with the now irreplaceable electronic uses as an addition.
Electricity generation is also capital intensive and operates within a special market setting. For each extra 1 kw electric fire (cost £10) bought and used at peak time, the E.S.B. needs to expend some £400 on equipment.

It is true that electricity's share of the total energy market has been steadily growing, a fact which reflects the attractions which this energy form has for all market sectors, domestic, commercial and industrial alike. Electricity suffers from one disadvantage which may prove to be major in a time when disruption of supplies due to industrial action is becoming a frequent occurrence. It cannot be stored. In this it suffers by comparison with other energy forms. The consumer of oil, coal or peat can, to some extent, shield himself against the effects of strikes by storing a few weeks' (or month's if he is wealthy enough) supply. The electricity consumer cannot do this. He is, therefore, at considerably greater risk from industrial action or technical problems which threaten electricity supplies.
It is for this reason also that district heating schemes which involve combined heat and electric power production warrant close scrutiny. Such schemes are attractive in that they bring about an overall saving in energy consumption. But they also hand over to the electricity utility a further large slice of the energy market, thereby increasing the community's dependence on a centralised source.

In developing the electricity supply we welcome the dual fired 300 MW station to be built on the Clare shore of the Shannon. It may well be the prototype for incremental units that combine appropriate scale, economy and flexibility. These attributes contrast with those of a nuclear power station, at least for a decade to come. In the interests of conservation of primary energy and the consumer's freedom to choose, the E.S.B.'s terms of reference should be up-dated. New terms of reference should compel electricity production to fall in with a national energy strategy and prevent unjustified growth in electricity.

INDIGENOUS SOURCES

Adequate stock has been taken of hydroelectric, native coal and turf resources, continuous re-evaluation of them should be made as plant needs to be replaced, and changes in imported or additional sources occur. The use of natural gas in electricity generation is open to question, except for minor peak lopping. There is a good case for using townsgas rather than electricity for lopping peaks, caused by sudden demand for heat.(Booth.4.4).

Although the ESB is to be congratulated on the marked improvements it has brought about in the efficiency with which it converts peat into electricity it may be questioned whether the still rather low efficiency peat-fired stations represent the optimum use of this valuable native fuel. Obvious alternatives are as a chemical feedstock, for gas manufacture or as a source of domestic heating in conjunction with an efficiently designed stove. The last two might be seen in association with the likely introduction of more coal into our fuel mix.

RENEWABLE RESOURCES AND NEW TECHNIQUES

A number of factors combine to favour Ireland in the exploitation of renewable energy sources. The island has a temperate climate, without serious extremes of temperature. Many of the sources lend themselves to decentralised uses, so that our (by European standards) relatively low density of population is advantageous. We have some of the best sites in Europe for windpower, and some of the best conditions in the world for wave energy. A National Science Council report has pointed out that the ratio of solar energy availability to primary energy demand is higher in Ireland than in any other EEC country - two to three times as high as that for France or Italy, about ten times that of Germany and the UK, and sixteen to seventeen times that of Belgium and the Netherlands. "It follows that certain solar energy applications should have greater impact in Ireland than in any other EEC country". (4.5).

Ireland should be playing a leading role in global terms in harnessing some of these indigenous resources to useful purposes, given our particularly favoured circumstances. Our participation in international programmes brings us considerable benefits through sharing the cost of research and thus enabling the resources which we have to devote to energy R & D to go further, and because the pooling of expertise may enable work to proceed more quickly to the stage of commercialisation. However, such participation inevitably involves an element of compromise between the participants, and Irish priorities are very different from those of, say, Germany, USA, Japan. Such programmes must be regarded as adjuncts to, but not as replacements for, direct Irish efforts primarily oriented towards domestic requirements.

The average percentage of national research budgets allocated to energy in 1976 by the nine member countries of the EEC was 12.6%; Ireland's allocation was the lowest at 0.9% (4.6).

PRE-1990 APPLICATIONS

Solar Energy

Analysis of the characteristics of the demand for energy suggests that the greater part of domestic energy consumption and a lesser proportion (though still more than half) of industrial and commercial consumption is used to provide low grade heat at temperatures less than 100°C. The technical feasibility of utilising solar energy for thermal applications is essentially proven and the main task now is one of development. In countries where significant resources have been committed the technology is already at the commercialisation stage.

Wind Energy

There is a correlation between the average diurnal and annual patterns of wind energy availability and periods of peak electricity demand. Energy-Ireland suggests that the most serious handicap to the practical development of wind power is its intermittency. In a recent study (4.7) Prof.B.Sorenson claimed that up to 25% of the average Irish electrical load could be supplied by wind generators acting in a fuel saving mode without storage; the fraction of the total load covered could

be increased if storage were included in the system. Elsewhere (4.8) Sorenson has stated that the addition of 10 to 20 hours of storage in a wind system makes that supply as dependable as one large nuclear plant operating at a 70% capacity factor. Since storage is already considered to be useful in the grid (vide Turlough Hill) it need not necessarily be thought of as an added burden due to the use of wind power. The island communities along the Atlantic coast would be ideal testing grounds for equipment and for storage and distribution.

Biomass

Energy crops are an exciting possibility for application in Ireland, and one in which applied research is already underway. The use of short rotation forestry on marginal land or cutover peat could provide a variety of energy forms renewably and at a cost close to that of petroleum. (4.9.). There are many technical problems to be solved in the fields of operations research, forestry, agricultural engineering and energy engineering, but they are being addressed with vigour in Europe and the U.S.A. It is feasible that a contribution could be available pre-1990.

POST-1990 APPLICATIONS

Wave Energy

In quantitative terms the potential for an electrical generating system based on wave energy is very great. The engineering problems are considerable but possibly no greater than those tackled in exploiting North Sea oil. The prize is substantial and we would urge the active promotion of international activity in building and testing of devices. Steps should be taken to gather information on Irish conditions.

Photovoltaic and Photothermal.

This is a field where a breakthrough derived from the more academic sides of chemistry and physics could have a radical effect. Research will proceed apace in the major commercial laboratories, but work of individual scientists in this country should be supported.

SOME RENEWABLE SOURCES QUANTIFIED

The following might contribute in the order of 1 MTOE/yr. according to current information.

a) Products of a short rotation forestry programme in 1990 started in 1980 and continuing to plant 10,000 acres a year (4.9).

b) Domestic solar systems providing 20% of domestic heating (6% of total primary energy) (4.10).

c) 10 km of Salter system wave energy devices (4.11).

At the present time of development, estimated costs of alternatives range from less than 1.5 times (Biomass) to more than 20 times (Wave energy) greater than conventional fuels, and these factors will become smaller, especially as conventional fuel prices rise. One MTOE of renewable resources is equivalent to 6.6% of 15 MTOE in 1990. This does make Energy-Ireland's 0.6% contribution from renewable resources look defeatist.

At least 1 MTOE of indigenous renewables seems a feasible if ambitious target, and would reduce our level of dependence to below 80%. A target for the year 2,000 could be in the order of 10 MTOE (5 biomass + various system).

(compare 1 650 MW nuclear power station = 0.8 MTOE).

ENERGY USES

Because of the present low level of energy self sufficiency, it is obvious that industrial development should entail a low energy input per unit of G.D.P., labour or other natural resources. A sector which should be favoured is food processing, as a downstream consequence of intensified agriculture and fishing. Textile and pharmaceutical manufacturing, which are dependent on water and air quality and tourism, which is obviously environment dependent, must continue to flourish.

There are already signs that energy utilization is being well tailored to the needs of industrial development. Perhaps the biggest is the allocation of Kinsale natural gas to manufacture of urea for fertilizer. Natural gas is very suitable for use in ceramics manufacture and crystal glass making. In food processing the combined heat and power plants already installed are an example of appropriate source - need matching combined with high efficiency energy utilization.

In transport, a welcome innovation would be the electrification of the Dublin rail system. Increased efficiency of use at no greater primary energy cost could lead in turn to reducing private car mileage. The environmental benefits that could potentially accrue are obvious.

In the domestic and commercial sector, where low grade heat is the most important requirement, changes could include the more widespread use of solar panels, heat pumps, district heating and coalfired systems. These are all areas in which national research and development is appropriate and which complements efforts in energy conservation. The activities of manufacturing companies specialising in work at this scale should be encouraged, as the potential for export is very great. Wherever substantial quantities of heat are being dispersed from industry or electrical generation, the feasibility of using it should be examined routinely.

In general, there is no real reason for the percentage of electricity in the mix of sources finally consumed to change markedly. The projected alteration, in terms of primary energy used for generation, from a little less than 30% now, to 33% in 1990 is considered not un-acceptable.

TABLE 4.1. overleaf shows the range of uses and possible substitution between fuels, and grades the appropriateness of each fuel in each use.

TABLE 4.1.

USES AND DEGREE OF SUBSTITUTION OF ENERGY SOURCES

	Current						Additional
	Oil	Coal	Turf	N.Gas	Electric	Hydro	
Domestic heating	..	..	..	..	.		Biomass, solar
Industrial heat	..	..		..			
Traction	..			.	.		
Lighting					..		
Control					..		
Tool Power					..		
Chemical energy	..	..		..	.		
Electrical generating	..	..	..	.		..	Nuclear, wave*
Gas Manufacture	..	..	.				Biomass
Oil Manufacture		.					Biomass
Storage	..	..	..	.		.	Nuclear, biomass

* Also wind and photoelectric.
.. Appropriate and widely used match.
. Used or possible.

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Chapter 5

Nuclear Energy

INTRODUCTION

Since nuclear energy is essentially an "alternative" source for Ireland, we start by explaining some salient features enlarged on in refs. 5.1 - 5.4. There are two distinct processes for the exploitation of nuclear energy, fission and fusion. The former involves the splitting of heavy atomic nuclei and the latter is the fusing together of light atomic nuclei. Fusion has been the subject of co-operative international research for about 20 years now but it has proved to be a very intractable problem and a commercial fusion reactor is not expected to emerge until well into the next century; so we need not consider it here. The former process, fission, has however been successfully exploited for the past 30 years and commercial fission reactors have been operating throughout the world for 25 years. The technology developed rapidly in U.S.S.R., U.K., U.S.A. and France soon after the first U.N. Geneva Conference on The Peaceful Uses of Atomic Energy in 1955. Several types of fission reactor have been developed, each with its own set of technical advantages. It is as well for the layman to know this so that confusion does not arise due to picking up scraps of information relevant to only one type of reactor and then attributing them to all reactors.

PRINCIPLE

In present day commercial nuclear power stations the heat produced from a nuclear reaction is used to provide steam which then drives a turbine and so produces electricity. The nuclear reaction involves the fission of uranium atoms in the reactor core. The fraction of fissile uranium in the core is small and a very precise geometric assembly of fuel and moderator is required. The nuclear reaction is maintained by neutrons. These are produced by the fission process and they in turn can induce further fissions. To do this in a core with a small fraction of fissile material they must be slowed down by a moderator. The moderator materials are either graphite or a special form of water known as Heavy Water or ordinary water (Light Water). In the graphite reactors a gas is used as a coolant to carry the heat away. In the water reactors the water is used as both coolant and moderator. The core is so designed that over-heating of either moderator or fuel automatically terminates the fission reaction. It is for this reason that a nuclear reactor cannot explode like an atom bomb.

The energy released by the fissioning of 1 gramme of uranium - 235 is equivalent to the heat of combustion of 2.7 tonnes of coal. A nuclear fission driven electrical generator with an output of 650 MW consumes about 2 kilogrammes of uranium-235 per day.

Thus the principal advantage of nuclear energy is that its fuel is a concentrated energy store making it ideal for the supply of very large power requirements at competitive cost but it is quite uncompetitive if used to supply small or medium power needs.

FUEL SUPPLY

At the present time known world reserves of uranium are sufficient to fuel the existing reactors for their working life and also all reactors likely to be built between now and the end of the century. This may be compared with the oil situation where it is widely predicted that demand will outstrip available production by about 1990. In the absence of further uranium discoveries the future of fission power is dependent on the exploitation of the more widely available potential fuels such as Uranium 238 and Thorium 232. These non-fissionable isotopes are referred to as fertile isotopes since they can be converted to fissionable isotopes by neutron bombardment. Uranium -238 can be converted to Plutonium -239 and Thorium -232 to Uranium -233. The commercial future of nuclear fission power is dependent upon establishing and maintaining a correct mix of burner, convertor and breeder reactors.

The technological success of fuel supply and reactor design, and their public acceptability is measured by the fact that some 200 power reactors are now in operation in the world. In Europe, in 1976, they contributed 8.1 per cent of all electricity generation, which is almost one per cent of energy supplied to the consumer.

The failure to demonstrate fuel reprocessing and nuclear waste disposal satisfactorily is a major cause for concern.

RADIATION HAZARDS

The danger to health from ionizing radiation was quickly recognised in the early days of X-rays and radium. The scientists and doctors involved in this work met to establish codes of practice and exposure limits for themselves and their fellow workers. The International Commission for Radiological Protection (ICRP) evolved from these meetings.

Three types of biological damage are recognised as resulting from ionising radiation.

a. Rapid tissue destruction which results from the high acute dose, and includes the 'radiation burns' received by early scientific workers.

b. Mutagenicity (alteration of genetic properties) of somatic tissues leading to cancer. Examples are the cancers of the tongue suffered by the painters of luminous clock dials 40 years ago and the leukemias suffered by more modern workers. A particular danger rises from situations where bioaccumulation of radioactive atoms is likely. The accumulation of I^{131} by the thyroid gland giving risk of cancer of that organ is one example. Strontium ^{90} tends also to be accumulated in mammalian bone, irradiating bone marrow and thus giving rise to increased possibility of leukemia.

c. Mutagenicity of reproductive tissues giving rise to 'genetic damage' or the production of deformed offspring by man and all other organisms.

At relatively high levels it is clearly recognised that biological effect is a function of the strength of radiation received by a tissue multiplied by exposure time. In theory it is straightforward to design safe containment for nuclear facilities and appropriate work schedules for industrial staff.

At lower levels, those which affect the public at large, there are difficulties in setting theoretically safe limits. This problem occurs because of the following kinds of reason:

a. We are being subjected to low levels of natural radiation already, e.g. from K^{40} in rocks, soil and seawater and from cosmic rays.

b. There are many known causes of cancer and probably even more unknown.

c. Because the effective target is a single living cell, increased exposure through biological or chemical concentration of radioactive elements is possible.

d. There may be a long latent period before the biological ill-effects become apparent.

e. Virtually no information exists regarding large populations which have been exposed to similar low levels of excess radiation under otherwise controlled conditions.

Codes of practice for radiation exposure are thus continuously being revised. They are now based on a new concept of collective dose or the sum of all the individual doses over the population as a whole. This concept can best be understood by an analogy. It is known that if one hundred people each smoke one hundred thousand cigarettes throughout their life there will be more cancer in that group compared to a group of one hundred non-smokers. The collective dose concept assumes that if each of ten million people smokes one cigarette in his or her life there will be the same number of increased cancers. The cost to society would be the same in both cases even though in the latter case the individual risk is negligible.

A major drawback to this approach is that human populations are very heterogeneous in their susceptibilities and habits. A pregnant woman is many times more vulnerable to radiation damage from a bone seeking isotope such as Strontium -90 than (say) a middle aged man. Another major criticism is that 'Health Physics', which adopts a sophisticated medical and actuarial approach to human health, has not yet examined natural ecosystems for radiation effects. To assume that, if man is protected, then ecosystems are equally free from damage is fallacious (5.5)

Nevertheless, because of their conservatism, independence and facilities for constant reappraisal, the codes of the I.C.R.P. are the most reliable guidelines available.

ACCIDENT RISKS

Since a nuclear reactor cannot explode like an atom bomb the safety concern is related to the large quantities of radioactive materials in the uranium fuel. These can only be released by some malfunction causing the overheating and melt down of the fuel. Overheating automatically shuts down the fission reaction but the heat from the short-lived radioactive materials present for the first hour or so after shut down could produce fuel melt down. There are numerous systems employed to prevent such a melt down and these are backed up by structures and systems designed to trap any released material. In designing these systems it is assumed that there will be unreliable components and human operational errors. The failures and mistakes that occur in practice are carefully assessed to ensure, first of all, that their frequencies are within the design assumptions and, secondly, to try and ensure that these particular failures will not occur again. It is very important that all such abnormal occurrences are recorded and made available for analysis. The world wide publicity given to even the most trivial incidents does ensure that these incidents are not overlooked or concealed. Even with the worst plant accident the risk of serious or fatal injury to the general public only arises in certain adverse sets of circumstances. This would arise if the release was followed by rain coupled with a delay in evacuating people living near the reactor. The risk of this happening has been the subject of a number of studies. For the United States the risk of ten fatalities or more has been estimated at about once in a million years.

In Ireland the Nuclear Energy Board would have the task of checking the safety design of any proposed nuclear power station and ensuring that it complied with the safety requirements established over the years in other countries.

The methodology for carrying out such risk assessment, like all predictive techniques, is fraught with technical and philosophical difficulties. The 'Brown Ferry' incident discussed in the Flowers Report (5.3) is remarkable for both the non-predictability and great economic cost of the event. Whilst we agree that there is a very low probability of human life being directly at risk from nuclear power station malfunctions, there is a much higher likelihood of an economically crippling breakdown. The current problems with the 'Hunterston B' reactor in Scotland serve to illustrate this point.

SECURITY

The risk of sabotage in a nuclear plant is cause for concern; however, it is unlikely that any sabotage attempt could cause injury outside the plant. It would be difficult to arrange the full succession of events necessary for a major release of radioactivity. Any attempt to eliminate the various protective measures would take considerable time and could cause a reactor trip (a fast shut-down) and so reduce the risk of a major release. The security measures required to guard against this risk would be a matter for the judgement of the Government, the Nuclear Energy Board and the security forces. For obvious reasons it is not the practice

to disclose the nature of these security measures. Reports of measures at nuclear establishments abroad have raised fears of excessive infringements with civil liberties. However these reports have related to establishments where nuclear weapons or weapon materials are stored and do not relate to commercial power stations.

FUEL WASTE

On discharge from the reactor the fuel contains about half a ton of fission products and a tenth of a ton of plutonium. The remaining material-Uranium- has an enrichment about the same as natural uranium. The bulk of the fission products are non radio-active or become so in a short time. There are about thirty kilogrammes (66 lbs) of long-lived fission products that need to be isolated from the environment for a period of about five hundred years. To achieve this isolation it is proposed to incorporate the waste in glass and then dispose of these conditioned wastes in locations where there is known to be little interaction with the inhabited environment. Sites proposed include the deep oceans, impervious granites or clays and salt mines.

In spite of the proposals for the separation and disposal of fuel waste, this problem still remains unsolved. This situation is a major reason for delay in the expansion of nuclear power.

The high level fission product wastes also contain trace quantities of plutonium and similar materials whose radioactivity lasts for thousands of years. The activity of these materials would be comparable to the activity of the original uranium in ore form. The hazard would be less since the materials would have a greater degree of isolation from the environment. Recently it has been suggested that these disposal methods are adequate for the disposal of complete fuel elements including all the plutonium. There are techniques available for incorporating any form of nuclear waste into artificial rocks which would be stronger and more impervious than natural rocks which are known to be capable of holding materials for millions of years. Again this idea is little more than a laboratory scale model.

For Ireland it is likely that spent nuclear fuel would be shipped abroad for reprocessing and the separated fission products conditioned for ultimate disposal. Initially this disposal might be carried out abroad but eventually we would be required to provide our own disposal site.

RADWASTE AND DECOMMISSIONING

The strict control on radioactive releases to the environment results in the accumulation of low-level radioactive wastes within the power station. These wastes are processed to a solid form suitable for storage. They are normally stored on site in facilities designed to withstand any conceivable fire,flood or other accident. The facilities are designed to last a hundred years and the radioactivity would have decayed to normal natural levels before this. The reactor and containment could be dismantled at the end of life and the radioactive components removed for ultimate disposal. This procedure would really be justified if the site were required immediately for another station. A simpler

procedure is to use the containment as a secure solid waste repository designed to last a hundred years. Nearly all the radioactivity would have decayed away during this time. The residual waste could then be more easily handled and removed.

Very few large scale decommissioning exercises have yet been carried out.

FUEL TRANSPORT

The movement of spent fuel requires about a dozen shipments a year. The risk of injury to any member of the public from these shipments is remote since the containers used are designed to withstand a variety of accidents including crashes and fires. Hijacking these containers would be difficult to say the least. They are so heavy that the transporter can only travel at the rate of a few miles per hour and cranes capable of lifting the containers are few and far between. As far as loss at sea is concerned the technology is available to recover a sunken container before any significant loss of radioactivity occurs.

Safety and security problems would arise if the smooth functioning of this routine procedure were to be interrupted for any reason. Public anxiety might remain high because of the novelty of the transport procedure and the potential dangers which have to be contained by elaborate engineering.(5.4)

ENVIRONMENTAL EFFECTS

The construction of a nuclear power station would have effects on the environment comparable to any power station construction programme. These include the effect of the station and associated transmission lines on land use and wild life. The cooling water would discharge heat and chemicals into the sea with a consequent effect on marine life. The measures required to mitigate any adverse effects from these activities are similar to those used with conventional power stations.

One major problem which has to be addressed is that of scale, especially if it is assumed that Carnsore is planned in the long term as a 'Nuclear Park' with more than one reactor.

The actual routine emissions of radioactive materials from nuclear power stations have on average been restricted to a level that gives the most exposed member of the public an annual dose of around one per cent of the ICRP recommended limit.

A convenient summary of routine gaseous and liquid releases from a range of reactor types is given in 5.4.

NUCLEAR POWER AND NUCLEAR WEAPONS

The supply of nuclear materials is governed by the terms of the Non-Proliferation Treaty of 1968 and associated Treaties and Agreements. The stimulus for this Treaty was an Irish U.N. motion calling for action on nuclear disarmament and

measures to halt the spread of Nuclear Weapons. The main provisions of the Treaty are that the Nuclear Weapon states undertake not to transfer nuclear weapons or control over them to any other state and not to assist any non-nuclear weapon state to acquire a nuclear weapon capacity in any way. The non-nuclear weapon states who are signatories to the Treaty undertake neither to manufacture or otherwise acquire weapons nor even to seek or receive assistance to do so. These states also undertook to accept safeguards or verification systems on their Nuclear programmes. All states undertook to make the application of these safeguards obligatory on any nuclear materials or equipment supplied to non-weapon states. In return for accepting these obligations,the non-weapon states were promised assistance in the development of their Civil Nuclear Programme. Finally, all the parties undertook to pursue further negotiations on disarmament in good faith.

The great weakness of the Non-Proliferation Treaty is that not all States have signed it. One reason given for this is that they are not prepared to accept the principle that the world can be divided into nations that can be trusted with nuclear weapons and those that cannot. In Europe, France, a nuclear weapon state, is not a party to the Treaty but she has declared that she will apply the treaty in respect of commercial operations as well as exports and her civil programme comes under Euratom safeguards provision. Non-signatory states are now obliged to accept safeguards on all imported nuclear materials and technologies. These safeguard provisions on imports do not prevent a non-signatory state from using indigenious technologies and materials to construct nuclear weapons. At the present time efforts are being made to strengthen the verification procedures on nuclear exports and to include under these procedures any technologies or materials derived from these exports.

Ireland has obligations under the Non-Proliferation Treaty and under the European Treaties. Contracts for the supply of any nuclear services would contain provisions demanding the application of safeguards procedures together with international supervision with provision for the termination of the contract in case of default. There is a reciprocal obligation in respect of any materials supplied by Ireland for processing abroad. There is the possibility that such material would be diverted to military use in violation of the terms of the covering Treaties or Agreements. The risk of this happening is remote. These services are provided by countries which have substantial nuclear programmes with access to stocks of nuclear materials that are large in comparison to any materials likely to be supplied by Ireland. Violation of an Irish Agreement would invalidate not only the Irish Agreement but all Agreements with other countries and so effectively terminate all imports of nuclear materials. Finally the export of materials for processing or the storage of such materials abroad under international supervision is not regarded in any way as a breach of neutrality.

THE COSTS OF NUCLEAR ENERGY

Throughout ENERGY-IRELAND there is the assumption that decisions to be taken with respect to future energy supplies must be based on cost considerations. The Discussion Document states that "we can never let our energy costs be significantly higher than the energy costs of our competitors". Later in the document some data based on C.E.G.B. and E.E.C. findings are presented which suggest that nuclear power will be cheaper than either coal or oil. Unfortunately, the figures given in the document are misleading as a guide to the costs of electricity by different fuels in Ireland. The International Energy Agency was far less certain about the comparative advantage of nuclear over coal as a method of production in a recent report on the prospects for steam coal to the year 2000. (5.6).

They find, for example, that coal will be competitive with nuclear in baseload operations in Western Europe if low sulphur coal can be delivered to utilities at a price in the range $ 32 - 36 per t.c.e. (at 1976 prices). Such a range is available for imports into Western Europe from Poland and South Africa, it is estimated.

The I.E.A. produced the following forecasts of costs per kilowatt/hour for different techniques for the period 1986- 2006 using normal load, assuming after 1985 a 2.5% real price increase p.a. for oil, 1 % p.a. for coal and 0% for uranium. Running time is assumed to be 5,500 hours per year.

Nuclear:	2.38 U.S.cents at 1976 prices
Oil:	4.05 - 4.28 U.S.cents at 1976 prices
Coal:	3.03 - 3.60 cents at 1976 prices depending on emissions levels.

It should be noted that the coal estimates are some 50% higher than the CEGB figures in 'Energy-Ireland' while nuclear costs are 70% higher. They bear little relation to C.E.G.B. figures which are clearly inappropriate in the context of future decisions to construct nuclear or coal stations. They are also higher for nuclear and, on average, lower for coal than the EEC figures in Energy-Ireland. In addition, the nuclear costs are based on a power station of 1100 MW size which is nearly twice that projected by the ESB. The cost, at 1976 prices, was assumed to be $ 700 per installed kw. Thus a 600 MW plant would cost £210 million on this cost basis. Recent informal estimates of the expected cost of a nuclear facility suggest that the costs have increased by more than 50% since 1976. If so, costs are outpacing the level of prices generally and so the above relativities would have to be altered.

Finally, Mr. S.Coakley of the ESB in May 1978 said (5.7) that ESB studies suggested little or no price difference in the cost of nuclear or coal generated power.

To sum up, data on comparative historic costs in other countries cannot be uncritically applied to a future project in Ireland and any attempt to do so can only be more speculative. A more meaningful assessment can only be based on a comparison of actual tender prices for specified sites and taking into account the system restrictions on the load factors for large units.

SECURITY OF SUPPLY

Under normal operating conditions, and in the short term, security of electrical supply depends on the correct surplus of installed capacity over and above peak demand. This means that any breakdown may be readily counteracted by running an alternative generator. It is important to have diverse plant size in relation to peak demand. To give a simplified example:

Suppose that the present installed capacity was met by four nuclear driven generating sets of 650 MW each. If one set were unable to supply power, for any reason, peak demand could come close to, or even exceed, available capacity. Thus the probability of being unable to meet demand would be equal to the probability of one set being out of action. On the other hand, suppose that the total installed capacity was composed of twenty-six 100 MW sets; then the probability of being unable to meet peak demand would be equal to the probability of six sets being out of action simultaneously. It can be seen from this example that a relatively large number of relatively small sets gives the best security of supply. Of course, the E.S.B. understand this very well and are to be congratulated on their performance over the past fifty years, particularly on the prompt installation of hydro generation and storage schemes and on their wise conservation policy. It seems to us that they are being led into economic difficulty by the extravagant forecasts of ENERGY-IRELAND and, possibly, that they are working to outdated terms of reference. In other words, the problem of nuclear generation in Ireland today is that a single economically available set from the nuclear market represents a disturbingly large proportion of presently installed capacity and smaller nuclear sets are unlikely to be available because they are uneconomic in world terms.

In the longer term the main advantage of nuclear power in Ireland is that fuel for some three years operation could be stored on site. This would ensure a strategic reserve of electrical supply capacity to be added to other indigenous sources. The role of nuclear power as a strategic reserve does, however, merit special study and should not be accepted simplistically.

NUCLEAR POWER IN IRELAND

In 1973 the Government gave approval in principle to a nuclear project. A year later the ESB submitted a site report giving the results of the preliminary studies on its preferred site at Carnsore Co.Wexford. Even though the project was deferred indefinitely in 1975, the site evaluation work continued. The Nuclear Energy Board examined the ESB site report with the assistance of European experts and approved

the site in principle. The next stage involves the preparation of enquiry documents by the ESB and subsequent evaluation of tenders. The application for outline planning permission would also be processed at this stage. The Tenders for station construction would provide the ESB and the Government with the necessary data to evaluate the economics of the project. If this was satisfactory the preferred contractor would submit detailed designs for evaluation by the Nuclear Energy Board. This entire process would take about four years to complete. The actual construction work would take five to six years.

The ESB would be required to apply for a licence before initiating each significant step of the project. The NEB would evaluate the safety of each design proposal. It would also be responsible for setting limits on radioactive discharges from the station taking into account the results of the environmental surveys that are in progress or planned. It would ensure that all the conditions and regulations were complied with. This would be done by continuous monitoring and inspection at all stages of design, construction and operation of the plant.

CONCLUSIONS AND MAJORITY OPINION ON NUCLEAR POWER IN IRELAND

A nuclear generating facility can be constructed to be acceptably safe under normal operating conditions provided that the highest standards of design, construction, operation and maintenance are set and maintained.

We could store enough fuel to run a 650 MW nuclear driven generating set for about 3 years. In other words, the E.S.B.'s nuclear proposal has the advantage that about 5% of our total national primary energy demand for three years could be stockpiled against the event of a fuel supply emergency.

On the other hand, nuclear power has some disadvantages, including the following:-

a) The economic case for nuclear power in Ireland before 1990 is unproven, thereafter the picture is even less clear.

b) Long term disposal of radioactive waste and decommissioning of plant have not yet been demonstrated.

c) Long term biological effects of radiation dosage from specific materials are not sufficiently understood.

d) There is no means of achieving absolute security against terrorism, with all its consequences.

On any one of the grounds a) to d) above we urge An Taisce to oppose any irretrievable decision before 1984 to proceed with nuclear power in Ireland. We do not exclude the possibility that solutions to the above problems might be found in due course.

References - Chapter 5.

5.1. J.T.McMullan, R.Morgan & R.B.Murray (1977) Energy Resources. Edward Arnold. London.

5.2 W.C.Patterson (1976) Nuclear Power, Penguin Books London.

5.3 Flowers Report. Royal Commission on Environmental Pollution, 6th.Report. Nuclear Power & the Environment, Chairman, Sir Brian Flowers. H.M.S.O. 1977.

5.4 Anon. (1973) Nuclear Power and the Environment. International Atomic Energy Agency, Vienna.

5.5 See Chap.6 and ref. 6.4.

5.6 Anon (1978). The prospects for steam coal to 2000. International Energy Agency. Paris.

5.7 ICEM conference 'Irish Options within an EEC Energy Policy', 5.May 1978: "We have examined and made an economic comparison several times between coal and nuclear with different accounting methods and in general there is not an overwhelming case economically for either,if the fuels were to retain their current services expressed in real terms".

Chapter 6

Enviromental Aspects of Energy Policy

> "A resolution was adopted by the Council of the E.E.C. on 3rd.March 1975 calling on Member States to take environmental impact into account in energy policy; to reduce the harmful environmental impact of energy production and use and to investigate the special problems associated with the development of energy".

GENERAL STATEMENT

All benefits obtained from the use of energy are diminished in the long term by both reductions in finite resources and environmental pollution. The problems of finite resources are readily addressed by conventional economics and energy accounting e.g. Chapman (6.1). The environmental disbenefits of energy use in some cases may be readily quantified, whilst in other cases lack of fundamental knowledge restricts calculations to crude estimates.

As an example of quantifiable disbenefits, the effects of sulphur dioxide and smoke are theoretically quantifiable in terms of a) the health of the human population in excess mortality and morbidity costs; and loss of earnings;
b) damage to the fabric of cities - paint, metals, etc.;
c) damage to crops; d) damage to ecosystems. Current work in the 25 countries of the OECD is setting monetary value on this type of pollution, (Bromley, 6.2). Such information will provide a firm basis for decision making on the

strategic choice of fuel and the investments to be made towards pollution abatement.

Where scientific or economic information is not sufficient to allow objective assessment of a particular environmental impact, the following principles should be adopted in developing policy.

1. As in general planning, assume that the worst case applies Research should discover whether or not this is the case.

2. Whilst human health (in its broadest sense including general "well being") will be a prime consideration, attention must also be directed to the function of ecosystems exposed to the pollution. Even from a politically and economically realistic viewpoint, it is argued that man's survival and ecosystem function are tightly linked on a local and a global level. On a smaller scale direct economic and health effects may result from neglect of particular ecosystems.

3. Monitoring of environmental effects must play a key role in long term management.

4. In general the environmental effects of smaller and more dispersed installations are more acceptable than larger.

(Conurbations should be regarded as a single source of pollution, and economies of scale in pollution abatement are most likely to be applicable).

5. Environmental aspects of the whole of a particular fuel cycle must be considered. Even when they do not directly affect Ireland, it is inevitable that prices and even non-availability of a fuel will be a reflection of environmental aspects of production or waste disposal. For example the mining of coal or uranium ore presents large industrial health and landscape problems, and with the disposal of radioactive fuel waste represent three areas in which environmental costs of fuel are generated outside of Ireland.

6. The likelihood of technological success in solving environmental problems should not be assumed. (By analogy, marketing problems should be solved before embarking on production of a commodity).

7. Protection of man from cumulative pollutants such as toxic metals or radioactive substances does not ensure in theory that the remainder of the ecosystem is free from hazard. This would only be the case if man were a true 'top carnivore'.
See for examples Odum (Table 4-1.) (6.4)

FUEL CYCLES AND THEIR ENVIRONMENTAL EFFECTS

Fuel cycles may be analysed in terms of commonplace and inevitable impact on the environment and of risks of more severe damage occurring when technological safeguards fail. The Tables 6i-iii, which are derived from Jeffrey (6.5), are included to emphasise two points. That there are separate and different impacts at different phases of all fuel cycles is the most important. Whilst a scale of extent, severity and duration of ecological damage has been constructed, and we have been accustomed to learning about the effects of oil spill accidents (for example), comparison is nevertheless difficult. A second point is the difficulty in making a comparison between risks at varying probability of occurrence.

TABLE 6 i A CLASSIFICATION OF GENERAL ENVIRONMENTAL IMPACT

Class	Impact
1	Negligible - existing ecosystem unchanged.
2	Slight local change (within .5km).
3	Slight but widespread effects.
4	Ecosystem radically modified and degraded.
5	Occasional serious local damage.
6	Occasional widespread serious damage.
7	Rare local ecosystem destruction.
8	Rare widespread ecosystem destruction.
9	Irreversible widespread destruction at low probability.

Examples: 1. - visitors to a good beach. 2. - limestone quarry. 3. - road building. 4. - older design smelters. 5. - road tanker accident. 6. - release of slurry into a lake. 7. - Seveso & Flixborough incidents. 8. - large forest fire. 9. - major volcanic eruption or earthquake.

TABLE 6 ii A ROUGH SCALE OF HUMAN HEALTH IMPACTS

Class	
A	Excessive industrial deaths or danger to the public not known.
B	Accident rate acknowledged to be high.
C	Chronic disease or accidental death danger to the public.
D	Potential danger of large scale loss of life.

TABLE 6 iii COMPARISON OF FUEL CYCLES BASED ON ENVIRONMENTAL IMPACT CRITERIA IN TABLES 6 i and 6 ii.

Fuel	Production	Preparation Distribution Storage	Utilisation	Solid Residue	Comments
Petroleum	2+5 A/B	2-6 A/C	2-3 A/C		Oil spills & SO_2
Turf	3-4 A	1 A	2 A	2 A	Derelict land problem if suitable use not found.
Electricity	1-3 A-C	1 A	1 A		Impact depends on fuel plus thermal effects.
Hard coal and coke	3-4 A-B	1-5A	2-4 A/C	2-5 A	SO^2 and Smoke plus effects of mine.
Natural gas	1 A	1 A-C	1-2 A		Lowest impact fossil fuel.
Uranium 235	3-4 A-C	1 A	2 A or 9 D	8 C-D 7 A	Risks at very low probability plus waste difficulties. Radon in mines.
Solar heating	1 A	1 A	1 A		Potentially very low impact.
Biomass	3-4 A	1 A	2 A	2 A	Resembles turf?

Fuel	Production	Preparation Distribution Storage	Utilisation	Solid Residue	Comments
Wind	1 A				Visual impact like pylons?
Wave	3 A				Effects on coastal geomorphology?

CURRENT FUEL CYCLE POLLUTION

There are two methods by which pollution may be estimated and compared; by calculation and by direct measurement (monitoring). Monitoring in fact is seldom used to reconstruct a complete quantitative pattern of emission, but more usually to provide a measure of dose at a particular sensitive point. Monitoring enables an index of quality of the air of a city or the waters of a sea to be continuously updated. More specifically monitoring enables investigations to be made of the cause-effect or dose-response relationship in health or ecological terms.

SULPHUR DIOXIDE AND OXIDES OF NITROGEN

At the present time SO_2 (sulphur dioxide) is the most significant air pollutant because of the high consumption of oil. In 1973 McManus (6.6) indicated that electricity generation gave rise to approximately 100,000 $t/SO_2/y$ (tons of SO_2 per year), the rest of industry 100,000 $t/SO_2/y$ and remaining domestic and commercial activities another 40,000 $t/SO_2/y$. In the case of more modern ESB stations this SO_2 is generally dispersed by the high stacks characteristic of the Poolbeg and Tarbert power stations. At the present time this high stack policy is appropriate and effective for larger sources. In future the quantity of SO_2 emitted per unit of electricity produced may be reduced by reduction in sulphur content of fuel and by emission control equipment.

SO_2 is certainly the most widely studied and, therefore, best understood air pollutant. Although the health effects are known to be extensive, abatement involves known technology and is generally a matter of costs. Chemically SO_2 degrades ultimately to sulphate (SO_4) which is abundant in soils and waters. Most of the problems arise from radicals and acids which exist as intermediates. More knowledge is required of the quantitative dynamics of SO_2 removal so that more precise predictions may be made of the fate of that produced by particular sources. Because of high wind speeds and low population density in Ireland as a whole, the impact of SO_2 has so far been quite low. Dublin is the special case where unsatisfactory incidents are known to occur. (Dublin Corporation 6.7 ; Dean 6.8; Kevany & Bailey 6.9).

Oxides of nitrogen originate in relatively small quantities from petrol engines. Vehicle densities and atmospheric conditions do not appear to justify the serious view taken of these pollutants in the U.S.A. (Their emission in larger quantities from industry might, however, be a more difficult problem).

SMOKE AND PARTICLES

Smoke is a mixture of the products of incomplete combustion plus combustion residues. Droplets of water may also condense as another visible combustion product. Smoke control policies have undoubtedly been a great success, producing

not only many health benefits in industrial conurbations but also gains in fuel economy. The widespread use of turf briquettes in Dublin may occasionally give rise to unsatisfactory conditions, but at present the smoke situation is improving from year to year (Dublin Corporation, 6.6).

HEAT

Release of chemical energy inevitably warms the environment. The scale of environmental heating ranges from the trivial and virtually undetectable effects of isolated dwelling; the urban "heat island" phenomena, equivalent to micro-climatological effects; reaching their most extreme form in the condenser cooling of large electrical generating stations. In this last case, volumes of water proportional to generating capacity at approximately 15°C above ambient temperature are discharged to large lakes, rivers, estuaries or coastal waters. It is most unlikely that generating stations of the size range envisaged for Ireland are likely to give rise to problems arising from heat alone. Ecological interactions between heat and other factors such as organic matter need careful appraisal, case by case.

SOLID WASTE

Ash from coal or turf fired installations at present is a small problem and coped with at very local level.

OIL POLLUTION OF THE SEA

Whether chronic low level oil emissions or acute pollution incidents are considered, it is now generally recognised that their occurrence relates fairly simply to quantity of oil moved. The various Bantry Bay incidents, culminating in the Universe Leader spill, have taught us that technology alone will not prevent environmental damage. Technological sophistication must be combined with effective organisation and disciplined management. It is encouraging that need for international legislation is now commonly recognised in Europe. The volumes of oil moving in our coastal waters are bound to increase and we should both encourage the introduction and implementation of international control.

RADIO-ISOTOPES

Since 1964 the Irish Sea has received discharge of radio-isotopes as low level waste from the Windscale reprocessing works. Wastes from both civil and military reprocessing are probably discharged. The information presented for example in the 1974,1975,1976 Fisheries Radiobiological laboratory Reports (6.10, 6.11. 6.12) do not permit a scientific evaluation of the ecological effects of this discharge, or into which environmental compartments it is distributed. The information these reports contain is aimed at demonstrating that in the short term the quantities of isotopes passing to man are below acceptable limits. The analyses presented of the edible parts of fish, of seaweeds or of sediments are not sufficiently detailed to permit comparison of one year or area with another. It is not even known if non-edible fish parts contain higher levels than the muscle tissues examined.

Specifically not examined are the whiting - a bottom feeding fish, deep sediment samples and the sediment and organisms filtered from sea water samples.

Equal activity contour maps for the dominant isotope caesium 137 (CS 137) are presented for filtered sea water in both Irish and North Sea areas. The I.R.P.C. limit for this substance is 900 pica curies per litre (PCi/L) which is approximately 3 times the total beta emission of natural seawater.

To illustrate the available data, two selected observations are quotes here as objective statements. a) This limit is exceeded for a few square km. around the discharge point on the Cumbrian coast, b) The values for a point midway between Dublin and W.Anglesey are as follows:

July 1974	July 1975	January 1976
12.5	29	51
		p Ci CS137/L filtered seawater

(At this rate of increase the limit would be reached in 25 years).

Since high levels of CS 137 have only been discharged from 1974 onwards, when the quantity increased from 20 - 30 x 10^3 curies/yr. to more than 100 x 10^3 curies/yr., it can only be concluded that this isotope is accumulating. Its half life is 30 years, it is known to be absorbed on sediments and yet no research has indicated how the discharged isotope is partitioned between water, sediments, organisms, and locality.

This lack of information illustrates a fundamental flaw in the attitude towards environmental effects. The assumption was made that dilution would account for dispersal and that low level wastes could be safely discharged. Without more information this cannot be considered to be demonstrated. Comments on a number of unsatisfactory features of the present Windscale factory were made by Parker (6.13) in the Report on the Windscale Enquiry. They bear out our misapprehensions about discharges of Cs^{137} into the Irish Sea.

Viz: 1. Higher discharges of Cs^{137} were made in the past than predicted because of unforeseen circumstances. (2.24).

2. Agreement with a witness that more control needs to be exercised, and that aspects of monitoring and reporting were unsatisfactory. (10.54 - 10.57).

3. Agreement with a report stating that much remains unknown about the ecological fate of discharged isotopes. (10.16, 10.17).

This example may be used to illustrate two general observations. First, that energy linked pollution is an international problem.

Second, how the large costs of reducing this discharge could become part of the general fuel cycle bill. It must be pointed out that the highest levels of discharge have already been reduced, and plans for the future reprocessing plant are lower still.

LEAD

Lead additions to petrol on the one hand give enhanced fuel economy and on the other are suspected of contributing to undesirable health effects in urban populations, especially children. It is clear from McManus (6.6) that Dublin is the main area of concern. Co-ordinated research now in progress will indicate the magnitude of the problem within the E.E.C. (see Jeffrey 6.14, Archer, 6.15).

ENVIRONMENTAL EFFECTS IN THE FUTURE

The environment to 1990

Two features of the energy situation for the next 11 years seem to be agreed by most analysts, a) that oil imports are unlikely to drop, b) that coal will be a major fuel. Quantities of SO_2 emitted will rise approximately in proportion to final energy provided, unless measures are taken to abate this pollution. E.E.C. controls on sulphur content of fuel oils will play one role, but it may well be the case that low sulphur fuels will be allocated on a priority basis to more densely populated zones of Europe.

The major potential consequence of increasing use of coal will be higher levels of smoke than at any time in the past.

If coal is to be used more widely in domestic heating, then the technology of combustion has to make a substantial leap forward. Lovins (6.15) is optimistic that solid fuel use efficiency and pollution abatement may be combined at a domestic scale.

The use of coal for future electricity generation and other centralised uses will imply the initial installation of stack emission control equipment. Fluidised bed technology also has a role in emission control. By these means a general reduction of SO_2 and particulates should be achievable. The other major disadvantage of coal in power stations is the quantity of pulverised fuel ash (P.F.A.) produced. This material is an embarrrassment in some areas, for example, the many C.E.G.B. stations on the South Yorkshire coalfield. Such a concentration of coal burning stations will not occur here, and it would be rational to utilise P.F.A. in building material such as cement and lightweight blocks. As such, the ash would represent a benefit rather than an environmental problem.

The problems of oil and coal, which are largely addressable by current technology, would be avoided if natural gas were to be more available as a source of heat. (It is worth remembering that 20% of the gas yield of the U.K. is equivalent to our total energy requirements). Relatively small additional gas finds could make a substantial difference to the optimum pattern of fuel use in Ireland.

One possible quantitative scenario for air pollution trends and energy demands in Ireland to 2,000 A.D. is formulated by Reilly and Duggan (6.17). This is based on the premise that primary energy consumed in 1990 will amount to 15 MTOE (for 100% GDP rise) and that by then a 650 MW nuclear power station will be operating. The quantity of coal consumed is in this case increased by 5.5 fold and gas oil use doubles. With current levels of emission control, smoke would increase 3 fold and SO_2 by only 1.6 times, taking a decrease in the sulphur level of oil for granted. This stresses the need for an enhanced level of emission control.

Another feature of this predictive exercise is estimated values in 1990 for Dublin, which, even now, is seen to be close to an unsatisfactory situation. Winter smoke levels will increase by three-fold and the winter SO_2 will double, it is predicted. Whereas it may not be necessary to impose national air pollution control regulations, it will probably be essential to ameliorate the Dublin atmosphere by smoke control procedures. The lead emission problem may also need to be addressed by the strategic use in Dublin of imported fuel for the next five years until low lead petrol is produced at an Irish refinery.

Two other pollution "hot spots" may also need special regulatory treatment, namely, Cork and Shannonside. In the latter it may be expected that the conjoined effect of large oil and coal-fired power stations, the alumina plant and possible smelter may well be substantial. Pollution dose to

Limerick and the surrounding agricultural hinterland should be investigated, and appropriate planning set in train.

THE ROLE OF ENERGY CONSERVATION

It seems obvious that energy conservation is a powerful tool in reducing pollution. To aim to use 20% less energy for a given purpose is achievable within the next decade or so. It seems likely that it would also be a very cost effective mode of pollution control, and might,on occasion, be seen as an alternative to other measures.

NUCLEAR POWER

The principal environmental disadvantage of nuclear power for Ireland is that it cannot replace sufficient of the conventionally polluting energy sources and yet brings the threat of different and greater pollution. On an international scale, two major sectors of the fuel cycle, reprocessing and waste disposal, are environmentally so unsatisfactory that a technical stalemate exists. Both are complex problems and seem as far from solution as many alternative sources of energy are from being developed. When they are solved it will be at a high economic cost. If they are not solved, fuel availability will become difficult and the storage of our own unreprocessed fuel may be a necessity.

This is not the place to comment in detail on a planning application for a nuclear power plant, but the principal categories of objection on environmental grounds are as follows:

a) The nature of normal and possibly abnormal discharges of isotopes to the Irish Sea, bearing in mind the presence of other nuclear installations.

b) The risks attached to the storage and transportation of irradiated fuel.

c) The potential damage to the agricultural industry of even small unplanned releases via stacks of isotopes such as iodine - 131. A relatively small degree of damage could lead to substantial economic loss in a competitive economic situation, with export markets for processed milk products being at hazard.

Compared with a pair of smaller modern coal-fired generating stations, especially if the scale was small enough to recover waste heat, a nuclear power station is environmentally very unattractive.

ALTERNATIVES - POST 1990

The development of the major alternatives, biomass, wave power, solar thermal and possibly photovoltaic will certainly bring environmental problems. These problems are seen as being smaller in scale than the massive air pollution problems of today and vastly preferable to the virtually non-addressable problems of isotope disposal.

In a future which reduces dependence on finite resources, there should be optimism regarding environmental quality.

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Chapter 7

Ireland's Energy Options up to 1990 and beyond

For reasons given in preceding Chapters, until 1990 at least, Ireland will, barring 'lucky strikes' be dependent on imports of oil and coal for all her needs in excess of about 2.1 MTOE, obtainable from already identified indigenous sources. Although renewable sources such as Solar, Waves and Wind could together supply more than any conceivable demand, by 1990 their development is very unlikely to have reached major commercial proportions. But in a number of specific applications, such as those affecting remotely placed communities, the renewable sources should be developed immediately in all cost effective cases. It can also be stated, unequivocably, that all conservation methods must be applied as soon as they become cost effective. Energy-Ireland's laissez-faire acceptance of only a 10% conservation factor is regrettable We know that much more is possible and that by 1990 a conservation factor of 20% (based on the evidence of such documents as the Henry Report) relative to present practices should be the aim. Of course, as indicated in the Government's Green Paper 'Development for full employment', new attitudes and revolutionary methods and behaviour must be developed in order to achieve this, and the Government is expected to take the lead.

In this chapter, we restate the Expected Growth Case of Energy-Ireland's Table 9, in Table 7.1.below:
Taking our highest estimate for energy demand in 1990 of 16 MTOE, with 20% conservation, this reduces to approximately 13 MTOE, or to 14.5 MTOE if Energy-Ireland's 10% target is achieved. For the sake of argument we take the latter worst case. In the outcome, energy demand will depend, among other things, strongly on the exact nature of those industrial processes and products which become economically successful. In this respect we may assume that organisations such as the I.D.A. will preferentially promote industrial activity which, on balance, enhances secure job creation, that is, not jobs with high energy requirements which may be at risk if energy prices should escalate.

TABLE 7.1. 1990 Energy Demand (incorporating the GNP and conservation assumptions from Energy-Ireland's Expected Growth Case.)

Primary Source	Electricity		Non-Electricity		Total	
	MTOE	%	MTOE	%	MTOE	%
- Indigenous fuels	0.9	20.0	1.2	12.0	2.1	14.48
- Imported fuels likely						
Coal	1.4	31.0	1.2	12.0	2.6	17.93
Oil	1.8	40.0	5.0	50.0	6.8	46.90
-* Optional fuels						
Coal/Renewables/ Natural Gas/Oil	0.4	9.0	2.6	26.0	3.0	20.69
TOTALS	4.5	100.0	10.0	100.0	14.5	100.00

* Various combinations of these are possible.

The actual figures entered in Table 7.1, then, are meant to convey relative magnitudes rather than precise amounts. The following considerations have been taken into account.

1. Electricity generation will consume up to 4.5 MTOE, that is three tenths of total primary energy demand or less. We agree that no new solely oil-fired generating sets should be installed after the present back-log is cleared. For reasons given in Chapter 5, we reject nuclear energy for Ireland by 1990 and recommend the ESB to coal-fired or dual fired (coal or oil) generating sets. Such an arrangement affords more flexibility than Energy-Ireland's scenario owing to the smaller set size than nuclear and, provided we face up to the hydrocarbon pollution problem, is more acceptable socially. A highly critical attitude must be taken to any expansion of the electrical share of the national energy mix, especially artificial expansion to justify going nuclear.

2. For the remaining 10 MTOE of non-electrical energy demands we would like to see the indigenous fuels playing a larger role here than in the electricity sector. For example: we would prefer to see turf burned in closed boiler units for the home so that high efficiency levels can be achieved. This makes best use of our turf resources. We would, however, not encourage the rapid depletion of our indigenous resources, as is currently the case with the price of turf pegged artificially low. In the case of coal,

we would suggest that a smaller share be consumed in the non-electricity sector than in the electricity sector, because in electricity generation, economies of scale make the task of pollution control easier.

3. It is important to leave some options open. Clearly, if the price of oil declines in the future, owing to large new areas of discovery in the world, then Ireland will want to benefit from this. However, if the price of oil rises substantially, we will see considerable additional scope for renewables, and this possibility should be actively prepared for. Meanwhile, with 50 years (7.1) worth of proven natural gas reserves in the "free world" based on 1977 rates of commercial production, this fuel should not be ignored. There would appear to be little difficulty in finding a demand for natural gas or any form of gas, providing the price is competitive. In Britain, where the price was particularly low, piped gas sales quadrupled (7.2) during 1966-1976. Also, LPG growth in Ireland has been vigorous. If one were to use the fuel share approach employed by Energy-Ireland in relation to electricity, Ireland could absorb a good 2 to 3 MTOE of gas, given time. The economic viability is not known, but there are several possibilities. One would be the piping of natural gas from Britain, the North and South of Ireland using the same link. As in the case of the nuclear power station, a line linking North and South would be needed. Another possibility in the

future, which must not be precluded, is synthetic natural gas (made from coal, a high BTU gas similar to natural gas) which in some reports (7.3) is already comparable in price with nuclear electricity and is due for commercialisation in 1985. It is important to have a discussion of these options which is open, and not like the unpublished inter-departmental report denying the Kinsale gas to Dublin. Secretiveness automatically rouses objections, possibly not justified, (though it may be questioned that to burn .66 MTOE of natural gas in electricity generation rather than pipe it to be used like townsgas, would be to lose the most part of the output of the proposed nuclear power station).

A very large contribution to the flexibility of our energy use can be achieved if every house has at least two ways in which it can be heated, for example, by oil or by turf. Not only does the consumer gain in security but with space heat forming such a large share of national energy use, risks of disruption, for whatever reason, are diminished.

So to summarise, the main considerations which should be taken into account,over and above those dealt with in Energy-Ireland, are to match the fuel to the correct use, (7.4) to make best use of our indigenous fuels, to allocate fuels requiring pollution abatement to large scale users, and to encourage flexibility at the user end as well as to keep options open. The ultimate option,obviously,is to reduce fuel use altogether by finding realistic measures to encourage conservation as suggested in Chapter 3.

References - Chapter 7.

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7.3 I.E.A. Prospects for Steam Coal to 2000. December 1978.

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Chapter 8

Recommendations

This chapter comprises a list of specific items which arise from the text and which, in our view, will prove useful in developing policy.

ECONOMIC ASPECTS

Improve forecasting techniques through detailed sectional end use descriptions and models which may be examined in the light of inter-departmental economic and technical criteria.

In particular, conduct a regular sample census of energy consumption broken down by final use e.g. low grade heat, traction etc. (possibly incorporated in some of the existing regular surveys at little extra cost.)

Survey a number of large energy consuming firms to discover whether the new machinery they are likely to buy, when replacement time comes, will be more or less energy efficient.

List some of the industries which are likely to establish or grow here in the next decade, and check their energy requirements using foreign energy intensities if need be.

CONSERVATION

A dynamic, vigorous and imaginative conservation policy should be adopted which makes use of the best overseas experience and develops cost effective answers to our own needs. This policy should be many sided and pervasive. The following elements

appear to us to be essential.

Education should extend across the board from National School curricula to University courses. Getting concepts right in the public mind is of paramount importance.
Information should be readily available to householder and industrialist alike so that decisions may be made on an adequate basis.
Training courses in all the technical aspects of correct use of energy consuming devices should be encouraged.
Research and development into both hardware and appropriate stategies must be continued e.g. heat pumps, total energy schemes, district heating, fuel use efficiency studies.
Regulations may have to be used to ensure -

a) Optimum insulation of buildings of all kinds

b) Efficiency of operation of various types of equipment e.g.vehicles, heating equipment

c) That use of inappropriate fuels is not encouraged, e.g. to ensure best use of electricity.

Pricing and incentives should be used to facilitate the proper allocation of energy. Current interference in pricing is probably having an adverse effect.
Encouragement should be given to business operating in this field, order to "prime the pump" for supply of insulation, equipment and enterprises associated with recycling of materials.

Energy conservation, the wise use of energy resources, is clearly within An Taisce's domain, and together with other voluntary organisations should seek an active role.

SOURCES AND USES

Flexibility and versatility are of paramount importance whilst moving into a period of great uncertainty. We must be prepared for the contingencies of coal and natural gas being better buys than petroleum. Biomass offers a number of possibilities for utilisatión that must be explored through operations research and pilot study procedures. Continued encouragement must be given to prospectors consistent with protection of national interest.

International support should be sought for pilot scheme trials of the alternatives . Co-ordinations of source-use matching should be part of industrial planning.

Analyse all options carefully in the light of many possible contingencies, e.g. biomass; interconnectors for electricity and natural gas; wide use of solid fuels as heat.

NUCLEAR POWER

Oppose the installation of a nuclear facility in Ireland for generation before 1990.

ENVIRONMENTAL ASPECTS

In all new installations best possible practice should be followed in pollution control of large sources.

R.&.D. is needed for optimising heat output smoke and SO_2 emission of small scale solid fuel heating installation. Draft smoke control regulations should be drawn up for key localities and co-ordinated with an energy supply plan. This would include advice on regional fuel allocation, especially for new installations; tactical use of fuels such as natural gas, low lead petrol.

International co-operation should be involved to seek answers to problems of international pollution. Particular problems are pollution control in the Irish Sea, and the broader one of international air pollution associated with watershed acidification.

The potential role of energy conservation practice in long term reduction of pollution should also be investigated. Techniques for the economic assessment of pollution damage should be examined as decision making tools.

Definitions and Units

Energy is needed to do work and work is done when a force accelerates a mass.
Energy and work are measured in the same units.

McMullen et al (1) generally describe known energy resources and briefly show how energy conversion efficiency is limited by the Laws of Thermodynamics.

Due to the historic manner in which the applied sciences and the various branches of the energy industries have developed there are a number of systems of measurement and much confusion is caused by the different units in each of the systems. Relatively recently an international body was set up to try to clear up some of this confusion by establishing a consistent set of units appropriate for use in all the applied sciences. The system they proposed is now said to be the preferred system of units and it is called the System Internationale or simply SI.

The SI unit of energy and of work is the JOULE (J).
The multiples which are applied to it and to other energy units are:

Multiples

Prefix	Abbreviation	Number
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}

Other units of energy which grew up historically and are still used are:

Units

Calorie (cal)	= 4.1868 J
British Thermal Unit (BTU)	= 1055.06 J
Therm	= 105.506 MJ
Kilowatt-hour (kwh)	= 3.6 MJ
Tonne of oil equivalent (TOE)	= 41 868 MJ

The MTOE has been used throughout Energy-Ireland and in this report because it is a conveniently sized unit when discussing national annual requirements.(50.103 MTOE per year = 1 million barrels per day, 7.5 barrels of crude oil = 1 tonne approx.)

Power is the rate at which work is done or the rate at which energy is converted.

The SI unit of power is the Watt (W)

1 Watt = 1 Joule per second.

When discussing energy in economic terms we are concerned with the output occurring as a result of energy use and the following expressions occur.

Where E is the amount of energy consumed per annum G is the Gross Domestic Product and Δ means the actual change from one year to the next:-

1. Percentage change in energy consumption: $\frac{\Delta E}{E} \times 100$

2. Marginal change in energy consumption (with respect to GDP) : $\frac{\Delta E}{\Delta G}$

   This can be seen as the energy used per unit of incremental output. It is mentioned in Energy-Ireland p.49, then confused with "efficiency".

3. Energy intensity (or intensiveness): $\frac{E}{G}$

   This gives the average amount of energy used per unit of GDP.

4. Energy effectiveness: (or efficiency) $\frac{G}{E}$

   This gives output per unit of energy input and is the inverse of energy intensity.

5. Energy elasticity (with respect to GDP): $\frac{\Delta E}{\Delta G} \times \frac{G}{E}$

   This is the percentage change in energy consumption per one per cent change in GDP (i.e $\frac{\Delta E}{E} \times 100$ divided by $\frac{\Delta G}{G} \times 100$)

This is defined in the Department's Energy Forecasts 1978-1990 as a "growth ratio" (p.6) and confused with energy intensity (p.7). So long as the elasticity is greater than 1, energy intensity is rising i.e.

$$\frac{\Delta E}{\Delta G} > \frac{E}{G}$$