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Fuel and Power in Ireland: Part I

Energy Consumption in 1970

by

J. L. BOOTH

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73 LOWER BAGGOT STREET, DUBLIN 2

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General Introduction

The use of fuel and power, or energy, in Ireland is the subject of these papers. Energy is needed to provide heat, light, and motive power to run our factories and homes, and to transport ourselves and the goods we consume from one place to another. In some instances we buy these services direct (as when we travel by public transport) and in others we own appliances with which to produce them from commercially available forms of energy (as, when we travel in our own cars, we use petrol). Ultimately we are in all cases buying services, or satisfactions of one sort or another, and here we are particularly interested in the energy involved in the provision of these services.

Each of the various commercially available forms of energy has its special physical and economic characteristics that make it more suitable for providing some particular services: petrol is primarily a transport fuel, and electricity is particularly well suited for lighting, for example. Yet, in principle, any of the basic forms of energy can be adapted to providing any of the services associated with the use of energy; a car *could* be made that would run on turf, but it would not be a very efficient device either technically or economically.

The supply of and demand for different forms of energy are subject to forces similar to those which bear upon the supply and demand for other groups of closely related commodities, like food or housing for instance. Indifferent substitution of one commodity within the group for another is not generally the case, but the extent of possible substitution is sufficiently large to justify the collection of the commodities concerned into a group, and to warrant study of the behaviour of the group as a whole. This, then, is the justification for considering as a group the different forms of energy, of fuel and power, that are used in Ireland.

The bulk of the work described in these papers is analytical in an historical sense. Its object has been to identify over a period from 1950 to 1963 how much energy was consumed in Ireland, in what form that energy was supplied, and for what purpose it was used. The combined emphasis upon the historical and statistical aspects proved necessary because the study of fuel and power has received relatively little attention in Ireland and both statistical data and descriptive information was lacking. It is hoped that this paper will do something to correct that deficiency.

However, the first and most important of the four papers that make up the series deals with the future and with projecting Ireland's energy needs forward to 1970. The remaining three papers may be regarded as supporting evidence and explanatory background material.

The four papers are, or will be :

Part I Energy Consumption in 1970.

Part II Electricity and Turf.

Part III International and Temporal Aspects of Energy and of Electricity Consumption.

Part IV Sources and Uses of Energy.

The author is an employee of the Royal Dutch/Shell Group of companies whose services were made available to The Economic Research Institute for the year from April 1964, to April 1965, to undertake the study which has resulted in the publication of these papers. He is responsible for their contents including any views expressed therein.

The author is grateful to a number of organisations for help in gathering together such statistical material on fuel and power consumption in Ireland as is available, and particularly to the following :—

Department of Transport and Power
Central Statistics Office
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Bord na Móna (Turf Board)
ESSO Petroleum Company (Ireland) Ltd.
Irish Shell and BP Ltd.

He is also indebted in a personal way to a number of people in these and other organisations who read and commented on the earlier drafts of this series of papers. They bear no responsibility for any errors or omissions.

Fuel and Power in Ireland: Part I

Energy Consumption in 1970

By J. L. BOOTH

INTRODUCTION TO PART I

The first part of this series of papers describes a forecast of energy consumption in Ireland up to 1970.

The year 1970 is chosen for the forecast because it is the end-year of the current programme for economic expansion, known as the Second Programme. The targets of that programme are outlined and they form the basic framework to which the projection of energy consumption is tied. Their achievement is a general assumption fundamental to the forecast pattern of energy use in 1970 that is built up. Additional, and more specific assumptions are made when necessary.

Reference is frequently made to work described in other parts of this series of papers and to figures and information contained therein. A list of titles to these other parts is given in the General Introduction.

PART I: ENERGY CONSUMPTION IN 1970

Summary

Energy consumption in Ireland from 1950 onwards will be described at some length in Part III of this series of papers. A forecast of consumption in 1970 is undertaken in the present paper, Part I. Table (i) shows how the resulting forecast compares with two selected years of the historical period; further comparisons are given in Tables 14, 15 and 16.

Commercial energy consumption is expected to grow at an average annual rate of 4·9 % p.a. between 1963 and 1970.

The Second Programme for Economic Expansion

A short outline of the aims and objectives of the Second Programme was laid by the Government before each House of the Oireachtas in August, 1963. This was followed in July, 1964, by a second

TABLE (i): ENERGY CONSUMPTION IN IRELAND; 1953, 1963 AND 1970

Form of Energy	1953 actual	1963 actual	1970 forecast
Indigenous Coal	164,000 tons	205,000 tons	145,000 tons
Mechanically-cut Turf[1]	666,000 tons	2,172,000 tons	3,555,000 tons
Hydro-electricity	437,000,000 kwh	684,000,000 kwh	720,000,000 kwh
Total Indigenous Energy[2] ..	$20{\cdot}5 \times 10^{12}$ Btu	$40{\cdot}2 \times 10^{12}$ Btu	$51{\cdot}2 \times 10^{12}$ Btu
Imported Coal	1,728,000 tons	1,436,000 tons	950,000 tons
Petroleum Fuels[3]	670,000 tons	1,550,000 tons	2,900,000 tons
Total Imported Energy[2] ..	$71{\cdot}5 \times 10^{12}$ Btu	$100{\cdot}1 \times 10^{12}$ Btu	$145{\cdot}6 \times 10^{12}$ Btu
Commercial Energy[2]	$92{\cdot}0 \times 10^{12}$ Btu	$140{\cdot}3 \times 10^{12}$ Btu	$196{\cdot}8 \times 10^{12}$ Btu
Hand-won Turf	3,132,000 tons	1,750,000 tons	1,500,000 tons
Total Energy[2] ..	$123{\cdot}3 \times 10^{12}$ Btu	$157{\cdot}8 \times 10^{12}$ Btu	$211{\cdot}8 \times 10^{12}$ Btu

Notes: [1]Includes Turf Briquettes.
[2]Conversion Factors are set out in Notes to Table 3; $25{\cdot}8 \times 10^6$ Btu equals one ton of coal.
[3]In the main these were domestically-refined products in 1963 and will be in 1970.

document ("Part II") that described in more detail the means to be adopted to achieve the targets, and the contributions expected from the major sectors of the economy. At the same time a publication by the Department of Agriculture set out at greater length the programme for agricultural development ("Agriculture in the Second Programme for Economic Expansion").

The basic principles of the First Programme were described in Part I of a 1958 White Paper and they remained fully applicable to the Second Programme. The private sector is expected[1] to be the principal source of new productive projects and public activity will concentrate on expenditure to increase the competitiveness of Irish goods in export markets. Higher productivity and greater competitiveness remain the key to permanent improvements in employment and community welfare.

The Second Programme covers the period up to 1970. Its chief objective is to raise the real national income by 50% in the 1960's (subsequently raised to 51 %, between 1960 and 1970), in line with the collective target of the O.E.C.D. This will require an average annual rate of increase in Gross National Product at constant market prices of 4·3% p.a. from 1963 to 1970. With employment expected to grow at nearly ¾% p.a. (a net increase from 1963 of 81,000 persons employed to a total of 1,136,000 in 1970), an average annual rate of growth of nearly 3½% p.a. in productivity or output per worker will be needed. By 1970, net yearly emigration should be reduced from 21,000 in 1962 to at most 10,000.

The increase in real GNP is expected to be shared between the main productive sectors of the economy in such a way that these sectors grow at the following average annual rates :—

	1960 to 1970	1963 to 1970
Agriculture, forestry and fishing	2·9% p.a.	3·8% p.a.
Industry	7·0% p.a.	7·1% p.a.
Other domestic	3·6% p.a.	3·6% p.a.

These rates of growth refer to "gross" sectoral products at factor cost including depreciation (i.e. they relate essentially to the value added to the cost of materials, fuel, etc., plus or minus indirect taxes and subsidies). Taxes and subsidies are expected to increase on balance at the same rate as national product. Net foreign income is thought likely to decline because of foreign disinvestment and borrowing.

On industry will be imposed the additional task of making up any shortfall in the projected expansion in agricultural output (and some shortfall is already apparent). The latter will concentrate on cattle and cattle products since these are the export markets which show most promise. In order to secure maximum efficiency and competitiveness of industry the process of reducing protection by tariff reductions will be continued, with selective action where necessary.

To achieve these increases it is a pre-condition that investment be raised as a proportion of GNP. It is envisaged that Gross Domestic Capital Formation must increase its share of GNP from the low rate of 14% in 1960 to at least 18% in 1970. An important corollary is that consumption spending should not increase as fast as GNP. In fact, by 1963 the share of Gross Domestic Capital Formation had already exceeded this target, and the target has since been raised to this 1963 level (18·4%). Other adjustments have been made to the pattern of expenditure expected and the current objectives are expressed in the following average annual rates of increase for each of the three main uses of resources :—

	1960 to 1970	1963 to 1970
Gross domestic capital formation	6·5% p.a.	4·4% p.a.
Personal consumption	3·6% p.a.	3·6% p.a.
Expenditure by public authorities	5·5% p.a.	6·4% p.a.

Imports and exports are expected to become more important in proportion to GNP, the ratio of the value of imports to GNP rising from 38·0% in 1960 to 45·6% in 1970, that of exports from 37·9 % to 44·0%. Thus, an insignificant export excess in 1960 is thought likely to become an import excess of just over 1½% of GNP by 1970. By 1963 the import excess had already risen to nearly 3½% of GNP. If imports continue to grow faster than exports then, of course, the amounts available for investment and for consumption spending within Ireland will be correspondingly restricted.

To achieve the 1970 target visible exports will have to increase at 6·9% p.a. and invisible exports at 4·1% p.a. on average between 1960 and 1970. This in turn will call for a rate of increase of 9·6% p.a. in industrial exports during the decade. Visible imports are expected to grow at an average annual rate of 6·1% p.a. and invisible imports at a rate of 6·6% p.a.

This is the framework of the Second Programme. The achievement of its aims depends upon many factors and not least upon a progressive attitude being taken towards industrial relations and upon acceptance of the need for rises in money incomes to be at least matched by increases in productivity. In the following paragraphs the author is concerned

[1]"Second Programme for Economic Expansion", August 1963, para. 21.

with fitting into this framework a probable pattern of energy supply and consumption in 1970. The more detailed provisions of the programme for the development of individual sectors of the economy, not referred to above, will be called upon where necessary.

Steps in Forecasting Energy Consumption

Now, at the forecasting stage, the object will be to take the provisions of the Second Programme as basic assumptions and to derive from them such conclusions as they permit about the future pattern of energy use. In this process, as in all forecasting, a large number of further assumptions will be needed; some of these assumptions will be explicitly made and commented on, but the majority will remain implicit in figures chosen and in methods adopted without their existence being remarked. The forecaster can use only the material at his disposal and where he cannot proceed by reasoned inference for lack of data he must make guesses, intuitive or arbitrary as the case may be.

Forecasts will be made at a number of levels. At each level it will be necessary to call upon results of a preliminary analysis of the supply and use of energy in Ireland in its international, temporal, and sectoral aspects that was undertaken with the aims of forecasting specifically in mind. This preliminary analysis, in its various stages, will be described in some detail in later papers in the present series and has already been referred to in the General Introduction.

First, a set of global forecasts will be derived using the results of some cross-section regression analyses of energy consumption and of electricity consumption in a number of countries. These forecasts can only be expected to provide the broadest of general indications. Second, and also at the global level, the consumption of all forms of fuel and power will be projected to 1970 using the results of a time-series regression analysis of energy consumption in Ireland since 1950.

The third step will be to consider the historical development of the supply of each form of fuel and power and to forecast the supply of each (independently) in 1970. A total will emerge that can be compared with the global forecasts just described. Fourth, and finally, the consumption of energy by each of the four major consuming sectors of the economy will be projected up to 1970 and the likely pattern of fuel use within each sector will be estimated. By aggregation again, totals will be formed to be compared with those of the preceding three exercises.

It will be necessary in conclusion to force some reconciliation between the forecasts made at these four levels in order to present a final best estimate of what the position will be in 1970.

Global Forecasts from International Comparisons

In Part III of this series of papers will be described a statistical comparison that was made of the levels of energy consumption per head in a number of countries throughout the world. The intention of the comparison, which used regression procedures, was to relate the level of energy consumption per head in a country in 1962 to the country's national income or product in the same year. It was found that certain other variables were also influential factors in the relationship. For technical reasons the relative importance of hydro-electricity as a source of energy proved significant, as did a rough measure of the average climatic conditions prevailing in the country. Also, to give some allowance for structural differences between mainly agricultural and mainly industrial countries, the share of agriculture in the national product was introduced as a regressor variable, and indeed in the case of European countries alone this variable proved more significant than national product itself.

Two regressions are referred to here: the first used data for 39 countries across the world and retained all four explanatory variables, and the second used data for the 16 European countries included in the sample. In this latter case only three of the explanatory variables were retained.

The 39-country cross-section regression yielded the following regression equation

$$
\begin{aligned}
Y - 1{\cdot}988 = 1{\cdot}982\,(X_1 - {\cdot}850) & \qquad (R^2 = {\cdot}83) \\
- {\cdot}0175\,(X_2 - 19{\cdot}7) & \\
- {\cdot}0607\,(X_3 - 5{\cdot}9) & \\
+ {\cdot}295\,(X_4 - 1{\cdot}2) &
\end{aligned}
$$

where Y is Total Energy Consumption in tons of coal equivalent per head

X_1 is GDP at factor cost in U.S. \$'000 per head

X_2 is percentage share of Agriculture in GDP

X_3 is percentage share of Hydro-electricity in Energy Consumption

X_4 is a Climate Index

Now, the predictions of the Second Programme refer to GNP at constant market prices, but a quick check reveals that between 1952 and 1962 GDP at factor cost and GNP at market prices grew in almost exactly the same proportion. It is therefore unlikely to be too much of a distortion to suppose that GDP at factor cost grows up to 1970 at the 4·4% p.a. expected (from 1962) for GNP. The Second Programme gives no forecast of population, and so it will be assumed that population rises slowly over the period to about 2·9 millions in 1970.[2] Thus it is estimated that GDP per head will rise from $755 in 1962 to $1,037 in 1970 (in the purchasing power-adjusted, 1938-exchange-rate dollars used in the analysis).

The percentage share of agriculture is expected to decline slowly from 23·4% in 1962 to 22·5% in 1970 (of GDP; GNP-based figures are about $1\frac{1}{2}$ points lower). The percentage share of hydro-electricity may be estimated roundly to fall from 1·7% in 1962 to 1·3% in 1970. The climate index corresponding to Ireland remains unchanged at 2.

Substitution of these values in the above equation gives a predicted level of energy consumption in 1970 of 2·825 tons of coal equivalent per head. This is the same as a total consumption of 8,193,000 coal equivalent tons, or $211{\cdot}4 \times 10^{12}$ Btu, with hydro-electricity included at its heat value.[3] Assuming that some 720 million units of hydro-electricity will be generated in 1970 and that the heat rate at thermal power stations then operating will be 12,500 Btu/kwh on average (compared with 14,600 in 1962; net heat input/sent-out electricity), instead of counting as $2{\cdot}6 \times 10^{12}$ Btu hydro-electricity should count as $9{\cdot}0 \times 10^{12}$ Btu on an equivalent fuel consumption basis. This adjustment brings the estimate of total energy consumption in 1970 up to 217·8, in comparison with $149{\cdot}1 \times 10^{12}$ Btu in 1962; the implied rate of growth is 4·8% p.a. It may be remarked that this estimate includes non-commercial turf.

An alternative estimate may be derived from the regression analysis of energy consumption in 16 European countries using the following regression equation:

$$\begin{aligned} Y - 2{\cdot}554 = &-{\cdot}110\,(X_2 - 13{\cdot}8) \qquad (R^2 = {\cdot}85) \\ &-{\cdot}040\,(X_3 - 8{\cdot}5) \\ &+{\cdot}493\,(X_4 - 1{\cdot}8) \end{aligned}$$

with the same meanings attached to the variables (GDP was in this case not significant). This equation cannot, unfortunately, be used in a similar straightforward manner for forecasting because, on eliminating GDP as an explanatory variable X_2 (the percentage share of agriculture) has to take over its rôle as a measure of the development of the economy. Normally as an economy grows so its dependence on agriculture falls, with agricultural output per head more or less unchanged. But the special emphasis to be given to Irish agricultural exports means that agriculture's share of GDP is expected to decline only slightly as the economy advances. To correct roughly for this it may be supposed in this prediction model that the absolute level of agricultural product does not increase and that its share therefore declines not to 22·5% but to 17·7% in 1970.

Substitution of this value for X_2, and the same values as before for X_3 and X_4, leads to a predicted per capita consumption of energy of 2·512 tons of coal equivalent per head, or 7,285,000 tons of coal equivalent in total ($188{\cdot}0 \times 10^{12}$ Btu). Adjusted for hydro-electricity as before, total energy consumption in 1970 is estimated at $194{\cdot}4 \times 10^{12}$ Btu with an average rate of growth between 1962 and 1970 of 3·4% p.a.

The two estimates are reasonably close together given the limitations of the method, the one indicating a growth rate of 4·8% p.a., the other of 3·4% p.a. Confidence limits for these estimates would of course be impossibly wide.

To forecast electricity consumption a similar procedure may be followed and advantage taken of statistical analyses of the levels of electricity consumption throughout the world, and their dependence on such factors as national product, that will be described in Part III.

First, a regression of electricity consumption per head for the full cross-section of 39 countries in 1962 may be referred to. A set of four explanatory variables similar to those used in the analysis of energy consumption were brought into the regression; the only difference in fact was that the third variable, the share of hydro-electricity, was measured as a percentage of all electricity consumption, for reasons that are explained in Part III. Two of the variables were rejected on grounds of significance and the following regression equation resulted

$$\begin{aligned} Y - 1{\cdot}721 = &+2{\cdot}331\,(X_1 - {\cdot}850) \qquad (R^2 = {\cdot}72) \\ &+{\cdot}0254\,(X_3 - 44{\cdot}9) \end{aligned}$$

where Y is Electricity Consumption per head in '000 kwh

X_1 is Gross Domestic Product per head in U.S. $'000

X_3 is percentage share of Hydro-electricity in all Electricity Consumption

Substitution of appropriate estimates of the values of X_1 and X_3 in Ireland in 1970 (GDP of $1,037 per head and hydro-electricity 15% of all electricity consumption) yields the forecast that electricity consumption per head will increase from 920 kwh in 1962 to 1,390 kwh in 1970, or total electricity

[2]In E.R.I. Memorandum No. 21 "Recent Demographic Developments in Ireland", C.E.V. Leser suggests an increase in population of about this order.

[3]Following the convention adopted in UN Statistics, international comparisons were made with hydro-electricity included in this way i.e. as the heat value of the electricity produced. In making temporal comparisons and for the purposes of forecasting hydro-electricity is counted as the heat value of the fuel that would have been needed to produce it in thermal power stations.

consumption from 2,598 million kwh to 4,030 million kwh in 1970. This represents an average annual rate of growth of 5·6% p.a.

A second regression was carried out using the data for European countries alone. From this sample Norway and Sweden had to be excluded because of being such heavy users of electricity and therefore untypical members of the sample of countries. As in the case of energy consumption, the percentage share represented by Agriculture in the country's Gross Domestic Product proved more significant as an explanatory variable than GDP itself, and moreover the continued retention of GDP in the regression could not be justified statistically. The regression equation was

$$Y - 1{\cdot}741 = -{\cdot}086\,(X_1'' - 14{\cdot}7) + {\cdot}0105\,(X_3 - 41{\cdot}4) \qquad (R^2 = {\cdot}84)$$

where X_1'' is percentage share of Agriculture in GDP and Y and X_3 take the same meanings as above.

On substitution for estimated 1970 values of the regressor variables this equation predicts that electricity consumption per head in Ireland will increase from 920 kwh in 1962 to 1,206 kwh in 1970. Total consumption would increase from 2,598 million kwh to 3,490 million kwh a rate of increase of 3·8% p.a.

Both these estimates of the rate of growth in electricity consumption are low; indeed, the inadequacies of a cross-section model for use over time are very serious in the case of electricity consumption because of the continuous technical innovations that are taking place. What is happening is that the increasing importance of electricity with time is a fact of life everywhere that is not taken into account in a static regression model. These estimates cannot therefore be taken very seriously.

Global Forecasts from Time-Series

The forecasts considered next are derived from regression models using time-series data of energy consumption in Ireland from 1950 to 1963. In the principal regression, which is described in Part III of this series of papers, four explanatory variables were considered: real national product, the average price of energy, time, and a measure of winter temperature conditions. A regression of commercial energy consumption on these variables gave the following regression equation, two of the variables being rejected for lack of significance

$$Y - 2{\cdot}025 = 1{\cdot}64\,(X_1 - 2{\cdot}739) + 0{\cdot}27\,(X_4 - 1{\cdot}999) \qquad (R^2 = {\cdot}92)$$

where Y is log Commercial Energy Consumption in 10^{12} Btu

X_1 is log GNP at constant (1953) market prices in £ million

X_4 is a variable relating to annual winter temperatures

At 1953 prices, GNP in 1963 was £649 million. The 35% increase by 1970 expected in the Second Programme would bring it to £876 million. This gives an estimated level of commercial energy consumption in 1970 of 229×10^{12} Btu under average temperature conditions; the implied average annual rate of growth is 7·2% p.a. from $140{\cdot}3 \times 10^{12}$ Btu in 1963. It may be noted that the trend rates of growth from 1950 to 1963 and from 1958 to 1963 were, respectively, 3·2% p.a. ($R^2 = {\cdot}80$) and 6·7% p.a. ($R^2 = {\cdot}99$). Extrapolated to 1970 these trends would suggest levels of consumption of 175 and of 221×10^{12} Btu respectively in 1970.

Total energy consumption can be predicted in a similar way in relation to GNP and gives an estimated consumption in 1970 of $234{\cdot}1 \times 10^{12}$ Btu ($R^2 = {\cdot}79$), a rate of growth (from $157{\cdot}8 \times 10^{12}$ Btu in 1963) of 5·8% p.a. Simple projection of trend rates of growth over time gives estimates of $175{\cdot}2 \times 10^{12}$ Btu (1950 to 1963; 1·5% p.a.; $R^2 = {\cdot}51$) and of $228{\cdot}0 \times 10^{12}$ Btu (1956 to 1963; 5·4% p.a.; $R^2 = {\cdot}90$) in 1970.

Electricity Consumption

In Part III of this series of papers will be discussed the statistical analysis of the growth of electricity consumption in Ireland since 1950 in two parts. First, a regression model was set up to relate annual consumption to GNP, time, and average winter temperature, over the 1950 to 1963 period; then, since temperature did not prove to be significant a more detailed examination of quarterly consumption was made in relation to time and temperature, and very close correlations were discovered.

The model using annual data indicated an elasticity over the 1950 to 1963 period of about 3·9 between the growth in electricity consumption and the growth of GNP ($R^2 = {\cdot}89$). With GNP forecast to increase at 4·3% p.a. this would suggest that electricity consumption might grow at 16·8% p.a. Such a rate would seem unreasonably high and indeed there were strong statistical grounds for preferring simple time trends. The trend rates of growth in annual consumption were 8·7% p.a. from 1950 to 1963 ($R^2 = {\cdot}99$), and 10·4% p.a. from 1958 to 1963 ($R^2 = {\cdot}99$). The latter rate of growth is suspiciously high because it takes no account of the effects of the abnormally low temperatures during the last years of the period.

This was confirmed by the analysis of quarterly data, which gave temperature-corrected trend rates of growth of 8·8, 8·3, 8·4 and 8·2% p.a. (R^2 was very close to unity in all cases) for the four quarters of the year (relating in fact to the period 1957 to 1963; the inclusion of 1957 makes little difference). If consumption under average temperature conditions in each of the four quarters of 1970 is predicted separately and the resulting estimates are added together, the estimated total consumption of electricity in 1970 is 4,917 million kwh (the prediction in fact related to consumption after deducting generation and transmission losses; it was 4,434 m.kwh, split by quarters 1,342; 945; 890; and 1,257). From the actual 1963 total consumption of 2,851 m.kwh this represents a rate of growth of 8·1% p.a. It may be remembered that 1963 was a cold year and consumption in that year was above trend; thus, measured from a 1963 base the forecast rate of growth in consumption appears slightly deflated in comparison with the historical trend.

Global Forecasts Compared

It will be useful at this stage to summarise the various global forecasts described above. This is done in Table 1.

The forecasts in Table 1 differ considerably from each other. This is indeed a characteristic of all forecasting work, not only of purely statistical extrapolations as those are, that the margin of uncertainty is wide and reliance on one method rather than another is a matter of judgement.

In the case of energy consumption it is felt that more reliance can be placed on forecasts derived from time-series regressions using GNP as principal explanatory variable. However, the respective forecasts of total energy consumption and of commercial energy consumption are inconsistent with each other to the extent that they imply a fall in the use of hand-won turf from its current rate of 1,800,000 tons to only some 300,000 tons. This seems very unlikely. Suppose that it falls to, say, 1,500,000 tons and that the adjustment is shared equally between the two forecasts; this gives the following estimated level[8] of consumption in 1970, which may be taken as best estimates at this stage:—

Commercial Energy 224×10^{12} Btu (6·9% p.a. 1963–70)

Total Energy 239×10^{12} Btu (6·1% p.a. 1963–70)

In the case of electricity consumption the most satisfactory correlations were obtained with Time as principal explanatory variable rather than GNP, and indeed R^2 very close to one were realised. A simple extrapolation of the trend would therefore seem to be the most reasonable way of forecasting electricity consumption at this global level. For the sake of argument a best estimate of 8·5% p.a. will be taken as the likely rate of growth up to 1970, to give consumption of 5,050 m.kwh.

Forecasts of Supply by Form of Primary Energy

The third step in the forecasting scheme is to consider the supply of each of the primary forms of energy independently and to attempt to derive some estimate of the quantities that may be available for consumption in 1970. This is not easy to do without admitting into the assessment considerations that are primarily related to consumption and to the end-use of energy. Nevertheless it will be a useful exercise if only to reveal whether or not there exist constraints on the supply of one form of energy or another.

The use of coal and coke has declined in importance over the last fourteen years, from representing 62·5% of all commercial energy in 1950 to 30·4% in 1963. In absolute terms the decline has not been quite so marked, falling from $54 \cdot 2 \times 10^{12}$ Btu in 1950 to $42 \cdot 7 \times 10^{12}$ Btu in 1963, of which some $5 \cdot 6 \times 10^{12}$ Btu were produced in Ireland (compared with $3 \cdot 6 \times 10^{12}$ Btu in 1950). The supply

TABLE 1: COMPARISON OF GLOBAL FORECASTS FOR 1970

Method of Forecast	Estimated Consumption in 1970 (growth rate)		
	Total Energy 10^{12} Btu	Commercial Energy 10^{12} Btu	Electricity 10^6 kwh
Cross-Section Analysis:			
—all countries	218 (4·8% p.a.)	—	4,030 (5·6% p.a.)
—European countries	194 (3·4% p.a.)	—	3,490 (3·8% p.a.)
Time-Series Analysis:			
—from GNP	234 (5·8% p.a.)	229 (7·2% p.a.)	8,440 (16·8% p.a.)
—trend projection 50–63	175 (1·5% p.a.)	175 (3·2% p.a.)	5,115 (8·7% p.a.)
—trend projection 58–63	228 (5·4% p.a.)	221 (6·7% p.a.)	4,917 (8·1% p.a.)[2]

Notes: [1]In the case of estimates under Cross-Section Analysis growth rates are calculated with respect to 1962 actuals; in the case of estimates under Time-Series Analysis with respect to 1963 actuals.

[2]Trend derived from temperature-corrected quarterly data for 1957 to 1963 period.

and consumption of coal will be described in Part IV.

It would be physically possible to increase production of coal from indigenous sources. The expansion of the power station at Arigna would make it possible to produce more semi-bituminous coal at that field. Present production is about 75,000 tons a year. However, an investigation by the Department of Transport and Power into the feasibility of increasing the generating capacity at Arigna showed that the increased use of low-grade Arigna coal would be altogether uneconomic.

Anthracite production could also perhaps be increased but it is more likely that production will fall in spite of the fact that anthracite can command very high prices in the domestic market of up to £17 a ton, if clean and of good quality. In recent years production has been about 130,000 tons a year. Production is in the hands of private enterprise, the two main producers being the Ballingarry and Castlecomer mines. The future of the Castlecomer mines is uncertain, however. With a view to assisting Irish producers in disposing of their output, in competition with British anthracite, the Department of Transport and Power has commissioned an investigation into the marketing of Irish anthracite.

Few constraints are likely to arise on the importation of either industrial or domestic coals. The former come from Britain, a country faced with a falling home market and keen to keep its exports as high as possible. Domestic coals come from various countries; but the export potential of the United States in particular is so great that supplies for the Irish market are well-assured.

To have some figures in mind, suppose that indigenous production of anthracite falls to about 70,000 tons a year in 1970, but that production of semi-bituminous coal continues at 75,000 tons. Then indigenous coal will contribute some $3{\cdot}8 \times 10^{12}$ Btu. Suppose further that imports of coal continue their long-term decline to between say 0·8 and 1·2 million tons in 1970, or $20{\cdot}6$ to $31{\cdot}0 \times 10^{12}$ Btu. Thus a possible level of coal and coke consumption (from the supply aspect) might lie between 24·4 and $34{\cdot}8 \times 10^{12}$ Btu in 1970.

The turf industry in Ireland will be discussed in some detail in Part II of these papers. The future supply of turf is relatively easy to estimate because Bord na Mona's production plans have to be set out, and the corresponding investment committed, well in advance. The Board estimates that by 1970 it will be producing and selling some 945,000 tons of machine turf, 2,150,000 tons of milled peat (excluding use for briquetting), and 465,000 tons of briquettes. These figures compare with sales of 943,000 tons of machine turf, 1,005,000 tons of milled peat, and 281,000 tons of briquettes in 1963/64. Machine turf output will show little or no growth, milled peat output for sale will more than double (all of the increase taking place by 1966), and briquette output will rise by 65% (most of the increase taking place after 1968 when the prospective new briquette factory in the Shannonbridge, Co. Offaly, area is planned to come into operation). There seems little doubt of the Board's ability to sell these quantities of turf and even, in the case of briquettes, to sell more if further quantities were available. Consumption for electricity generating will be discussed in some detail later.

On these estimates commercial forms of turf will contribute $38{\cdot}1 \times 10^{12}$ Btu of primary energy in 1970, a rate of growth of 6·0% p.a. over the 1963 level of 25.4×10^{12} Btu.

It has already been mentioned that hydro-electricity may be expected to contribute some $9{\cdot}0 \times 10^{12}$ Btu in thermal power station-input equivalent.

The remaining primary source of energy is imported petroleum and here, as with coal, there are no foreseeable supply constraints. For all the discussion one hears of the future scarcity of oil as world's reserves begin to run down there is no short-term prospect of a world shortage of oil. In economic terms such statements are meaningless since all goods are scarce and their relative scarcities determine their relative prices; goods that are not scarce are free. So with oil one should not think in terms of absolute quantities available but rather in terms of the quantities that can be made available at different price levels. As oil becomes more difficult to find and to produce, costs will rise and less oil will be forthcoming at a given price. The present situation is that more oil could easily, even in the short-term, be produced than is currently being consumed, and there is a strong downward pressure on prices. The oil industry has been lamenting for some time now what it considers to be the inadequate return it is securing on its (admittedly risky) investments. It is almost a matter of certainty (political developments apart) that the price of oil in world trade will not move strongly upwards for some years; it is a matter of opinion how long this period will last, but it will at least cover the years included in this examination of Ireland's future energy needs. Oil supply in Ireland will be dealt with in Part IV of this series of papers.

Petroleum fuels contributed 25·4% of all primary commercial energy needs in 1950 and this share rose to 44·9% by 1963. The trend rates of increase in consumption of all petroleum fuels were 7·3% p.a. from 1950 to 1963 and 12·3% p.a. from 1958 to 1963. The rates of increase in the various fuels included in the total varied quite widely. Perhaps the most reasonable projection procedure is to extrapolate the

TABLE 2: TENTATIVE PROJECTIONS TO 1970 OF OIL FUELS' SUPPLY

Product	Consumption in 1963	Trend period selected	Trend rate of growth	Consumption in 1970
L.D.F.	4·9 th. tons	—[1]	—	50·0 th. tons
Motor spirit	104·5 m. gals.	1958 to 63	+ 5·9 % p.a.	144·6 m. gals.
Kerosines	23·0 m. gals.	1958 to 63	− 3·9 % p.a.	17·4 m. gals.
Gas/Diesel oils ..	86·8 m. gals.	1958 to 63	+10·3 % p.a.	172·4 m. gals.
Fuel oil	188·2 m. gals.	1950 to 63	+11·1 % p.a.	393·3 m. gals.
L.P.G.	18 th. tons	—[1]	—	25 th. tons
Total[2] ..	63·0 × 10^{12} Btu[3]	—	+ 8·9 % p.a.	115·0 × 10^{12} Btu[3]

Notes: [1]Consumption time-series for these products are not suitable for extrapolation; arbitrary estimates are shown (they are in any case of only minor importance).

[2]Total consumption in 1970 is the weighted aggregate of consumption of individual products and not the projection of a historical trend.

[3]See Note [3] to Table 3.

trend rates of growth of these individual fuels, the trends being taken over appropriate periods. One such scheme is given in Table 2.

The figures in Table 2 suggest that, from consideration of the individual products, total oil fuels' consumption might grow at 8·9% p.a. to 115·0 × 10^{12} Btu in 1970. To have a convenient bracket, the rate of growth might be taken to lie between 7% p.a. and 11 % p.a., which give levels of consumption in 1970 of 101·2 and 130·7 × 10^{12} Btu respectively.

Aggregation of the different energy sources leads to the pattern of supply in 1970 shown in Table 3. The resulting forecast of commercial primary energy consumption in 1970, shown in this Table, is not a single figure but a fairly wide range of possible levels of consumption, from 172·0 to 212·0 × 10^{12} Btu with a median level of 192·0 × 10^{12} Btu. The upper limit of this range is about 5% less than the best estimate selected earlier from the various global projections of energy consumption (224·0 × 10^{12} Btu). Some disagreement is suggested (even with such rough estimates) which it will only be possible to resolve at the fourth stage when patterns of consumption by sector are considered.

Forecasts of Energy Consumption by Sector

Each of the main consuming sectors will be considered in turn and forecasts made of their likely use of energy in 1970. Some of the energy used will be supplied in the form of gas and electricity and it will be necessary, as a second step, to estimate the quantities of primary energy that will be needed to produce the estimated total amounts of gas and electricity needed. This having been done, it will be

TABLE 3: TENTATIVE PROJECTIONS TO 1970 OF COMMERCIAL PRIMARY ENERGY SUPPLY

Form of Energy	Consumption in 1963		Projected Rate of Growth	Consumption in 1970	
	10^{12} Btu	%		10^{12} Btu	%
Indigenous Coal	5·6	4·0	—	3·8	2·0
Turf	25·4	18·1	6·0 % p.a.	38·1[4]	19·9
Hydro-electricity	9·2	6·6	0 % p.a.	9·0	4·7
Sub-Total	40·2	28·7	3·5 % p.a.	50·9	26·6
Imported Coal[1]	37·1	26·4	−8·1 (−5·1)−2·5 % p.a.	20·6 (25·8) 31·0	(13·5)
Petroleum Products[1]	63·0[2]	44·9	7·0 (8·9) 11·0 % p.a.	100·1 (115·0) 129·6[2]	(59·9)
Total	140·3	100·0	2·9 (4·6) 6·0 % p.a.[3]	171·6 (191·7) 211·5	(100·0)

Notes: [1] For these (imported) fuels ranges of possible rates of growth are shown; the percentages in the last column are calculated with respect to the median rates (given in brackets).

[2]These figures exclude Light Distillate Feedstocks in order to be consistent with the basic energy balance described in Part III; the difference is small.

[3]These are the growth rates corresponding to the aggregates shown in the next column.

[4]Excludes mechanically-cut turf from non-Bórd na Móna sources (small in quantity).

The following conversion factors have been used:

coal	25·8 m.Btu/ton	motor spirit	138,000 Btu/ton
machine turf	13·4 m.Btu/ton	kerosines	149,000 Btu/ton
milled peat	7·7 m.Btu/ton	gas/diesel oils	156,000 Btu/ton
turf briquettes	19·0 m.Btu/ton	fuel oils	164,000 Btu/ton
hand-won turf	10·0 m.Btu/ton	liquefied gases	43·7 m.Btu/ton.

Hydro-electricity has been converted into the fuel input required to generate the given quantity of electricity in thermal power stations at prevailing average efficiencies.

possible by aggregation to obtain a forecast of commercial primary energy consumption to compare with the estimates derived earlier.

Industry

In 1962, All Industry and Services (C.I.P. large establishments, excluding gas and electricity undertakings) consumed just less than 30% of all commercial primary energy used in Ireland, with consumption of secondary forms of energy (gas and electricity) counted as the input of primary energy required to produce them. This proportion had increased somewhat during the preceding ten years or so. Details will be given in Part IV of these papers.

To make allowance for the effects of the different average efficiencies at which the various forms of energy are consumed within industry, the "effective" consumption of energy of this sector was considered in a time-series regression analysis with volume of output, fuel price, and time as explanatory variables. Effective energy consumption is the sum of the heat contents of the individual forms of energy each weighted by its estimated average (relative) efficiency in use. The results of the regression analysis were not conclusive and two possible regression equations resulted, the one using volume of output alone and the other using fuel prices and time as explanatory variables, viz:

(i) $Y-1{\cdot}1111=+1{\cdot}25\ (X_1-2{\cdot}0226)\ (R^2=\cdot 81)$

(ii) $Y-1{\cdot}1111=-0{\cdot}71\ (X_2-2{\cdot}0211)\ (R^2=\cdot 84)$
$+\cdot 0143\ (T-6)$

where Y is log effective energy consumption in 10^{12}Btu,

X_1 is log volume index of output measured from 1953=100,

X_2 is log average fuel price per Btu measured from 1953=100, and

T is time in years with T=0 in 1950.

Industrial output is planned to increase at 7·1% p.a. 1963 to 1970. This growth rate refers to the output of All Industry and Services, while the volume index used in the above regression (i) refers to a slightly more restricted sector which excludes electricity and townsgas undertakings. The difference is unlikely to be of much significance for electricity output might grow a little faster than 7·1% p.a., and townsgas, which is much less important, considerably slower. Thus it seems not unreasonable to project the volume index of output of regression (i) at 7·1% p.a., from 135·4 (with 1953=100) in 1962 to 234·2 in 1970.

Average fuel prices had fallen to 90 in 1962, in relation to 1953=100, and it is reasonable to suppose that the decline will continue since the long-term effect at least is affected by the swing to heavy oils (which will certainly continue). Somewhat arbitrarily, a value of 75 will be taken for 1970.

The resulting estimates from the two regressions are as follows, with growth rates measured from a level of $17{\cdot}5\times 10^{12}$Btu in 1962:—

(i) $35{\cdot}1\times 10^{12}$Btu (9·1% p.a.)

(ii) $26{\cdot}0\times 10^{12}$Btu (5·1% p.a.)

The area of disagreement between these two estimates is large, but understandably so. The latter is basically a time-series extrapolation from a period of relatively slow overall growth, which takes no account of the accelerating growth of output. The former does this and is therefore to be preferred (although the preference cannot be justified in a purely statistical sense). The other estimate might be interpreted as the situation in 1970 if the ups and downs of the 1950's were to recur in the 1960's.

The next problem is to translate $35{\cdot}1\times 10^{12}$Btu effective energy consumption into actual energy consumption, and this requires some estimate of the contributions to be made by the different forms of energy.

In 1962 consumption of coal and coke was 415,000 tons, of which some 165,000 tons were used by industries in the Clay, Glass and Cement Group. These industries are known to be changing over to oil. If substitution of *oil* for coal elsewhere is just about balanced by increased coal consumption in those establishments that continue to use coal, then consumption in 1970 might be taken at 250,000 tons, though this will tend to be a high estimate. Turf consumption has been fairly stable at 75,000 tons or so and may be assumed to continue at this level. Gas consumption has grown rapidly in the last few years and reached 870 million cubic feet in 1962 and might be projected at 6% p.a. to 1,390 million cubic feet in 1970. A growth rate less than either the rate of growth of output or the rate of growth of all energy consumption (by industry) is chosen because townsgas is not available in some of the new industrial areas. Electricity consumption may be projected at its long-term trend rate of growth of 10% p.a., from 822 million kwh in 1962 to 1,765 million kwh in 1970. The fuel not so far considered is heavy oil, and this may be presumed to supply the remaining energy needs of the sector in 1970. Its contribution is shown in Table 4.

The figures in Table 4 present a picture of consumption in 1970 and of growth in consumption between 1962 and 1970 that appears to be reasonable. The rate of growth in heavy oil consumption is very high indeed but growth rates of this order of magnitude have been experienced in the use of industrial heavy oils in many European countries

TABLE 4: PROJECTION TO 1970 OF ENERGY CONSUMED BY INDUSTRY

Form of Energy;	Effective Energy Consumption; 10^{12} Btu[4]		Actual Energy Consumption 10^{12} Btu		Original Units[2]			Growth rate
	1962	1970	1962	1970	1962	1970	unit	1962–70
Coal and coke	5·9	3·6	10·7	6·5	415	250	th. tons	—6·2% p.a.
Turf	0·5	0·5	1·1	1·0	80	75	th· tons	0% p.a.
Heavy oils[3]	8·1	24·8	12·5	38·2	77·4	236	m. gals.	14·9% p.a.
Townsgas	0·3	0·5	0·4	0·6	870	1,390	m. cu. ft.	6·0% p.a.
Electricity	2·7	5·7	2·8	6·0	822	1,765	m. kwh.	10·0% p.a.
Total	17·5	35·1						9·1% p.a.

Notes: [1]The following relative efficiency factors have been used:
coal and coke ·55 heavy oils ·65
turf ·50 townsgas ·75
electricity ·95

[2]Conversion factors are as follows:
coal and coke 25·8 m.Btu/ton
turf 13·4 m.Btu/ton
electricity 3,412 Btu/kwh.
heavy oils 162,000 Btu/gal.
townsgas 450 Btu/cu. ft.

[3]Excludes Oil Refinery fuel consumption.

[4]Excludes automotive fuels.

(e.g. Germany) during recent years; such a rate of growth cannot be rejected simply because it is high.

All of the major industrial groups are not expected to increase output at the same rate, and there may in consequence be structural effects that are not allowed for in the estimates just derived. Without time-series of energy consumption by industrial group and without a considerable additional amount of information about the use of energy within each group, it is not possible to make separate predictions of the pattern of use of fuel and power by each. The Clay, Glass and Cement Group uses more energy per £ of net output, for instance, than any other group of industries and the output of this group is forecast during the Second Programme to grow faster than average, at 10·3% p.a. But what is not known is how the energy consumption of this group of industries has been related in the past to its output over a period of years and how it will be related in the future; nor is it known whether, for instance, electricity consumption is likely to grow particularly fast in this group of industries. To answer these questions requires considerable statistical information at the macro-level and knowledge of technical and commercial conditions at the micro-level. They are beyond the bounds of this paper.

Inland Transport

Consumption of energy for inland transport of passengers and goods represented in 1963 just under 15% of primary commercial energy consumption. That percentage had declined over the past decade or so, mainly because of the displacement of coal as a fuel for railway transport.

In forecasting the use of energy for transport purposes various difficulties are encountered. The first is that reliable historical data of the numbers of passenger-miles run and of ton-miles of goods carried do not exist; and therefore the growing transport needs of the economy cannot be related in explicit fashion to the growth of the economy itself over the past few years. Thus the forecast must rest, as far as these objective measures of levels of transport activity are concerned, on a foundation of not particularly reliable estimates. Furthermore, even given expected volumes of traffic, of passenger-miles to be run and of ton-miles of goods to be carried, that traffic can be distributed between road and rail, between private and public means of transport, between short- and long-haul, and between one type of vehicle and another in a variety of ways, and the way the traffic is distributed will affect the quantity and the type of the fuel needed. Again, the type of transport affects its pattern of use: when a family buys a motor-car it may begin to adopt an entirely different set of social habits and develop new transport needs accordingly, the distributor who acquires his own fleet of delivery vehicles may find that it pays him to set up an entirely different pattern of retail outlets. Finally, neither passenger-mileage nor ton-mileage would be acceptably autonomous variables for very long-term forecasting since both depend to an important extent upon the dispersion both of the population and of the centres of industrial and agricultural activity. The depopulation of rural areas, urban renewal, and suburban development will all slowly change the pattern of transport need, as will regional programmes of industrial development.

Both the data available and the scope of this paper are too limited to attempt a comprehensive survey of the possible future pattern of transport activity. In broad terms it will be assumed that the trend towards greater use of private passenger transport—the motor-car—will continue and that the increased transport of goods will be taken by road rather than rail vehicles. More specifically, the future consumption of road vehicle fuels will be projected by considering the possible rates of increase in the numbers of road vehicles and their annual utilisations. Fuel consumption for rail transport will be assumed to continue more or less at its present level. The basic analysis underlying these various predictions will be presented in detail in Part IV.

Road Transport

In Table 5 are given forecasts of the future populations of passenger and goods vehicles in road use. These forecasts are obtained by projecting to 1970 trend rates of growth calculated over selected historical periods. In the case of goods vehicles a low rate of growth in the numbers of vehicles is foreseen but this will be accompanied by a continuing trend towards the use of heavier vehicles, of greater carrying capacity, which in turn will lead to an increased fuel consumption per vehicle-mile run. An overall rate of increase in the volume of goods carried by road of about 6% p.a. may be expected, a rate which lies between the expected rates of growth of agricultural and of industrial production. Part II of the Second Programme mentions in Chapter 9 that the number of mechanically-propelled vehicles on the roads will grow to over 500,000 by 1970, and the total forecast arrived at in Table 6 agrees with this rough prediction.

The next step is to estimate the average numbers of miles run annually in 1970 by each type of vehicle. This cannot be done with any precision in the case of petrol-burning vehicles since, given only *total* petrol consumption, it is impossible to estimate independently the miles run by cars and by petrol-burning goods vehicles. It will be assumed here that petrol-burning goods vehicles have been running an average of 8,500 miles a year (including an allowance for miles run on other than business trips) and that this annual mileage remains unchanged in 1970. It can be estimated that the average annual mileage of private cars was 12,700 miles in 1953, and that it declined to 11,500 miles in 1963. For 1970 an estimate of 10,800 miles will be taken, which assumes that the decline will continue at about the same rate as more and more families in the lower income groups buy cars but tend to use them more exclusively for leisure activities. The deriva-

TABLE 5: FORECAST POPULATION OF ROAD VEHICLES BY TYPE IN 1970

Type of vehicle	Numbers of vehicles				
	Population Aug. 1963	Trend Rate of Growth	Period of Trend	Projected Rate	Population 1970
Private cars	229,125	9·4% p.a.	1957 to 63	9·5% p.a.	433,000
Exempt vehicles	5,059	5·0% p.a.	1958 to 63	3·0% p.a.	6,200
Taxis[1]	4,113	—	—	—	4,000
Motor cycles	49,529	6·0% p.a.	1960 to 63	3·0% p.a.	60,900
Goods vehicles (petrol)	30,570	—	—	−1·6% p.a.	28,400[3]
Total goods vehicles	44,743[2]	1·6% p.a.	1961 to 63	2·0% p.a.	51,400[3]
Goods vehicles (diesel)	14,173	—	—	7·0% p.a.	23,000[3]
Buses	1,514	1·5% p.a.	1958 to 63	1·5% p.a.	1,700
Miscel. vehicles	1,236	7·0% p.a.	1958 to 63	7·0% p.a.	2,000
Total vehicles	335,319				559,200

Notes : [1]includes hearses

[2]excludes electrically-propelled vehicles

[3]the breakdown by size and by fuel of commercial goods vehicles in 1970 is forecast as follows :

Unladen weight	Petrol	Diesel	Total
Up to 16 cwt.	13,000	0	13,000
16 cwt. to 2 tons	15,000	5,000	20,000
2 tons to 3 tons	300	2,700	3,000
3 tons and over	100	15,300	15,400
Total :	28,400	23,000	51,400

The average unladen weight is estimated to increase from 39 cwt. in 1963 to 44 cwt. in 1970.

tion of these estimates is described in Part IV.

The average annual mileage of diesel-driven goods vehicles is estimated to have increased from 13,500 miles a year in 1953 to 18,700 miles a year in 1963. This is already a fairly high mileage and a slightly slower rate of increase will therefore be forecast up to 1970, i.e. to 21,200 miles a year.

Average fuel consumption in 1970 may be estimated at ·027 gals/mile against ·028 in 1963 for private cars, ·060 gals/mile compared with ·064 in 1963 for petrol-driven goods vehicles, and ·080 gals/mile for diesel-driven goods vehicles, the increase from ·075 in 1963 being attributed to the increasing average unladen weight of these vehicles. Having made these assumptions, the derivation of forecasts of road vehicle consumption of fuel in 1970 requires only simple calculations, the results of which are shown in Table 6.

The figures in Table 6 suggest that petrol consumption will grow from 104·2 million gallons in 1963 to 154·7 million gallons in 1970, an average annual rate of increase of 5·8% p.a., and diesel consumption from 26·2 million gallons in 1963 to 48·3 in 1970, a higher rate of increase of 9·1% p.a. The projected rate of increase in petrol consumption is roughly the same as the trend rate of increase over the 1958 to 1963 period. That of automotive diesel is much less than the historical trend (over the same period) of just over 16% p.a., because the extremely rapid substitution of diesel—for petrol-burning vehicles must now begin to slow down as the possibilities of further substitution diminish. It is to be expected that the turning-down of the rate of growth will take place gradually, however, and that high rates of growth in diesel consumption will continue for a few years to come.

Rail Transport

The railways use only small quantities of fuel, some 29,700 tons of heavy diesel oil in 1963/64, or 7·8 million gallons. It will be assumed that the number of engine-miles run in 1970 will contract slightly, as rationalisation continues, but that about the same total volume of traffic will be carried in 1970 as in 1963/64. This will lead to loads being a little heavier and fuel consumption per engine-mile possibly a little higher. For simplicity, it may be supposed that the two effects balance each other and that fuel consumption 1970 remains at its 1963/64 level of 7·8 million gallons.

Agriculture

The agricultural sector absorbs about 3% of commercial primary energy consumption. Most of this energy is consumed in the form of tractor diesel oil, of which some 18·3 million gallons were consumed in 1963 in addition to 7·3 million gallons of tractor vaporising oil and insignificant quantities of motor spirit. Further information on consumption of energy in this sector may be found in Part IV.

During the period from 1958 to 1963 the total population of agricultural tractors grew at a trend rate of 6·8% p.a.; there were about 46,300 tractors registered in August of 1963. For the future one might suppose a slightly lower rate of growth of perhaps 4% p.a. It is shown in Part IV that the estimated number of hours a year that tractors are used fell on average from about 800 hours in 1950 to 500 hours in 1963, and this suggests that a decline in the rate of increase in the number of tractors employed is inevitable unless the annual use of tractors is to fall to very low levels. This suggestion is given weight by the fact that growth in agricultural output will be mainly confined to stock and to stock products rather than to cereals (where mechanical farming, and hence tractor use, is more intensive).

Suppose, therefore, that the population of tractors increases at 4% p.a. to 60,900 in 1970, that

TABLE 6: AUTOMOTIVE FUEL CONSUMPTION IN 1970

Type of Vehicle	Population 1970	Average Mileage	Average Fuel Consumption; gals/mile	Total Fuel Consumption; mil. gals.
Units of car transport[1] ..	481,000	10,800	·027	140·2
Goods vehicle (petrol) ..	28,400	8,500	·060	14·5
Total petrol	—	—	—	154·7
Goods vehicle (diesel)[2] ..	25,000	21,200	.080	42·8
Buses	1,700	—	—	5·5[3]
Total diesel	—	—	—	48·3

Notes: [1]The total number of units of car transport is the number of private cars and exempt vehicles plus three times the number of taxis plus one half of the number of motor-cycles, the weightings taking care of different mileages and fuel consumptions.

[2]Includes miscellaneous diesel-burning vehicles.

[3]Estimated from consumption of 4.6 million gallons in 1963.

annual use falls to 450 hours a year, that average tractor horse-power rises to 35 H.P., and that average fuel consumption falls slightly (with the further substitution of diesel for vaporising oil) to ·037 gals/HP/hour. Then total fuel consumption in 1970 would increase from 25·9 million gallons in 1963 to 33·5 million gallons, a rate of growth of about 3·7% p.a. Of this total there might be perhaps 4 million gallons of vaporising oil, the rest being tractor diesel oil.

To meet the targets of the Second Programme agricultural output must grow from 1963 to 1970 at 3·8% p.a. The growth-elasticity between fuel consumption and output was 1·4 during the 1950 to 1963 period. The estimate just derived would indicate that this elasticity should fall to about 1·0 in the future, which does not seem at all unreasonable. The correlation between output and fuel consumption was not sufficiently close to give very precise predictions.

Other Sectors

More than half the commercial primary energy consumed in Ireland is absorbed by this miscellaneous group of sectors for general lighting and heating purposes. Although it is the most important sector of energy consumption it is also the sector about which least is known and for which any forecast must be subject to wide margins of possible error. Such information as there is and such analysis as is possible is set out in Part IV of this series of papers.

Between 1950 and 1963 personal expenditure at constant prices grew at a trend rate of increase of 1·4% p.a., while over the same period the effective energy consumption of this sector grew at a trend rate of 2·8% p.a. (temperature adjusted); the growth elasticity between the two variables was about 1·7. For the future, personal consumption is foreseen in the Second Programme to grow at 3·6% p.a. Taking the relation to growth in personal consumption, a rate of growth of 6·1% p.a. (i.e. $3{\cdot}6 \times 1{\cdot}7$) in the effective energy needs of the sector is suggested. This would be more than twice the historical rate of growth and, moreover, would imply, (price changes apart) that expenditure on fuel and power would increase quite significantly over the period as a proportion of total consumption spending.

Leser's cross-section analysis of Irish household budget data for 1951–52[4] indicated an expenditure elasticity of about 0·5 between total household income and outlay on fuel, light, etc. This is a much lower elasticity than that mentioned above (which was derived from a time-series analysis). The comparison suggests that not only does spending on fuel and power increase with income from one household to another but also it increases over time, which can only mean that standards of heating, etc., are rising. This is an obvious conclusion of course.

The problem here, in projecting the total effective energy needs of this sector, is to know whether to expect a steady rate of increase over time at more or less the historical trend rate of growth, or to expect a more rapid increase owing to the higher trend rate of growth foreseen in consumption spending. In correlating the variables there was an R^2 of ·65 between effective energy consumption and time (with allowance for variations in average winter temperatures) and an R^2 of ·71 between effective energy consumption and personal expenditure at constant prices. Little significance can be attached to this statistical difference because of the unreliability of the energy data. The selection of one coupling of the variable rather than the other would make a difference of about 20% to the sector's 1970 energy consumption, or 10% of all energy consumption in that year. Forecasting is at its most difficult under circumstances like these; all that can be done is to compromise and choose a rate of growth of 4½% p.a., midway between the two possible rates of 2·8% p.a. and 6·1% p.a. These are the rates of growth obtained by using, to predict effective energy consumption in this sector, the equations obtained in regressions on time, (i.e. trend projection) and on personal expenditure at constant prices respectively. The compromise has some justification in that it implies an elasticity with consumption expenditure of about unity, which is not unreasonable in a country like Ireland which has already passed through the stage of take-off in its economic expansion. Comparison with the elasticity of 1·7 of the historical period need not be taken too seriously because of the different (and slower) conditions of growth that were then prevailing; but this is not supporting evidence, it merely does not contradict what is basically an arbitrary choice.

At 4·5% p.a. effective energy consumption would increase from $22{\cdot}6 \times 10^{12}$ Btu in 1962 to $32{\cdot}1 \times 10^{12}$ Btu in 1970. However, it seems preferable, because of the unreliability of the figures corresponding to any particular year, to project consumption not from a 1962 base but from a base of the average annual consumption during the five years from 1958 to 1962, with 1960 the year on which the average is centred. This procedure does not affect the projection of total effective energy consumption so much as the contributions of the various forms of energy, since the latter show quite large fluctuations from

[4]C.E.V. Leser: *A Further Analysis of Irish Household Budget Data* 1951–52; ERI Paper No. 23, August 1964; Table 5.

year to year both because of their inherent uncertainty and because of the varying effects on the consumption of each form of energy of different annual temperature conditions. Projected at 4·5% p.a. from this 1960-centred five-year average of $20{\cdot}2 \times 10^{12}$ Btu, total effective energy consumption in 1970 becomes $31{\cdot}4 \times 10^{12}$ Btu. The breakdown of this total between the various forms of energy needs careful consideration.

Commercial solid fuels together contributed some 45% of the total during the 1958–62 period, and consumption was increasing slowly at about 1½% p.a. By 1970 one might expect the use of coal and coke to fall as people turn more and more to some form of central-heating and hence possibly to other fuels, and even the consumption for room-heating may fall as the more efficient type of fire and the closed stove become more fashionable. However, the open fire is still so popular that one cannot foresee coal consumption taking too deep a plunge by 1970. From an average of 900,000 tons during the five years from 1958 to 1962, consumption might fall to perhaps 800,000 tons annually in 1970. Machine turf and turf briquette consumption may reasonably be expected to increase in accordance with Bord na Móna's plans for future production and sales, which foresee some 340,000 tons of machine turf and 420,000 tons of briquettes being sold in Institutional and Domestic markets in 1970. For present purposes it is convenient to consider all briquettes as being consumed in these markets and all industrial consumption of turf to be of machine turf; the appropriate adjustments bring the 1970 estimates of consumption to 300,000 tons and 460,000 tons respectively. The former implies an increase of one-fifth from consumption in 1962, while the latter estimate implies a doubling over the eight years.

Burning oil sales are likely to continue their steady rate of decline as this oil is displaced by bottled gas for cooking in areas not supplied with townsgas. Not too rapid a rate of decline is foreseen, however, for paraffin room heaters are likely to remain fairly popular in urban areas in houses not equipped with central heating (the great majority) because this form of heating (for intermittent use in particular) is cheaper than either gas or electricity even if it is not quite as convenient. Consumption of burning oil may be forecast to fall from an average of 16·4 million gallons a year during the 1958 to 62 period (15·7 million gallons in 1963) to 14·5 million gallons in 1970.

The likely growth in consumption of the heavier oils used for central heating is the major unknown in forecasting the use of fuel in this sector. It may tentatively be projected at its historical rate of 11·5% p.a., although this rate may have to be modified in balancing the total. From an average of 23·6 million gallons during the 1958 to 62 period consumption would increase, at this rate of growth to 70·1 million gallons in 1970.

Liquefied gases have probably passed through the period of very rapid growth which is often observed when a commodity first becomes generally available. Future growth is not easy to estimate; it is likely to remain fairly high because it will be increasingly used in rural areas and in urban and suburban areas not supplied with townsgas. A rate of growth of 10% p.a. up to 1970 might be foreseen, which would mean an increase from an average of 14,200 tons a year over the 1958 to 62 period to 36,800 tons in 1970.

For townsgas one expects a more rapid rate of increase in consumption in the future than in the past. With production costs falling through the change to oil-based gas-making, it is likely that gas prices will tend to fall rather than to rise and that substantial rebates will be offered for central-heating use. Townsgas is of course in many ways the most convenient form of fuel for central-heating proper (which excludes electricity) and gives the lowest installation costs. Given that its penetration of the central-heating market is likely to be delayed for a year or so both because expansion of this market is only now getting into its stride and because lower gas prices will not take effect immediately, one might forecast growth of perhaps 1 or 2% p.a. up to 1966 and 5 or 6% p.a. thereafter. For the whole period 3% p.a. would seem to be an acceptable figure. From an average of 24 million therms a year over the 1958 to 62 period townsgas consumption would increase to 32·3 million therms in 1970.

From 1950 to 1963 inclusive all domestic sales of electricity have grown at a trend rate of 9·6% p.a.; general domestic sales at a rate of 7% p.a. and rural domestic sales at a rate of over 20% p.a. Within domestic sales use for night-storage heating has probably grown most rapidly, at 11·0% p.a. Sales to commercial customers have increased at 8·8% p.a. In the future the rate of increase in rural sales will drop sharply because the rural-electrification programme is now substantially complete. All domestic sales are likely therefore to fall back towards the 7·4% p.a. rate of growth of general domestic sales, but the increasing weight of the faster-growing night-storage use seems likely to keep growth at around the 8% p.a. level. If commercial sales continue at nearly 9% p.a., then the overall rate of growth in electricity consumption for the sector as a whole can be projected at say 8·5% p.a. This would mean a consumption of 2,626 million units in 1970 compared with a 1,162 average for the 1958 to 62 period.

The use of hand-won turf in 1970 is estimated to fall by 25% from the 1958 to 62 average, to 1,500,000 tons in 1970.

Addition of the likely contributions of the different forms of energy yields a total effective energy consumption in 1970 of $30{\cdot}8 \times 10^{12}$ Btu, only $0{\cdot}6 \times 10^{12}$ Btu less than the separate prediction of the total made earlier and, therefore, in close agreement with it. The resulting estimates are set out in Table 7.

If these estimates are accepted, the shares taken by the different forms of energy of the total effective energy consumption of the sector will change considerably. The share of solid fuels will fall from 45% during 1958/1962 to only 34% in 1970. That of liquid fuels will increase from 20% to nearly 29% and that of electricity from 18% to over 26%. The importance of townsgas will decline marginally and the share of hand-won turf will fall from 10% to about 5%. These figures are shown in Table 8. The greatest uncertainty is associated with the forecast rate of increase in consumption of heavy oils, both because of the statistical uncertainty attached to the historical rate of growth and because adequate information is not available about the possible future use of these fuels. If the total consumption estimate turns out to be too large then it is likely that forecast consumption of heavy oils will suffer to the greatest extent.

TABLE 8: EFFECTIVE ENERGY CONSUMPTION BY SOURCE: OTHER SECTORS

Form of Energy	Percentage Shares		
	Average, 1950 to 1954	Average, 1958 to 1962	1970
Coal and coke	45	37	21
Machine turf	2	5	4
Turf briquettes	·1	3	9
Solid fuel	48	45	34
Burning oil	8	7	4
Gas diesel and fuel oils . .	6	11	22
Liquefied gases	0	2	3
Liquid fuel	14	20	29
Townsgas	9	7	6
Electricity	11	18	26
Hand-won turf	18	10	5
Total	100	100	100

Aggregate of Sector Forecasts

In Table 9 are shown the forecasts made for each of the four main sectors of consumption added together to give the total quantities of energy in final consumption in 1970. To convert these estimates into estimates of the quantities of primary energy to be consumed in 1970 it will be necessary to consider the supply of the forecast requirement of the secondary types of energy: gas and electricity.

TABLE 7: PROJECTION TO 1970 OF ENERGY CONSUMED BY OTHER SECTORS

Form of Energy	Effective Energy Consumption; 10^{12} Btu		Actual Energy Consumption					Growth Rate
			10^{12} Btu[1]		Original Units[2]			
	1960[3]	1970	1960[3]	1970	1960[3]	1970	Units	1960[3]—1970
Coal and coke . .	7·5	6·55	24·8	21·84	910	800	th. tons	− 1·3% p.a.
Machine turf . .	1·0	1·21	3·4	4·02	260	300	th. tons	+ 1·4% p.a.
Turf briquettes[4] . .	0·6	2·62	2·1	8·74	110	460	th. tons	+ 6·2% p.a.[5]
Solid fuel . .	9·1	10·38	30·3	34·6	—	—	—	+ 1·3% p.a.
Burning oil	1·5	1·30	2·4	2·16	16·4	14·5	m. gals	− 1·2% p.a.
Gas/diesel and fuel oils	2·2	6·65	3·7	11·08	23·6	70·1	m. gals	+11·5% p.a.
Liquefied gases . .	0·4	0·97	0·6	1·61	14·2	36·8	th. tons	+10 % p.a.
Liquid fuel . .	4·1	8·92	6·7	14·85	—	—	—	+ 8·1% p.a.
Townsgas	1·4	1·94	2·4	3·23	24	32	m. therms	+ 3 % p.a.
Electricity	3·6	8·06	4·0	8·96	1,162	2,626	m. kwh	+ 8·5% p.a.
Hand-won turf . .	2·0	1·50	3·6	15·00	2,020	1,500	th. tons	− 2·9% p.a.
Total . .	20·2	30·80						+ 4·3% p.a.

Notes: [1]The following relative efficiency factors have been used:

solid fuel	·30	liquid fuel	·60
hand-won turf	·15	townsgas	·60
electricity	·90		

[2]Conversion factors are as follows:

coal, coke and anthracite	27·3 m Btu/ton	burning oil	149,000 Btu/gal
machine turf	13·4 m Btu/ton	heavy oils	158,000 Btu/gal
turf briquettes	19·0 m Btu/ton	LPG	43·7 m Btu/ton
hand-won turf	10·0 m Btu/ton	electricity	3,412 Btu/kwh

[3]Average of five years 1958 to 1962.

[4]Covers all turf briquettes consumed, including small quantities used by industry.

[5]Based on 1963 consumption of 300,000 tons.

Table 9: ENERGY IN FINAL CONSUMPTION IN 1970

Form of Energy	1962	1970					Unit
		Industry	Transport	Agriculture	Other	Total	
Coal and coke	1,452	250	—	—	800	1,050	th. tons
Machine turf	234	75	—	—	300	375	th. tons
Turf briquettes ..	228	—	—	—	460	460	th. tons
Motor spirit	96·7	—	154·7	—	—	154·7	m. gals
Burning oil	15·8	—	—	—	14·5	14·5	m. gals
Vaporising oil	7·9	—	—	4·0	—	4·0	m. gals
Automotive gas oil ..	23·9	—	48·3	—	—	48·3	m. gals
Tractor diesel	17·3	—	—	21·9	—	21·9	m. gals
Other gas/diesel ..	39·5	} 236·0	7·8	—	70·1	89·7[1]	m. gals
Fuel oil	78·3		—	—		224·2[1]	m. gals
Liquefied gases ..	17	—	—	—	37	37	th. tons
Townsgas	29·4	6	—	—	32	38	m. therms
Electricity	2,153	1,765	—	—	2,626	4,391	m. kwh
Hand-won turf ..	1,835	—	—	—	1,500	1,500	th. tons

Note: [1]The total of other gas/diesel and fuel oils has been arbitrarily split in the proportion 1:2.5, compared with 1:2 in 1962, because the use of these oils is growing most rapidly in Industry which mainly requires the heavier oils.

Fuel for Electricity Generating

A detailed study of the supply of electricity in Ireland is described in Part II of these papers.

For the future, the generating plant which the Electricity Supply Board will be bringing into commission between 1964 and 1970 is already either under construction or at an advanced stage of planning. The additions to capacity in the years up to and including 1970 are given in Table 10.

Table 10: ADDITIONS TO CAPACITY; MARCH, 1964 TO 1970

Station	Fuel	Capacity	Commissioning date
Shannonbridge (1)	Milled peat.	40 MW	1964/65
Marina (1)	Oil	60 MW	1964
Ringsend (1)	Oil	2×60 MW	1965/66
Ringsend (1)	Oil	60 MW	1966/67
Lanesborough (1)	Milled peat.	40 MW	1965/66
Great Island	Oil	60 MW	1967/68
Great Island	Oil	60 MW	1968/69
Tarbert	Oil	2×60 MW	1969/70

Note: (1) These are extensions to existing stations.
Source: ESB *Annual Report* 1963/64.

With the additions to capacity shown in Table 10, the total generating capacity of the supply system will increase from 849·5 MW in March 1964, to 1,319·5 MW in 1970. This figure excludes any plant that may be brought into commission during the 1970/71 financial year. It also excludes the generating plant at Pigeon House (90 MW), which may or may not have been retired from service by 1970 but which (even if not) would make only a negligible contribution to electricity output; even now its function is to serve merely as stand-by capacity. The breakdown of generating capacity by fuel source in 1970 is shown in Table 11.

Table 11: GENERATING CAPACITY IN 1970

MW

Fuel Source	March, 1963	1970
Hydro	219	219
Irish coal	15	15
Imported coal/oil ..	288	678
Machine turf	117·5	117·5
Milled peat	210	290
Total	849·5	1,319·5

The aggregate forecast of consumption of electricity (see Table 9) showed sales of electricity rising from 2,153 million units in 1962 to 4,391 million units in 1970, an average annual rate of increase of 9·3% p.a. It will be supposed that, with the increasing density of consumption, the proportion of losses falls slightly over the period and that the gross output of electricity (total generated) grows at an average annual rate of 9·0% p.a. This is roughly the same as the E.S.B.'s present estimate of growth in output during the 1960's. From 2,850 million units generated in 1963 (calendar year) output would rise at this rate to 5,215 million units in 1970. The problem is to deduce from this total figure the quantities of fuel that are likely to be consumed in 1970.

In a year of normal water flow, output from hydro-electric stations is estimated at 720 million units. In a very dry year this figure could fall by a half and in a very wet year it could increase by a third. Any variation would affect the required output from thermal stations and in turn, the amounts of fuel that the latter would burn. In particular, variations in hydro output would tend to affect the output of electricity from stations burning imported fuels, but this is to over-simplify the picture since the extreme climatic conditions that would cause variations in hydro output would also affect the turf harvest. Thus, in a dry year with reduced hydro output the production of turf would be likely to be above average and vice-versa—but not necessarily so, for it happened in 1958 that Autumn rain, which reduced the output of turf, was followed by a very dry winter with hydro output much below normal. For the sake of simplicity, the present estimates will relate only to conditions in a normal year both for hydro and for the turf harvest. It may be mentioned that Bord na Móna are taking steps to increase the quantities of turf held in storage in order to be able to meet their targets in years of poor harvests.

The turf situation in 1970 has been studied by both the Electricity Supply Board and Bord na Móna in order to assess how much turf will be made available and how much consumed in an average year. It is estimated that 560 million kwh will be generated at machine turf stations and that 640,000 tons of machine turf will be consumed, of which 565,000 tons will be supplied by Bord na Móna (the difference represents the consumption of turf at the four small stations in the West of Ireland). Milled peat stations will produce 1,240 million kwh and will consume 2,080,000 tons of milled peat. These estimates relate to turf of standard moisture content.

If from the total estimated output in 1970 are subtracted the estimated outputs from hydro and from turf stations, there remains a total of 2,695 million units to be supplied by stations burning coal or oil. The Irish coal station at Arigna may be estimated to produce some 95 million units and to consume 55,000 tons of coal (roughly the same as in 1963/64). Stations burning imported fuel will supply the remaining 2,600 million units. It will be presumed that the price advantage remains in favour of oil and that oil will be consumed at dual-fired stations, as well as at specifically oil-burning stations.

The best of the oil stations (Ringsend) consumed about 11,600 Btu of heat (net) for each kwh of electricity generated in 1963/64. With so much additional oil-fired capacity in larger sets being brought into commission by 1970, it is reasonable to expect that the average heat rate of all oil stations in 1970 will fall to, say, 10,500 Btu/kwh generated. This would mean a heat input of $27{\cdot}3 \times 10^{12}$ Btu or a total oil consumption of 700,000 tons in 1970. This figure may be increased by ten thousand tons to 710,000 tons to include the small quantities of oil used at the milled peat and Irish coal stations. Compared with 333,000 tons of oil burnt in 1963 (calendar year) this indicates an annual average rate of growth in oil consumption of 11·4% p.a. The rate of increase may be less than this up to 1966 and exceed it in succeeding years since the additional milled peat capacity will come into commission during the early years of the period.

The expected situation in 1970 is set out in Table 12.

If the estimates given in Table 12 are borne out in the event, the overall efficiency of the supply system will have improved considerably in two senses. First, the average heat input to send out one unit of electricity will have fallen from 14,200 Btu in 1963 to 12,500 (see Note (2) to Table 12) in 1970, a decrease of 12%. Second, the average annual utilisation of plant will have improved from about 40% in the early 1960's to 45% in 1970. The characteristics of demand are expected to change relatively little and this latter improvement will be a consequence of the decreased weighting in total capacity of hydro and turf plant, supplies from which are vulnerable to unfavourable weather conditions.

It will have been noticed that no attention has been paid to two possible developments that might affect the future pattern of supply of electricity: the possibility of interconnection with the Six Counties and the possibility of pumped storage.

Interconnection with the North is to be studied by a joint committee that has recently been set up (early in 1965). If eventually approved, some two or three years might elapse before the connection is

TABLE 12: ELECTRICITY OUTPUT AND FUEL CONSUMPTION IN 1970

Fuel Source	Electricity Generated Million kwh	Plant Factor %	Heat Rate Btu/kwh	Net Heat Input 10^{12} Btu	Fuel Consumption 000 tons
Irish coal	95	72	13,200	1·23	55
Oil	2,600	44	10,500	27·30	700 (+10)[1]
Machine turf	560	54	15,200	8·51	640
Milled peat	1,240	49	13,200	16·37	2,080[1]
Total thermal	4,495	47	11,900[2]	53·41	
Hydro	720	38			
Total	5,215	45			

Notes: [1]10,000 tons of oil are estimated to be consumed at other stations of which 9,000 tons at milled peat stations.

[2]Equivalent to 12,500 Btu/kwh "sent out" from thermal stations.

actually put into operation. Its advantage would be that the risk of plant failure could be spread over a supply system with roughly double the capacity of that operated by the E.S.B. The latter could then think of reducing the margin of spare capacity needed to be prepared to meet such failure; both parties would naturally gain an equal advantage. There would also be the possibility of regular exchanges of power if spare capacity were available in one system that could supply power to the other cheaper than the latter could produce for themselves. This would depend on their being different patterns of load on the two systems, which at present seems unlikely. Also, and in the longer term, there is the prospect of joint ownership of thermal plants (e.g. nuclear), larger and, therefore, more economical than either system could support on its own—at the expense of course of the risk-spreading which is the most important advantage of an interconnection at this stage of the growth of the two systems. If an intertie is achieved before 1970 it is possible that the E.S.B.'s programme of plant installation might be reduced—or delayed—in the later years, but the net effect on the estimated fuel consumption would be too small and too intangible to be considered.

Pumped storage is the nearest thing to storage of electricity in bulk that has yet been devised. Thermal power stations, not required to meet consumer load, are operated to generate electricity that is used to pump water up into reservoir storage. This water then becomes available to generate electricity (like an ordinary hydro-electric station) at times of peak demand, thus reducing the total need of thermal capacity. Investment in thermal plant is replaced by investment in pumped storage capacity (i.e. in reservoir, pumping, and generating facilities) and possibly by reduced fuel costs (since more efficient plant is used for pumping than would be for peaking, but there are additional losses to consider). The economics are complicated and depend critically on assessments of risk. The E.S.B. has made feasibility studies of the use of pumped storage in Ireland but have as yet made no firm commitment. The chances of a pumped storage scheme being in operation by 1970 are therefore slight, and even if one were in operation the net effect on fuel consumption would be small.

Fuel for Gas Making

It is estimated that consumption of townsgas will increase from 30 million therms in 1963 to 38 million therms in 1970 (see Table 9 above). By then the two largest undertakings will have converted their gas-making plant to the use of oil and will be consuming little, if any, coal. The signs are that the smaller undertakings will follow the same pattern, and will be producing gas either from light distillates or from liquefied gases. Thus, it seems likely that little or no coal will still be used in making gas in 1970.

To produce 38 million therms ($3{\cdot}8 \times 10^{12}$ Btu) of townsgas at an estimated average process efficiency of, say, 80% would require the consumption of $4{\cdot}75 \times 10^{12}$ Btu of oil. The proportions of light distillates, of fuel oil, and of liquefied gases in which this total will be supplied cannot be known exactly but will possibly be in the ratios of 11 : 3 : 1 (respectively). This implies that 26·8 million gallons of light distillates, 5·8 million gallons of fuel oil and 7,000 tons of liquefied gases will be used for gas-making in 1970. The wide margins of error in these estimates will not be significant in total consumption in 1970.

The gas industry in Ireland is discussed in Part IV. With gas, as in the case of electricity there is the long-term possibility of revolutionary developments in supply, perhaps even more dramatic than the switch from coal to oil that has already begun. One is thinking of the prospect of importing natural gas in liquid form in refrigerated tankers, as Britain is now doing. It is likely, however, that no one centre of population in Ireland would offer a demand sufficient to justify such a venture, and that the linking by gas pipeline of all centres of consumption down the East coast of Ireland (both North and South of the Border) would be an essential pre-condition to its success. It is by no means clear that the project would offer worth-while economies since the cost of making gas has been reduced so sharply with the introduction of oil-based processes. There is only a small chance that such a plan, if undertaken, would be put into effect before 1970.

Primary Energy Consumption in 1970 from Sector Forecasts

The various steps have been completed and it is now possible to put together an aggregate forecast for 1970 of all primary energy consumption from the detailed sector forecasts. This involves adding to the estimates of energy in final consumption shown in Table 10 (excluding quantities of secondary energy consumed) the quantities forecast in the previous paragraphs to be consumed for generating electricity and for making gas. The resulting totals are shown in Table 13.

Consider first the estimate of commercial energy consumption in 1970 in Table 13 ($196{\cdot}8 \times 10^{12}$ Btu). This agrees very closely with the tentative projections of consumption in 1970 from supply considerations (i.e. $191{\cdot}7 \times 10^{12}$ Btu; median value) given in Table 3 above. It suggests that the "best" global estimate ($224{\cdot}0 \times 10^{12}$ Btu; see Table 1 and following text) was too high, although the difference is within the range of uncertainty of such a long-

TABLE 13: PRIMARY ENERGY CONSUMPTION IN 1970 FROM SECTOR FORECASTS

Form of Energy	1970 Final Consumption	1970 Electricity Generating	1970 Gas Making	1970 Total	Unit
Coal and coke	1,050	55	—	1,105	th. tons
Machine turf	375	640[1]	—	1,015	,,
Milled peat	—	2,080	—	2,080	,,
Turf briquettes	460	—	—	460	,,
Solid fuel	42·4	26·1	—	68·2	10^{12} Btu
Light distillates	—	—	26·8	26·8	m. gals.
Motor spirit	154·7	—	—	154·7	,,
Kero./vap. oils	18·5	—	—	18·5	,,
Gas/diesel oils	160·3	—	—	160·3	,,
Fuel oil	224·2	165·4	5·8	395·4	,,
Liquefied gases	37	—	7	44	th. tons
Liquid fuel	88·2	27·3	4·8	119·6	10^{12} Btu
Hydro-electricity	—	9·0[2]	—	9·0	,,
Total commercial energy	130·6	62·4	4·8	196·8	,,
Hand-won turf	1,500	—	—	1,500	th. tons
Total energy				211·8	10^{12} Btu

Notes: [1]of which some 565,000 tons will be supplied by Bord na Móna.

[2]720 million kwh times 12,500 Btu/kwh sent-out (thermal station heat rate).

term forecast. On the whole it seems preferable to accept the detailed predictions of the sector forecasts, but recognising the considerable possible uncertainty both in individual sectors and in the total.

Forecasts Adopted

The estimates finally adopted for 1970 and set out in Table 13 indicate that consumption of primary commercial energy will increase from 1963 at an average annual rate of 4·9% p.a. and consumption of all primary energy including hand-won turf at a rate of 4·3% p.a. The range of possible uncertainty is perhaps 2% p.a. above and below these estimated rates of increase.

Coal and coke consumption will fall from about 1,640,000 tons in 1963 to just over 1,100,000 tons in 1970 (of which there will be only small quantities of coke). Of this total, indigenous production may supply 145,000 tons (70,000 tons of anthracite and 75,000 tons of semi-bituminous coals) leaving a net import of about 950,000 tons of mainly household coals. Bord na Móna sales of machine turf will increase from 926,000 tons in 1963 to about 950,000 tons in 1970; milled peat sales (to E.S.B.) from 943,000 tons to about 2,100,000 tons; and briquette sales from 303,000 tons to 465,000 tons. All commercial solid fuels together will supply some $68{\cdot}2 \times 10^{12}$ Btu in 1970, almost exactly equal to what they supplied in 1963.

Consumption of petroleum fuels will increase at a high rate, and these fuels will supply $119{\cdot}6 \times 10^{12}$ Btu in 1970 compared with $63{\cdot}0 \times 10^{12}$ Btu in 1963. The rates of growth of the major products are as follows:

Motor spirit	+ 5·8% p.a.	1963 to 1970
Kero./vap. oils	− 3·1% p.a.	,,
Gas/diesel oils	+ 9·1% p.a.	,,
Fuel oil	+11·2% p.a.	,,

The quantities of the individual fuels likely to be consumed in 1970 were indicated in Table 13. If the Whitegate Oil Refinery continues to balance its output on demand for motor gasoline and other light distillates then it seems likely that the refinery will still be producing middle distillates (gas/diesel oils) to excess, that will have to be exported, although less, proportionally, than in 1963. On the other hand it seems likely that substantial imports of fuel oil will continue to be required. It is assumed that kerosines will continue to be imported.

The contribution from hydro-electricity will remain much the same in 1970 as in 1963. Hand-won turf consumption is likely to fall; a somewhat arbitrary estimate of 1,500,000 tons has been taken for consumption in 1970.

In conclusion, Tables 14, 15, and 16 show the likely future pattern of energy use in 1970 compared with a recent year and with a past year. Historical patterns of consumption are described and analysed in some detail in Part IV of this series of papers. Table 14 indicates the share of each form of energy in total consumption. The share of all indigenous forms of energy is seen to be falling slightly; the importance of solid fuels will also decline, from

TABLE 14: PRIMARY ENERGY CONSUMPTION BY SOURCE; 1953, 1963, AND 1970

Form of Energy	1953		1963		1970	
	10^{12} Btu	%	10^{12} Btu	%	10^{12} Btu	%
Indigenous coal	4·5	4·9	5·6	4·0	3·8	1·9
Turf	9·2	10·0	25·4	18·1	38·4	19·5
Hydro-electricity	6·8	7·4	9·2	6·6	9·0	4·6
Sub-Total	20·5	22·3	40·2	28·7	51·2	26·0
Imported coal	44·6	48·5	37·1	26·4	26·0	13·2
Petroleum fuels	26·9	29·2	63·0	44·9	119·6	60·8
Commercial energy	92·0	100·0	140·3	100·0	196·8	100·0
Hand-won turf	31·3	34·0	17·5	12·5	15·0	7·6
Total Energy	123·3		157·8		211·8	

TABLE 15: COMMERCIAL ENERGY IN FINAL CONSUMPTION; 1953, 1963 AND 1970

Type of Energy	1953		1963		1970	
	10^{12} Btu	%	10^{12} Btu	%	10^{12} Btu	%
Solid fuels	42·4	46·0	49·9	35·6	42·1	21·4
Liquid fuels	24·6	26·7	46·7	33·4	87·5	44·5
Total Primary Fuel	67·0	72·7	96·6	69·0	129·6	65·9
Electricity (primary input)	19·7	21·4	38·2	27·3	62·4	31·7
Townsgas (primary input)	5·4	5·9	5·2	3·7	4·8	2·4
Total Secondary Energy	25·1	27·3	43·4	31·0	67·2	34·1
Total Commercial Energy	92·1	100·0	140·0	100·0	196·8	100·0

44·5% in 1963 to 34·6% in 1970 (commercial forms only); and petroleum fuels' share will increase to more than 60% of commercial energy consumed in 1970.

Table 15 shows the breakdown of primary commercial energy consumption between that which is finally consumed in primary form and that which is transformed into secondary energy. The figures in this table reveal that a greater proportion of energy will be used in secondary form—as electricity and gas—in 1970 than in 1963, following the historical trend in this respect. Also emphasised is the increasing importance of liquid fuels at the expense of solid fuels.

Table 16 gives the breakdown of energy consumption by sector. Included in the consumption of each sector are the quantities of primary energy used for generating electricity and for making gas that are attributable to the sector's consumption of these secondary energies. The important change over the forecast period is the increased share of industrial consumption, which is associated with a considerably lower share for Other Sectors (mainly consumption for space heating).

TABLE 16: COMMERCIAL ENERGY CONSUMPTION BY SECTOR;
1950 to 1954, 1958 to 1962 and 1970

Sector of Consumption	1950 to 1954		1958 to 1962		1970	
	10^{12} Btu	%	10^{12} Btu	%	10^{12} Btu	%
Industry	25·0	26·9	33·3	28·7	71·6	36·4
Transport	17·9	19·3	17·5	15·1	30·1	15·3
Agriculture	2·5	2·7	3·8	3·3	5·2	2·6
Other Sectors	47·5	51·1	61·2	52·9	89·9	45·7
Total Commercial Energy	92·9	100·0	115·8	100·0	196·8	100·0

Appendices

GLOSSARY OF TERMS

Energy is the source of heat, light and mechanical power; as used here the term excludes human energy.

Fuels are vegetable and fossil sources of energy, including turf, coal, oil and natural gas.

Power is energy in the form of electricity (although this usage is not strictly correct).

Primary Energy is energy in its first-obtained form, before conversion into other forms of energy e.g. fuel into electricity.

Secondary Energy is energy that has been converted from its primary form e.g. townsgas.

Commercial Energy is energy that is supplied and sold for financial reward.

Total Energy includes both commercial energy and energy from non-commercial sources e.g. hand-won turf in Ireland.

Final Energy Consumption is the eventual use of energy to provide heat, light or motive power; it excludes the conversion of energy into secondary form.

Effective Energy Consumption is final energy consumption with each component form of energy weighted in the total according to its relative efficiency in use.

Final Consumption Sectors include Industry and Services, Transport, Agriculture and Other Sectors (Domestic and Commercial); all automotive fuels are considered to be consumed within the Transport Sector.

Transformation Sectors include the Electricity and Townsgas Industries.

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BIBLIOGRAPHY AND REFERENCES

General

Man and Energy by A. R. Ubbelohde, Hutchinson 1954.

Geography of Energy by G. Manners, Hutchinson 1964.

Gas Journal Directory 1963.

General Reports of European Coal and Steel Community.

National Power Survey 1964 Federal Power Commission.

Report of the National Fuels and Energy Study Group on An Assessment of Available Information on Energy in the United States, September 1962, Committee on Interior and Insular Affairs, 87th Congress.

L'Economie de l'Energie dans les Pays en voie de Devéloppement by Pierre Sevette, 1963, Presses Universitaires de France.

Etude sur les Perspectives Energétiques à long terme de la Communauté Européenne, December, 1962, Luxemburg.

Rapport General de la Commission de l'Energie, 1961, Paris, Imprimerie Nationale.

Conditions in Britain

Statistical Digest (annual) Ministry of Power (H.M.S.O.).

Annual Reports:—
Electricity Council (H.M.S.O.).
Central Electricity Generating Board (H.M.S.O.).
Atomic Energy Authority (H.M.S.O.).
Gas Council (H.M.S.O.).

Select Committee Reports:—
Electricity Supply Industry 1956 and 1963 (H.M.S.O.).
Gas Industry 1961 (H.M.S.O.).

Fuel Policy Cmnd 2798 (H.M.S.O.).

Price of Fuel by I.M.D. Little, 1953 Oxford University Press.

Marginal-cost Price of Coal 1956–57 by Millard Long, Economica XXIX No. 116, November, 1962.

Bulk Supply Tariff for Electricity by R. L. Meek, OEP Vol. 15, July 1963.

Economics of State Corporations

Investment, Financing and Valuation of the Corporation by M. J. Gordon, 1962, R. Irwin Inc.

Lessons of Public Enterprise (ed.) M. Shanks, 1963, Jonathan Cape.

Overhead Costs by W. A. Lewis, 1949, Allen and Unwin.

Depreciation and Replacement Policy (ed.) J. L. Meij, 1961, North-Holland Pub. Coy.

Financial and Economic Obligations of Nationalised Industries Cmnd. 1337, 1961 (H.M.S.O.).

Studies in Accounting Theory (ed.) W. T. Baxter and S. Davidson, 1962, Sweet and Maxwell.

Economic Performance under Public Ownership by W. G. Shepherd, 1965, Yale University Press.

Electricity Prices/Economics of Tariff Systems

Theory of Marginal Cost and Electricity Rates, 1958 OEEC.

Genesis of Present Pricing System in Electricity Supply by I. C. R. Byatt, OEP, March, 1963, Vol. 15.

Practical Applications of Marginal Cost Pricing in Public Utility Field by J. R. Nelson, AER, May 1963, Vol. LIII, No. 2.

Fully Distributed Costs in Utility Rate-Making by J. C. Bonbright, AER, May 1961, Vol. LI, No. 2.

Peak Loads and Efficient Pricing by P. O. Steiner, QJE, November 1957, Vol. LXXI, No. 4.

Statistical Cost Analysis by J. Johnston, 1960, McGraw-Hill.

Critique of Welfare Economics by I. M. D. Little, 1957, Oxford University Press.

Theory of Pricing in Public Enterprise (unpublished paper) by R. H. Barback.

Electricity Tariffs in Theory and Practice by H. S. Houthakker, EJ, Vol. LXI, No. 241, March, 1951.

Electricity Tariff Systems in Europe, ECE, EP/Working Paper No. 267, 5 July, 1963.

Theoretical Welfare Economics by J. V. de Graaff, 1962, Cambridge University Press.

General Principles Governing Electricity Tariff Framing, UNIPEDE, June, 1964.

Ireland-General:

Second Programme for Economic Expansion, 1963, Stationery Office, Dublin.

State-Sponsored Bodies by G. Fitzgerald, second edition (revised) 1963, Institute of Public Administration.

Financial Administration of Ireland by J. B. O'Connell, 1960, Mount Salus Press.

Report on Internal Public Transport, Parts I and II, October 1963, C.I.E. Dublin.

Irish Atomic Energy Committee Report, 22 May, 1958.

Electricity, Energy, and Turf (unpublished papers) by D. J. Reynolds.

Internal Finance for Capital Investment in ESB (unpublished paper) by D. Walker.

Bord na Móna, Journal of Inst. of Public Administration, Spring, 1959.

Ireland's Future in World Demand on Energy Resources by D. Flood, JSSISI, 1953–54.

Some Precursors of Bord na Móna by C.S. Andrews JSSISI, 1953–54.

Electricity Supply Board by R. F. Browne, JSSISI, 1951–52.

Electricity Supply Board Journal of Inst. of Public Administration, Autumn 1957.

Some Aspects of Inland Transport by D. J. Reynolds JSSISI, 1962–3.

Turf Development Programme Paper No. 7385, 1946, Stationery Office, Dublin.

Turf

Developments in Production and Utilisation of Turf in Ireland by H. M. Miller, BnM, 1961.

Review of Peat Resources and Development in Ireland by C. S. Andrews, BnM

Peat Industry of Today and Tomorrow by H. M. Miller, Bull. Inst. Civ. Eng. January, 1955.

Use of Peat in Industrial Installations in Ireland by F. Lunny, WPC, 1956.

Production of Peat Briquettes in Ireland by Brown and Belitz, WPC, 1962.

(selection of titles).

Air Pollution

Air Pollution in Ireland by F. E. Dawson, Administration 1959, Vol. VI, No. 2.

Breath of Life by D. E. Carr, 1965, W.W. Norton, New York.

International Clean Air Conference 1959, National Society for Clean Air, London 1960.

Air Pollution; Irish Times Features, June 29 and 30 and July 1, 1964.

Removal of Sulphur from Fuels and Products of Combustion by T. T. Frankenberg 1964, American Society Mechanical Engineers.

(selection of titles).

Statistical Sources:

A Statistical Abstract of Ireland.
Trade Statistics of Ireland (monthly).
Trade and Shipping Statistics (annually).
Annual Reports of : Revenue Commissioners.
Electricity Supply Board.
Bord na Móna.
Córas Iompair Éireann.

ABBREVIATIONS

ESB	Electricity Supply Board
BnM	Bord na Móna (Turf Board)
CIE	Córas Iompair Éireann (Transport Authority)
CSO	Central Statistics Office
CIP	Census of Industrial Production
HMSO	Her Majesty's Stationery Office, London
OEP	Oxford Economic Papers
OEEC	Organisation for European Economic Cooperation
AER	American Economic Review
QJE	Quarterly Journal of Economics
EJ	Economic Journal
ECE	United Nations: Economic Commission for Europe
UNIPEDE	Union of Producers and Distributors of Electricity
JSSISI	Journal of Statistical and Social Inquiry Society of Ireland
ERI	Economic Research Institute, Dublin
GDP	Gross Domestic Product
GNP	Gross National Product
Btu	British Thermal Units
kwh	kilo-watt-hour; 1 kwh=3,412 Btu
kw	kilowatt
MW	Mega watt; 1 MW=1,000 kw
p.a.	per annum
WPC	World Power Conference.

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