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Fuel and Power in Ireland: Part IV

Sources and Uses of Energy

by

J. L. BOOTH

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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 commodites 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 were 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:—

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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.

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By J. L. Booth

INTRODUCTION TO PART IV

The final part of this series of papers contains much of the statistical and descriptive material on which the forecast of Part I was based. It was compiled while the author was temporarily on the staff of The Economic Research Institute and data subsequently published have not been incorporated in the tables. In it is set out, as briefly as is compatible with adequate explanation, the course followed in analysing the material and preparing it for use as a lattice on which to stretch a projection to 1970. As will be seen, the data were not sufficiently detailed nor reliable enough to justify more than the simplest of analytical techniques. Where more elaborate methods were attempted the results scarcely justified those attempts.

Nevertheless for all its inadequacy and lack of classified detail it is important that the material presented in this paper should be available, not only as appendix and background to the forecasting work of Part I but also as reference data for other students in this field. Perhaps not all possible sources of data were investigated but a large number, and all the usual sources, were. More statistics, more compatible statistics, and more easily available statistics would have been welcome.

The first section deals with the types of energy that are used in Ireland, with their sources and with the extent of any indigenous reserves. Electricity and turf are referred to only in passing because they are covered more fully in Part II. The second section describes the consumption of energy in the various sectors of the economy.

SECTION 1: ENERGY RESOURCES AND SUPPLIES

Inanimate energy was already important to man's comfort and safety many thousands of years ago when he was still living in caves. He built wood-fires for warmth, for cooking, for lighting and to provide some measure of protection from marauding beasts. Wood is a hydro-carbon fuel that burns in air to release heat. To this day hydro-carbon fuels are man's principal source of inanimate energy and heat is still his principal energy need.

There are three naturally-occurring forms of inanimate energy that are of more than local importance. The first is the chemical energy of fuel, energy that is stored away in the chemical bonds within molecules. All hydro-carbon fuels, such as petroleum, natural gas, coal, lignite, turf, and wood contain energy in this form. Their energy is released by burning. Most of them consist of fossilised vegetable or animal matter. Their energy came originally from the sun and has been stored up in the earth for many millions of years. The storing-up process takes so long that the earth's stock of these fuels is virtually fixed. It is therefore exhaustible, and much research is continually being carried out to find out for how much longer the present stock will last.

The second naturally-occurring form of inanimate energy is water-power. This is the potential or gravitational energy of a weight of water at a height above its surroundings. When the water is released it flows downhill and it acquires kinetic energy (energy of motion). This energy can be harnessed by causing the water to drive a turbine. The turbine is usually connected to a generator shaft in order to transform the energy of its rotation into electricity.

The ultimate source of this energy is again the sun, which evaporates water from the surface of the earth and causes the vapour to rise and to condense as rain. At least some of the rain falls on high ground and, when collected, becomes a natural source of water-power. The process is self-perpetuating and is therefore inexhaustible in the sense that a given stock is not being consumed. On the other hand the rate of supply of energy from this source depends first on an area's geographical and climatic conditions and second on its recent rainfall. Very few countries are fortunate enough to be able to satisfy more than a small part of their energy needs from this source.

The other and most recently harnessed form of inanimate energy is that contained within matter itself, the energy which binds particles together in the nucleus of the atom. This energy is called nuclear energy; it was first successfully applied to producing useful heat little more than ten years ago. In principle there are two ways in which this fundamental type of energy can be released: by fission or the breaking-up of the nucleus of a heavy atom, and by fusion or the binding together of the nuclei of two light atoms. Only the former has so far been adapted for practical (and peaceful) purposes and the overall efficiencies achieved are still well below what will, it is hoped, be eventually possible. The "first generation" of atomic reactors makes use of only about one per cent. of the energy available in the nuclear fuel, but reactor types now at the research stage are capable of efficiencies of 70 per cent. or higher.

Uranium is the most important fissionable material found in nature but only a small fraction of naturally-available uranium is of the right variety for the fission process. Reactor systems are being developed that will be able to make use not only of the other sort of uranium but also of thorium, which is another heavy element found in the earth's crust. All in all the prospects are good that nuclear energy can be developed to provide a well-nigh inexhaustible source of inanimate energy. It must be emphasised, however, that only the first steps in its development have so far been taken; under present technology the world's capital stock of nuclear fuels is as exhaustible as that of the fossil fuels.

Because heat is very difficult to transport, the heat from an atomic reactor is converted into electricity, exactly as in a fuel-fired power station. The atomic reactor is a more expensive piece of equipment than the furnace part of an ordinary power station and this heavier capital expense must be balanced by lower fuel costs if the atomic plant is to compete in cost with the conventional plant. Within the next few years atomic plant will become widely competitive, it is thought, with conventional plant for very large power stations that can be worked at or near their maximum rate of output throughout their life-times. These conditions are only achieved in large interconnected electricity networks with high base loads. In Ireland there is little immediate prospect of using nuclear energy economically.

A number of other actual or potential sources of inanimate energy should be mentioned for completeness, although none of them is of more than minor, local significance now, nor likely to become so in the forseeable future. Geothermal energy is the heat of volcanic steam and hot water released through fissures in the earth's crust. The kinetic energy of wind is another and more commonly available source of energy; it has been used for many years for such purposes as pumping water up from wells and grinding corn. It can equally well be used on a small scale for generating electricity. Tidal energy is another natural form of kinetic energy that can be harnessed for electricity generating by means of tidal barrages. The final source that should be mentioned is the direct energy received from the sun as radiant heat and light.

To the author's knowledge, of these various sources only wind-power has been seriously suggested as an exploitable source of energy in Ireland[1] and this suggestion has not so far been taken up.

For the time being, therefore, Ireland must rely on fossil fuels and on water-power to satisfy her energy needs. Within her own territories she has access to certain limited quantities of these forms of energy, with the faintest possible chance that there are reserves of oil or of natural gas waiting to be discovered. The chances are sufficiently strong, at least, to encourage exploration and drilling work. Otherwise Ireland is fortunate enough to possess resources of turf, of coal and of water-power. Turf is her most abundant resource of energy, but turf is a relatively difficult fuel to exploit commercially.

Indigenous Resources of Energy

The total water-power potential of the Republic is estimated at 1,000 million KWh a year.[2] Of this total, 70% has already been developed and produces 700 million KWh in an average-flow year; the remaining sites are small and would be costly to exploit. This amount of electricity would require approximately one third of a million tons of coal to be burnt if it were to be produced in thermal power stations.

There appears to be no authoritative recent estimate of the remaining turf resources of the Republic. Nor would such an estimate be very useful were it merely to indicate a single total quantity. The economics of the commercial exploitation of turf depend to a large extent on the turf being of good quality and deposited evenly and thickly in large areas free from rock protrusions. As far as hand-cutting is concerned the regional distribution of turf resources is also important because turf will usually be cut by hand only where it is locally available. Hand-cutting is more flexible than

[1] Munro, H., "Prospects for Windpower Development in Ireland". Transactions, Institution of Civil Engineers of Ireland (1953).

[2] "The Energy Resources of the Republic of Ireland" by the Irish National Committee to the Sixth World Power Conference at Melbourne, October 1962.

mechanised cutting, of course, but it is too labour-intensive to be practised commercially.

An approximate figure can be put on the total turf resources of Ireland by inference from some facts given by Dr. C. S. Andrews.[3] The area of Ireland is just over 20 million acres and a general survey of the boglands made in 1809–14 indicated that approximately 15% of this area, or some 3 million acres, was peat land. A calculation has been made, which must be taken with the utmost reserve, that since 1814 some 1½ million acres have been cut away for fuel. Of the remaining peat area much is situated on mountainous or on rough land and therefore both yielding less turf per acre and incapable of being exploited commercially. Suppose, however, to have some figure in mind, that half of the original total quantity existing in 1814 remains. Next suppose that during the last 150 years production has averaged 3½ million tons a year. The remaining resources would then be, say, 500 million tons as a rather optimistic estimate (equivalent to about 250 million tons of coal).

Bord na Móna acquired over 130,000 acres of bogland, or about 10% of the area of bog at present remaining. This is estimated to give the Board access to reserves amounting to about 130 million tons of sod peat, with a wide margin of possible error. Equivalent to about 65 million tons of coal, this quantity of turf would last for over 50 years at current rates of production. The remaining turf will still be a non-commercial source of supply for much longer.

Compared with Great Britain, Ireland is poorly endowed with coal in spite of geological similarities between the two countries. The reason is that heavy erosion over the carboniferous rock has removed the thick and valuable upper coals found in Britain.[4] Only four rather restricted coalfields have been left: the Kilkenny or Castlecomer coalfield (sometimes called the Leinster coalfield); the Slieve Ardagh or Tipperary coalfield (including Ballingarry); the Arigna or Connacht coalfield; and the Munster coalfield.

The Castlecomer and the smaller Slieve Ardagh fields yield anthracite coal. A little of the coal at Castlecomer can be exploited by opencast working but most of it requires shafts to be sunk. Both fields suffer from the disadvantage of narrow seams and at Slieve Ardagh in particular the structure is much disturbed by folding and faulting. The more accessible seams have already been exhausted. Production from these two fields was 130,000 tons in 1962.

[3]"Review of Peat Resources and Development in Ireland" by C. S. Andrews to the International Peat Symposium at Dublin, 1954.

[4]D. W. Bishopp: A Short Review of Irish Mineral Resources, Stationery Office, 1943.

The Arigna field yields a semi-bituminous coal. One of the seams has already been worked out and the lower seam is of coal with high ash content. The coal outcrops continuously along the flanks of steep mountain blocks and is relatively simple to work. It is principally used for generating electricity at a power station located at the coalfield. Some 75,000 tons were produced from this field in 1962.

At the Munster coalfield structural disturbances have been so intense that there is little prospect of exploiting coal economically from this field.

Latest estimates of the resources of coal available in the three coalfields where deposits are workable are shown in Table 1.

TABLE 1: COAL RESERVES IN IRELAND

Field	Million tons	
	Proved workable reserves	Proved reserves of doubtful workability
Castlecomer	8·7	13·7
Slieve Ardagh	4·4	4·0
Arigna	18·3	—

Source: Office of the Geological Survey, Dublin.

At present rates of production these figures imply that supplies of anthracite will last for a hundred years or so, and that supplies of semi-bituminous coal from Arigna will last for more than two hundred years.

Taking all indigenous sources together Ireland has in recent years been producing some three-tenths of her total inland consumption of commercial energy. The remaining seven-tenths has to be met by imported supplies of either coal or petroleum.

Both coal and oil are imported and they and their derivatives compete with each other and with fuels from indigenous sources in many inland uses. The direct competition between coal and oil is not hindered by the State by direct or indirect control or by discriminatory taxation.[5] There is some protection of fuels from indigenous sources but this does not in general take the form of either duty or tax to be borne by imported fuels.[6]

Coal

Coal has traditionally been imported into Ireland from Great Britain. Indeed, coal is one of the commodities covered by the 1938 and 1948 Trade Agreements with that country, by which imports of

[5]Except for the preferential tariff of 3/- a ton on industrial coals from countries other than Britain.

[6]The exception to the general rule is the 1d. a gallon additional tax on automotive fuels imported as such rather than produced from imported crude-oil; little or no automotive fuel is in fact imported.

coal from other countries became subject to a preferential duty. This duty was not applied to large coals for household use in a number of years (and has not been applied now since about 1961) because of Britain's inability to supply Irish demand for this grade of coal. Coal for household use is being or has been imported from several other countries, those of importance being the United States, Poland, Western Germany and Belgium.

Whereas in 1953, for example, Britain supplied all the coal that was imported into Ireland, by 1963 that country's share of the Irish coal trade had declined to just over 40% of the total. Of the 580,000 tons imported from Britain in 1963, some 250,000 tons were gas-coals, roughly 100,000 tons were bituminous coals for household use, and 57,000 tons were anthracites (for household and general use). The remaining 150,000 tons were industrial coals used principally in cement factories. With both cement factories and gas undertakings switching rapidly to the use of oil products, trade in coal with Britain will continue to fall unless the demand for household coal in Britain declines sufficiently rapidly in relation to supply that British household coal becomes available again for export. This does not at present seem likely.

Coal from other sources is nominally for household use only, but including use in closed stoves and central heating appliances in institutions, offices and commercial premises. Undoubtedly some of this coal is also used in small industrial boilers: coal deteriorates and breaks up to some extent with transport and handling and the "screenings" of imported household coals are commonly sold for industrial use. The proportion of screenings may vary between 10% and 20% by weight.

Except for anthracites, which are shipped from South Wales ports, imported British coals are shipped from the Mersey and come mainly from the Nottinghamshire and Derbyshire fields. They are brought across the sea to Ireland in fairly small ships carrying perhaps four or five hundred tons, except that shiploads of more than a thousand tons are more common for industrial coals from Britain. Imported coals from the United States and from European countries other than Britain are carried in much larger ships of up to ten thousand tons.

The greater part of the coals imported into Ireland comes into Dublin. Unloading facilities in this port are not highly mechanised; small grabs have been installed in recent years and turn-around times have been improved but the trade is beset by labour problems. The Dublin Port and Docks Board has ambitious plans for improving unloading facilities generally and coal handling equipment in particular, but the trade is not sufficient to justify large-scale investment.

There may be about a hundred importers in the country who deal in coal, though for many of them coal is a small part of their trade. Some coal importers are also fuel merchants with their own distribution and retail systems. There are, or were, two coal importers' associations in Ireland. The national association, known as the Éire Coal Importers' Central Association, is no longer very active and many of its regional groups have disbanded. The Dublin Association is called the Irish Coal Importers Ltd. and this association deals, for instance, with many of the industry's labour problems. The sharing of the larger cargoes from the United States and Poland seems, however, to be arranged by individual agreements between importers. During the 1950's there was in existence an association to promote the use of coal and to give advice to consumers on technical matters but this association is no longer active. The coal trade is highly competitive.

The Electricity Supply Board is not at present importing coal for use in its power stations. The Dublin gas company is the largest single consumer of imported coal but this company too is in the process of changing over to oil.

The coal trade in Ireland, as in other countries, has suffered from the rapidly increasing use of fuel-oil in the industrial market. This market for coal has shown little if any growth over the last ten years or so and has probably declined recently since the cement factories at Limerick and Drogheda have changed over to oil. In the domestic market consumption of coal has been relatively stable at about one million tons a year. Consumption of energy in this market has grown but the increase has been supplied by oil, by electricity and by turf briquettes. The last fuel is a direct competitor of coal and the increased sales of baled briquettes have provoked coal merchants to market prepacked bags of coal of about the same weight as the bale of turf briquettes.

Railway use of coal has also fallen to a few thousand tons a year because of the change to diesel-engined locomotives.

Due possibly to the heterogeneous structure of coal supply and to the number and variety of interests involved, there is no immediate source of statistics of coal consumption in Ireland. Trade statistics show how much coal comes into the country and production statistics show how much is produced here, but for consumption data a variety of sources must be consulted. An attempt has been made to reconcile the various sources in Table 2. This table shows the total supply of coal and coke in Ireland for each year from 1950 to 1963 after subtracting exports and re-exports of these fuels. From the total supply in each year is subtracted the quantity delivered to the ESB and the

TABLE 2: COAL AND COKE SUPPLY

thousand tons

Category		1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Imports															
—anthracite		43	48	65	39	50	70	56	42	42	61	55	56	62	73
—gas coal		248	280	267	275	297	304	299	278	238	354	300	322	242	249
—steam coal (incl. household)		1,538	1,709	1,365	1,327	1,362	1,425	1,057	878	1,074	1,158	1,295	1,396	1,163	1,114
Sub-total		1,829	2,037	1,697	1,641	1,709	1,799	1,412	1,198	1,354	1,573	1,650	1,774	1,467	1,435
of which: from Britain		1,573	1,207	1,462	1,630	1,709	1,744	1,398	1,181	794	882	1,179	1,130	600	580
—other solid fuel imports		133	132	115	100	93	107	76	43	18	11	10	11	19	16
—less exports and re-exports		—	—	—	13	11	5	12	24	17	5	31	61	39	15
Total net imports		1,962	2,169	1,812	1,728	1,791	1,901	1,476	1,217	1,355	1,579	1,629	1,724	1,447	1,436
Production															
—anthracite		(95)	(100)	(100)	113	151	137	163	163	139	153	128	134	130	(130)
—semi bituminous		(45)	(45)	(45)	51	51	60	73	74	62	78	76	70	75	(75)
—coke		(75)	(90)	(80)	88	99	99	95	89	88	90	117	121	120	126
Total supply	(1)	2,177	2,404	2,037	1,980	2,092	2,197	1,807	1,543	1,644	1,900	1,950	2,049	1,772	1,767
Delivered to:	(2)														
—Electricity Undertakings		319	293	276	245	104	183	63	73	165	282	208	255	78	55
—Gas Undertakings	(3)	248	280	267	275	297	304	299	278	238	354	300	322	242	249
Consumed by:															
—other Industry and Services		460	375	400	455	480	510	295	315	380	455	435	410	415	(350)
—Railways		275	275	265	235	225	200	120	100	60	50	50	40	30	(20)
Sub-total		1,302	1,233	1,268	1,210	1,106	1,197	777	766	843	1,141	993	1,027	765	674
Apparent consumption of other sectors		875	1,181	769	770	986	1,000	1,030	777	801	759	957	1,022	1,007	1,083

( ) indicates estimate.

Notes: (1) Includes double-counting of coke produced in Ireland.
(2) The following average net calorific values are assumed:

Electricity	22·8 m.Btu/ton
Gas	28·0 m.Btu/ton
Industry	25·8 m.Btu/ton
Transport	25·8 m.Btu/ton
Other Sectors	27·3 m.Btu/ton
All Coal	25·8 m.Btu/ton

(3) Assumes all gas-coal imported is used by gas-works.

Sources: Import data from Trade Statistics; production data from Irish Statistical Bulletin; deliveries to Electricity Undertakings from ESB; for estimated consumptions of other Industry and Services and of Railways see Section 2.

quantity of gas-coal imported (assuming the latter to be destined exclusively for gas-works use). The estimated quantities consumed by Other Industry and Services and by Railways are also subtracted to leave a quantity representing the apparent consumption of other sectors. These would include households, institutions and commercial premises. Inaccuracies of the data and the effects of stock changes will both be magnified in these residual quantities, which might therefore be in error as much as, say, 20% in either direction.

Oil

Until 1959, oil used in Ireland had been imported in the form of refined products, but (following the international tendency for refineries to be established at or near the centres of consumption) a refinery was built at Whitegate near Cork and came into operation in July of 1959. The refinery is owned jointly by a group of major international oil companies. Products from the refinery are supplied to the marketing subsidiaries of these companies and to other oil marketing companies in Ireland (although the subsidiaries concerned supply most of the market).

The refinery is a comparatively simple installation. It has an atmospheric distillation column which produces a range of petroleum gases, a straight-run heavy gasoline, a variety of distillate oils in the gas/diesel range, and residual fuel oil. In 1963 it was using crude-oil from the Middle East, mainly from Iraq. The heavy gasoline is reformed by a catalytic process called "platforming" to produce motor spirit of the grades used in Ireland. Undesirable sulphur from gas/diesel oils is removed in a hydro-desulphurisation plant by reaction with hydrogen in the presence of a catalyst. The refinery produces no fuels in the kerosine range, no vaporising oil nor aviation fuel of any sort, no bitumen nor lubricants. These products and light fuel oil continue to be imported.

In 1963 the refinery produced just over 1½ million tons of oil products. Its nominal capacity is about 2 million tons a year. Up to now the pattern of refining has been balanced on the demand for motor spirit. As a result, surplus quantities of fuels in the gas/diesel range have been produced and exported. Surpluses are absorbed into the European supply networks of the oil companies involved in the refinery. Until 1962 fuel oils were also in surplus but by 1963 Ireland had become a net importer of these oils. Table 3 shows the supply of refined products in 1963.

Already by 1965 platforming capacity will only just be sufficient to meet demand for motor spirit but additional platforming plant will be in operation by 1966. Further major expansion is expected by 1970, including additional distillation capacity.

TABLE 3: IMPORTS, PRODUCTION, EXPORTS and CONSUMPTION OF OIL IN 1963

		Thousand tons
Imports by source:	Iran	98·7
	Iraq	1,259·5
	Saudi Arabia	252·1
	Total	1,610·3
Refinery throughput:		1,585·0
		1,563·8
Product balance*:—		

Product	Imports	Production	Exports	Bunkers	Inland use
Butane and propane	8	18	10	—	18
Motor spirit	8	331	7	—	339
White spirit	3	—	—	—	3
Kerosine/vap. oil	88	—	—	—	89
Gas/diesel oil	13	477	142	9	316
Fuel oil	263	676	40	97	797
Other products	61	10	4	—	64

*Aviation fuels excluded; these are all imported.
Source: OECD Oil Statistics.

Table 5 shows deliveries of petrol products into inland consumption from 1950 to 1963 inclusive; aviation and ocean bunker fuels are excluded. Also excluded are products destined for non-energy uses, like industrial spirits and solvents, bitumen and lubricants. Taken together these products represent about 7% by weight of the major energy products shown in Table 5.

The trend rates of growth of the different products may be compared by fitting straight lines to the logarithms of their annual levels of consumption. The results are shown in Table 4 and on Chart 1 appended.

The trend rates of growth over the whole period from 1950 to 1963 must be looked at with some suspicion because of the interruption of supplies

Table 4: TREND RATES OF GROWTH IN THE CONSUMPTION OF PETROLEUM PRODUCTS

Product	Period of trend	Trend rate of growth % p.a.	R^2
Motor spirit	1950 to 1963	+ 2·8	·76
Motor spirit	1958 to 1963	+ 5·9	·99
Burning oil	1958 to 1963	− 2·1	·80
Vaporising oil	1958 to 1963	− 7·3	·95
Automotive gas oil	1950 to 1963	+13·0	·98
Tractor diesel	1956 to 1963	+11·4	·85
Other gas/diesel	1956 to 1963	+ 6·8	·89
Total gas/diesel	1950 to 1963	+12·2	·96
Fuel oil	1950 to 1963	+11·1	·80
All products[1]	1950 to 1963	+ 7·3	·90
All products[1]	1958 to 1963	+12·1	·92

Note: [1]Included also are LPG's and LDF's (see Table 5).

caused by the Suez crisis of 1956 and 1957 (see Chart I appended). This seems to have affected the growth in consumption of different products in different ways. In the case of motor gasoline, consumption fell sharply in 1957 but instead of recovering to its previous level in the years immediately following the same trend rate of growth as that of the 1950 to 55 period seems to have re-established itself from the lower base. Consumption of this product has grown at nearly 6% p.a. in recent years. In the case of gas/diesel oils a new and lower rate of growth seems to have established itself since 1957, but still relatively high at about 12% p.a.

Consumption of both the kerosine-type fuels, burning oil and vaporising oil, seems to have been little affected by the Suez crisis except for a temporary fall in consumption in 1957. Consumption of these fuels has been declining in recent years.

Fuel oil consumption shows large fluctuations from year to year, mainly due to variations in the quantities used for generating electricity. It is therefore difficult to assess the effects of the Suez crisis at this global level; the trend rate of growth over the whole period has been just over 11% p.a.

Total consumption of all energy products shows all these various effects compounded. The time-series is too short in comparison with the apparent period of fluctuation from peak to peak to draw precise conclusions. The longer term trend from 1950 to 1963 has been nearly 7½% p.a. but over the six years since 1958 consumption has grown at over 12% p.a. The appended chart shows this very clearly.

The lighter petroleum products are sufficiently specialised for it to be relatively easy to identify by which classes of consumer they are used. The heavier products have a number of applications and are used by a wide range of consumers, and it is therefore more difficult to identify consumption of these products by sector. An attempt is made in Table 6, by subtracting from total consumption of gas/diesel and fuel oils those quantities known or estimated to have been used for transport purposes, for electricity and gas making, and by other Industry and Services, to establish the amounts used by other sectors. These other sectors include households, offices, commercial premises and shops, and institutions—schools, hospitals, etc.—where oil is used mainly for central-heating (industrial uses also include some central-heating, of course).

The apparent consumption of these sectors is a residual amount and it magnifies not only the effects of errors in the figures subtracted but also the effects of stock changes in railway diesel and in industrial oils. The series indeed shows violent fluctuation from year to year, its most alarming feature being the very high levels of apparent consumption in 1956 and 1957. The most feasible explanation is that in 1956 there was considerable stock-piling by industry[7] towards the end of the year when prices began to rise very rapidly, while consumption began to fall with the onset of the recession. In 1957 measures might have been taken to increase storage capacity to guard against further supply crises and this increased capacity would have been filled as soon as prices had fallen to reasonable levels, as they had by the end of the year. Industrial consumption of oil, as distinct from deliveries, was very low in 1957 because of the recession.

The Supply of Energy to the Final Consumer

Figures for the total quantities of primary energy consumed in Ireland from 1950 to 1963 have been given in Table 10 appended to Part III, Section 2. Not all the energy shown in that table was energy sold into final consumption; some was converted into secondary form before being sold for consumption, and in particular into either electricity or townsgas. It may be noted that the refining of crude-oil and the briquetting of milled peat are also in principle processes of energy transformation, but that they are

[7]This might well have been occasioned by the conversion of certain cement plants to oil; the plants concerned are reconverted to coal in the following year it is understood.

TABLE 5: DELIVERIES OF PETROLEUM (ENERGY) PRODUCTS INTO INLAND CONSUMPTION

	Million gallons (5)													
	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Light distillate feedstock	—	—	—	—	—	—	—	—	—	1·0	1·6	4·5	5·0	4·9
Motor spirit[1]	64·1	69·3	72·5	75·8	80·0	84·1	87·1	71·8	78·7	81·3	85·1	91·6	96·7	104·5
Burning oil[2]	14·3	15·8	15·6	15·6	16·8	16·8	16·7	15·1	17·2	16·9	16·6	15·5	15·8	15·7
Vaporising oil[3]	8·7	11·0	12·3	12·5	12·8	12·8	12·3	10·7	10·6	10·3	9·1	9·1	7·9	7·3
Automotive gas oil	5·7	6·3	6·6	6·8	7·8	8·9	10·6	10·5	12·7	14·8	17·2	20·7	23·9	26·2
Tractor diesel[4]	...	...	...	...	...	...	10·7	8·0	11·1	13·3	14·7	17·5	17·3	18·3
Other gas/diesel[4]	14·6	16·4	17·1	18·7	23·4	28·6	27·6	25·6	29·7	30·3	32·6	32·8	39·5	42·3
Fuel oil	34·9	48·1	40·3	49·5	56·1	89·0	105·3	85·7	76·2	80·8	76·9	98·1	153·9	188·2
Liquefied petroleum gases	0·4	0·4	0·8	0·8	0·8	0·8	1·6	2·4	4·0	5·2	6·0	6·4	6·8	7·2
Total (10^{12} Btu)	21·2	25·0	24·6	26·9	29·7	36·7	41·5	35·1	36·3	38·3	39·1	44·8	56·0	63·6

Notes: [1]Includes motor spirit used for agricultural tractors and farm machinery. Small quantities of industrial alcohol, which is mixed with regular grade petrol, are included.
[2]Excludes kerosines used for space-heating boilers.
[3]Includes tractor vaporising oil only.
[4]Breakdown not available before 1956. Other gas/diesel includes small quantities of kerosine used for space-heating boilers.
[5]For conversion into weight and heat units the following factors apply:—

	Gallons per ton	'000 Btu per gallon
Light distillate feedstock	320	130
Motor spirit	303	138
Burning oil	285	149
Vaporising oil	275	149
Automotive gas oil	267	156
Tractor diesel	267	156
Other gas/diesel	265	156
Fuel oil	233	164
Liquefied petroleum gases	400	110

Source: Information made available by the principal oil companies; LPG consumption estimated from OECD oil statistics and from value data for imports of these gases from Trade Statistics.

Table 6: GAS/DIESEL AND FUEL OIL CONSUMPTION

million gallons

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Gas/diesel oils:														
Total deliveries	14·6	16·4	17·1	18·7	23·4	28·6	38·3	33·6	40·8	43·6	47·3	50·3	56·8	60·6
Less tractor diesel (deliveries)	(2)	(2)	(3)	(5)	(7)	(9)	10·7	8·0	11·1	13·3	14·7	17·5	17·3	18·3
Less railway diesel (consumption)	0·2	0·3	0·5	1·0	1·3	2·9	4·8	6·1	6·7	7·2	7·2	6·7	7·7	7·9
Balance	12·4	14·1	13·6	12·7	15·1	16·7	22·8	19·5	23·0	23·1	25·4	26·1	31·8	34·4
Fuel oils:														
Total deliveries	34·9	48·1	40·3	49·5	56·1	89·0	105·3	85·7	76·2	80·8	76·9	98·1	153·9	188·2
Less ESB use (deliveries)	5·0	5·8	4·4	9·7	19·5	38·4	49·7	31·2	23·1	17·0	10·5	28·6	65·6	86·5
Balance	29·9	42·3	35·9	39·8	36·6	50·6	55·6	54·5	53·1	53·8	66·4	69·5	88·3	101·7
Gas/diesel and fuel oils:														
Balance of consumption	42·3	56·4	49·5	52·5	51·7	67·3	78·4	74·0	76·1	76·9	91·8	95·6	120·1	136·1
Less oil company use	0·4	0·5	1·1	1·2	1·3	1·4	1·3	1·1	1·2	1·5	1·8	1·9	2·1	1·8
Less gasworks use (deliveries)	(1)	(1)	(1)	(2)	(2)	(2)	(3)	(3)	(3)	3·4	(3·6)	(4·0)	(7·9)	(14·0)
Less industrial use (consumption)	26·8	35·4	37·6	36·8	41·8	44·3	43·6	34·5	47·8	52·0	58·4	60·3	77·4	n.a.
Less water transport use	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(2·5)	(2·7)	(3·0)	(4·0)	(4·0)	(4·0)
Apparent consumption of other sectors	13·8	16·5	6·8	9·5	3·6	16·6	27·5	32·4	21·6	17·3	25·0	25·4	28·7	n.a.

( ) Indicates estimate. n.a. Indicates not available.

Source: Data for total deliveries of gas/diesel and fuel oils, for deliveries of tractor diesel oil, and for oil company use from information made available by the principal oil companies; data for deliveries to ESB from ESB; for estimates of consumption by Railways and by Industry see later sections.

here counted as production processes because they are carried out by the enterprises supplying those forms of energy. To an extent, therefore, the figures presented as total energy consumption in Ireland are too low: they are missing the amounts of energy lost at the oil refinery in the manufacture of oil products and at peat-briquetting plants in the manufacture of briquettes. The omissions are of small importance.

Energy in liquid or solid form is commonly available to the consumer and can be purchased locally much like any other goods. However, if the consumer has a preference for, or a specialised need of, energy in the form of electricity or gas he must either convert the liquid or solid fuel himself or pay someone to do it for him. Many consumers do want electricity and gas, of course, and it is economically attractive to produce these secondary types of energy in bulk and to install the means of distribution they require.

The bulk production of electricity and gas is economically attractive. But it may be noted that this is not the case with all forms of energy. Heat, light and motive power, the forms of energy that the consumer ultimately uses, cannot be produced in bulk in this way except in special circumstances. In some European countries, for example, the waste heat from electric power stations is distributed in the form of hot air, hot water or steam to houses in the locality, to be used for central heating. However, it would be very inefficient and therefore costly to transport heat in this way over any distance. Light and motive power would be even more difficult to carry.

The choices facing the consumer and the reasons that will prompt his selection of a particular form of energy to apply to a particular task will be discussed in the next section. Here the intention is to point out that the consumer requires at least some of the energy he uses in forms that are specially produced for him. Primary energy is consumed in the production of these secondary types of energy (i.e., electricity and towns gas). Table 7 shows (commercial) primary energy consumption broken down between primary energy that is consumed directly and primary energy that is transformed into electricity and gas; hydro-electricity is regarded as an input into the production of secondary energy. Figures shown under electricity and gas indicate primary input into the production of these forms of energy (not the heat value of the energy produced).

The point of most interest in this table is the increasing relative importance of secondary energy, and particularly of electricity. Where in 1950 input of primary energy into secondary energy production represented some 22 or 23% of all primary energy consumption, by 1963 that share had risen to 31%. Indeed, its share would have been even higher latterly had not the increasing efficiency of transformation of primary into secondary energy tended to work in the reverse direction.

Imported gas coal, gas oil, and heavy fuel oil are used in Ireland for making towns gas; coal, machine turf, milled peat, and fuel oil are used for making

TABLE 7: COMMERCIAL PRIMARY ENERGY CONSUMPTION BY TYPE OF ENERGY IN WHICH FINALLY CONSUMED; 1950 to 1963

10^{12} Btu

Year	Primary energy consumption[1]				by type of energy in final consumption						Total[2]
	Fuels		Hydro-electricity	Total[2]	Primary fuels			Secondary energy			
	Solid	Liquid			Solid	Liquid	Total	Electricity[3]	Gas[3]	Total	
1950	57·8	22·0	6·8	86·6	45·4	20·5	65·9	14·4	4·9	19·3	85·2
1951	64·6	25·0	7·0	96·6	51·3	23·7	75·0	16·4	5·5	21·9	96·9
1952	58·0	24·6	7·0	89·6	40·1	23·5	63·6	18·8	5·2	24·0	87·6
1953	58·3	26·9	6·8	92·0	42·4	24·6	67·0	19·7	5·4	25·1	92·1
1954	61·5	29·7	11·8	103·0	49·4	25·8	75·2	21·9	5·5	27·4	102·6
1955	64·8	36·7	7·8	109·3	49·9	29·6	79·6	22·0	5·5	27·5	107·0
1956	64·6	41·5	7·7	103·8	43·6	32·5	76·1	21·9	5·5	27·4	103·5
1957	49·8	35·1	9·4	94·3	36·4	29·0	65·4	23·3	5·4	28·7	94·1
1958	53·1	36·3	12·0	101·4	38·8	31·7	70·5	25·5	5·4	30·9	101·4
1959	60·9	38·2	8·3	107·4	38·4	32·9	71·3	27·3	5·4	32·7	104·0
1960	65·1	38·9	14·1	118·1	45·1	36·2	81·3	32·5	5·6	38·1	119·4
1961	70·0	44·2	10·9	125·1	46·8	38·5	85·3	32·3	5·1	37·4	122·7
1962	66·1	55·4	9·6	131·1	47·8	42·8	90·6	35·7	5·0	40·7	131·3
1963	68·1	63·0	9·2	140·3	49·9	46·7	96·6	38·2	5·2	43·4	140·0

Notes: [1]See Table 10 appended to Part III, Section 2 for details.
[2]Totals do not agree exactly because electricity and gas producers' stock changes and oil company use of oil products have been excluded from final energy supply.
[3]These quantities represent primary energy input into electricity and gas manufacture, less coke output in the case of gas; details are given in the sections relating to electricity and to gas.

electricity. The gas industry produces both towns gas and gas-coke but, for convenience, the quantities of coke produced are deducted in Table 7 from this industry's consumption of coal.

Townsgas

In 1963 there were 22 townsgas undertakings in Ireland. All but three of these undertakings were privately owned: those at Drogheda, Limerick, and Youghal, Co. Cork, were owned and run by the local Corporation (or Urban District Council in the case of Youghal). Each of the 22 undertakings had its own gas-plant and operated quite independently of the others. The Alliance and Dublin Consumers' Gas Co. in Dublin produced about three-quarters of all the gas consumed in the Republic. The Cork Gas Consumers' Co. produced one-eighth, or half of the remainder, and the other 20 undertakings shared what was left.

Historically, the gas industry has been associated throughout Europe with the carbonisation, or coking, of coal. In gas-making proper, coal with a high content of volatile matter is heated with air and steam to produce coal gas of calorific value around 450/500 Btu per cubic foot. Perhaps 30% of the heat content of the coal is turned into gas. The gas produced is composed mainly of hydrogen and methane but it also contains lesser proportions of carbon monoxide, nitrogen, oxygen and carbon dioxide. Carbon monoxide is the poisonous element in coal gas. Apart from process losses the remainder of the original heat content of the coal is mostly left in the form of coke, which is basically fixed carbon in combination with small quantities of moisture and ash, and of coal tar, the familiar sticky, liquid substance sometimes used in road-making. About half the heat content of the coal is left in these forms, most of it as coke.

The principal industrial use of coke is for iron-making in blast-furnaces. In this use a very strong coke of high quality, called metallurgical coke, is required. The gas-coke produced in ordinary gas-making processes is too soft for this purpose and must therefore find other markets. As a fuel it has the advantage of being smokeless, but the disadvantage of needing controlled combustion conditions and so unsuitable for household use on open fires. For small or large stoves and for industrial boilers it is, however, an excellent fuel although it can command little premium over any other fuel for these appliances. Unless there exist statutory regulations about the use of smokeless fuels there is little specific demand for gas-coke as such and this form of coke fetches no more than the same price on a heat basis as coal or fuel oil. This price may well be less than the price of the gas-coal from which the coke was made.

Hence, the traditional problem of gas-making has been that of producing a by-product in greater proportions than the main product, and a by-product moreover which barely covers its production costs insofar as these can be isolated. A partial solution has been found in the use of some at least of the gas-coke produced in combination with gas-oil to make what is called carburetted water gas, a gas similar to coal gas but with a higher content of carbon monoxide. The process has the advantage of not needing expensive capital equipment; on the other hand there are so many competing uses for gas-oil that this has become an expensive form of feedstock.

A later development in the story of making gas from coal is worthy of mention: the total gasification of coal to produce a gas of low calorific value. This is a very capital-intensive process, only likely to become economic in large size with cheap coal available, and it produces a "lean" gas which has to be enriched with gas of greater heat content from some other source. Its future is uncertain.

In Ireland many of the small gas undertakings still use old-fashioned horizontal retorts, making gas from coal in an intermittent and rather inflexible process. A few of the larger undertakings have installed the modern and efficient vertical retorts and a few have carburetted water gas plant. The more recent history of gas-making in Ireland requires a brief preliminary discussion of other sources of gas.

In the early 1950's processes began to be developed to use petroleum products for making gas. The plant had a low capital cost and the great advantage of producing little by-product, and certainly no embarrassing surplus of coke. The original plants were designed to use heavy fuel oil as feedstock but recently plant has been designed that can use feedstocks varying from heavy fuel oil to the lightest refinery tail gases. There are many varieties, some of which are more suitable for producing richer gases from certain ranges of feedstock, and so on. The latest plant is capable of making gas at a pressure high enough to be passed directly into transmission mains.

The coming of oil-based gas introduced considerable flexibility into an industry that had hitherto been tied to expensive equipment and a difficult by-product. In particular the use of oil makes it possible to meet peak seasonal loads much more economically, and it also provides a source of supply, where needed, for enriching gases from other sources of lower quality.

A further possibility opened up by the siting of oil refineries closer to the markets for products is the use for gas-making of the petroleum gases produced at the refinery. Refinery tail gases have already been mentioned. These are very rich gases consisting mainly of methane that are often either flared off or used for refinery heating. They are of too variable a composition for safe direct use as towns gas but make an excellent feedstock for a reforming process. The other gases produced at the refinery are the liquefied petroleum gases, butane and propane. Propane is used in industry as a local source of heat and butane and butane/propane mixture are commonly used for domestic bottled-gas appliances. Either can be stored in liquid form and either can be mixed with air and used directly as towns gas. They are thus very suitable for meeting peak-loads or for enriching lean gases (within limits) in the larger gas undertakings, and they can be used economically as the sole source of supply for a small undertaking. One of the smaller undertakings in Ireland relies entirely on a propane-air mixture for its source of gas.

In some parts of the world, gas—mostly methane—is available naturally and large resources have been discovered in the search for oil. When the natural gas liquids have been condensed from it this gas can be piped directly into consumers' homes and factories. It is a very rich gas, usually very clean and easily controlled; it requires a different type of burner from that used for ordinary towns gas. Alternatively, it can be reformed chemically to produce a gas of lower calorific value suitable for ordinary use.

Natural gas can be liquefied only at very low temperatures. Thus, where pipeline transportation is not feasible the only alternative method of transportation is under refrigerated conditions. Natural gas is now being delivered into Britain from the Sahara in liquid form using tankers with special heat-insulated storage. The gas is liquefied at the collection port and pumped into the insulated tanks of the vessel. At the delivery port it is re-gasified and pumped directly into a gas transmission pipeline running right across the country. It is finally used for enriching lean gases or as a feedstock in a reforming process at the major centres of consumption along the route. Britain will shortly have a direct supply of natural gas from the North Sea.

One advantage of any gas based on petroleum or natural gas is its freedom from toxic substances like carbon monoxide.

The two most important undertakings in Ireland have already begun to turn to oil as their source of gas. The Cork undertaking installed in 1960 an Onia-Gegi plant, a reforming process based in this case on light distillates from the Whitegate oil refinery. In 1962, the Dublin undertaking commenced operation of a "Segas" plant using fuel oil as feedstock to supplement existing vertical coal-carbonising retorts and carburetted water-gas plant. This undertaking is installing one of the ICI hydrogenation plants using light distillate feedstocks. The Segas plant will be retained for stand-by purposes and all coal-based processes will be displaced entirely. The problem of surplus coke, which has had to be exported as far afield as Norway, will thus be eliminated. By the switch to oil production costs are being greatly reduced.

In 1962 some 29·4 million therms of townsgas were produced in Ireland. This is equivalent to $2 \cdot 9 \times 10^{12}$ Btu or some 110 thousand coal tons. Per head of population this level of production represents just over one million Btu per inhabitant. Table 8 shows levels of *per capita* production in other selected European countries, both for the Towns-gas Industry proper and for total gas production including coke-oven gas, blast-furnace gas, refinery gas, liquefied petroleum gases and natural gas.

TABLE 8: GAS PRODUCTION PER HEAD IN EUROPEAN COUNTRIES IN 1962

Country	Towns gas	All gas	Main sources of supply other than Towns gas
	Million Btu	Million Btu	
Austria	·41	13·70	Natural gas
Belgium	·90	16·00	Coke-oven and blast furnace gas
Denmark (1963)	1·21	1·42	Refinery gas
Finland	·25	·92	Liquefied pet. gases
France	·33	13·00	All sources contribute
Greece	·03	·16	Liquefied pet. gases
IRELAND	1·04	1·25	Liquefied pet. gases
Italy	·27	7·50	Natural gas
Netherlands	·80	9·10	Coke-oven and blast-furnace gas
Norway	·15	·24	Liquefied pet. gases
Portugal	·11	·49	Liquefied pet. gases
Spain	·16	2·40	Coke-oven and blast-furnace gas
Sweden	·72	·90	Liquefied pet. gases
Switzerland	1·07	1·07	None
United Kingdom	4·40	7·70	Coke-oven and blast-furnace refinery gas
Germany (F.R.)	1·23	15·40	All sources contribute

Source: UN, Annual Bulletin of Gas Statistics for Europe, 1963.

This table makes it clear that in proportion to the country's population the townsgas industry in Ireland is of some European significance. On the other hand the quantities of gas of all kinds produced in Ireland are small in comparison with those European countries blessed with supplies either from natural sources or from their iron and steel industries (and associated coking plant).

The annual rate of production (and of consumption) has grown, if at all, only very slowly in Ireland. Table 9 shows the production of gas in each year from 1953 to 1963, the consumption of coal for gas-making, and the amounts of coke produced. Since

1957 production has increased at an annual rate of some 2% p.a., while before 1957 there was little sign of growth. Coal consumption varied in rough proportion to gas production until 1962 when the effects of the use of oil for gas-making made themselves felt for the first time.

TABLE 9: GAS AND COKE PRODUCTION, AND COAL CONSUMPTION; 1953 TO 1963

Year	Gas Production 10^{12} Btu	Coal Consumption thousand tons	Coke Production thousand tons
1953	2·63	267	88
1954	2·71	277	99
1955	2·72	271	99
1956	2·69	273	95
1957	2·63	284	89
1958	2·65	261	88
1959	2·66	269	90
1960	2·81	292	112
1961	2·76	281	121
1962	2·94	264	120
1963	3·00	242	126

Source: Census of Industrial Production, Annual Data; Irish Statistical Bulletin.

TABLE 10: GASWORKS USE OF OIL; 1959 TO 1963

Year	Consumption[1]		Deliveries[2]
	m. galls	th. tons	th. tons
1959	n.a.	n.a.	13
1960	n.a.	n.a.	14
1961	4·0	17	10
1962	5·7	24	26
1963	12·8	53	66

n.a. = not available.
Sources: (1) Central Statistics Office.
(2) O.E.C.D. Oil Statistics.

In Table 10 is given the available information about the use of oil by gas-works. The data are too scanty for a detailed historical analysis of gas-making as a process of energy transformation. However, to have some idea of what takes place, suppose that in 1953 2 million gallons of gas-oil were used, and that the average calorific values of gas-coal and of coke were 28·0 m.Btu/ton and 27·5 m.Btu/ton respectively. Then the following heat balances can be formed for 1953 and 1963:—

	10^{12} Btu	
	1953	1963
Heat input:		
coal	7·48	6·78
oil	·31	2·07
Total	7·79	8·85
Heat output:		
gas	2·63	3·00
coke	2·42	3·47
Total	5·05	6·47
Input/output ratio	65%	73%

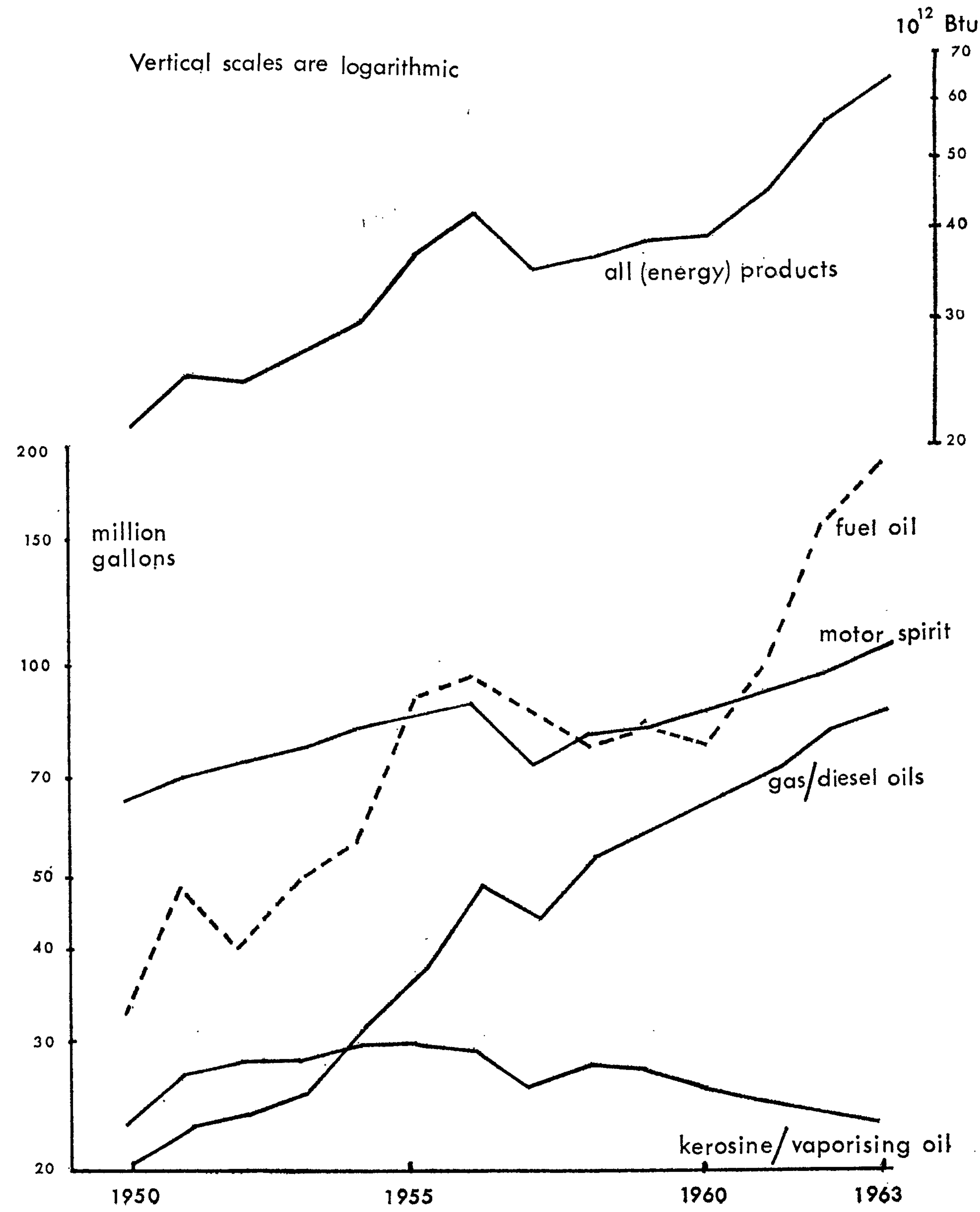
These figures give some sign of increases in efficiency through improved gas-making techniques. Unfortunately the change in the amount of coke produced per ton of coal used makes it difficult to assess how much oil is needed to displace one ton of coal to produce the same quantity of gas. In rough terms, however, it may be taken that if oil will yield twice as much gas as coal on a therm for therm basis then one-third of a ton of oil will displace one ton of coal (and, of course, the latter's by-product coke too).

The main uses for gas are for cooking and home-heating. Relatively little gas is used for industrial purposes. One of the consequences of its mainly domestic load is the considerable variation in the rate of consumption of gas from hour to hour during the day and from season to season during the year. For example, peak consumption of gas in the Dublin area was estimated at 3 million cubic feet per hour in 1961. In the same year total consumption of gas in Dublin was 4,700 million cubic feet. The ratio of the average hourly rate of consumption to the peak rate of consumption is as 1:4, roughly. Thus, whereas demand for electricity has a load factor of about 50%, that of gas is only about 25%.

The supplier of gas is, however, in a much happier position than the supplier of electricity when faced with variations in demand because, unlike electricity, gas can be stored (in the familiar round gas-holders and to some extent in the distribution mains themselves). Thus the supplier of gas is usually (as far as production is concerned) only concerned with variations in consumption from one week to the next. Weekly consumption tends to follow a seasonal pattern of variation. The relevant load factor for gas consumption is not the relation between average and peak *hourly* load but that corresponding to weekly or even monthly load. The gas supplier also has a problem in keeping up the pressure in the mains during brief peaks in consumption, but this is relatively less serious.

It has been estimated that to meet the peak demand for gas throughout the country with electrical energy would require the installation of about 550,000 kilowatts of generating capacity, or two-thirds as much again as is at present installed. There is therefore little doubt, considering the high capital cost of electricity generating plant, that the gas industry in Ireland performs a useful service. Indeed the question is rather the reverse, whether it could not perform a more useful service by taking a greater part of the heating and cooking load, and especially that part which contributes to peak demand for electricity.

CHART I (appended to Part IV, Section I): Inland Consumption of Petroleum Fuels; 1950 to 1963.



SECTION 2: THE CONSUMPTION OF ENERGY

In the previous section the supply of energy is traced as far as the final consumer. Part is transformed along the way into secondary forms of energy, with the result that the consumer is presented with considerable choice of the form of energy he will use. He is free to select not only from the primary liquid and solid forms of energy but also from the secondary forms, gas and electricity. This section considers who is the final consumer, how much energy he consumes, and some of the factors that affect his choice of one form of energy rather than another.

In making an analysis of energy consumption it would be technically most appropriate to use a classification of energy use tailored specially for the analysis. Such a classification would identify how much energy is used for heating, for lighting, for stationary motive power, and for transport. Within each of these categories the quantities of energy used would be separated according to the principal types of appliance in which the energy is consumed. Thus, in heating uses for example, furnace uses would be separated from boiler uses, industrial boiler uses from domestic boiler uses, open coal fires from closed stoves, etc. The need for this classification arises because competition between the various forms of energy depends to a major extent upon the use to which the energy is put and upon the type of appliance in which it is consumed. The choice of a form of fuel for a railway engine is determined by considerations quite distinct from those which govern the choice of heat source for domestic central heating. In the first place this is because different technical possibilities apply. In the second place, having once installed a particular type of appliance the consumer's choice of a form of energy is limited by the specific characteristics of the appliance, and there may be no choice left at all—as in the case of the motor-car, which is made to use petrol. The classification of energy consumption by end-use and by appliance would make it possible to identify how much and what services the consumer requires. These may be described as the underlying realities of the situation.

As so often happens, however, the available information is not sufficient (in general) for these underlying realities to be uncovered. What information is available tends to be arranged according to the economic function of the consumer and not according to the use to which he puts the energy he buys. Thus it is possible to know how much energy is used in Industry but not how much of that energy is used for comfort-heating rather than for industrial processing of raw materials. Furthermore, information about types of appliance is very scanty indeed and, even when available, usually relates to the annual sale of appliances in use. Who knows, for instance, how many gas cookers are in use in Ireland and how much gas is used for cooking?

There are notable exceptions to this general lack of information and road transport is an important instance. Here the appliances themselves—cars and lorries—are of sufficient importance (in a fiscal sense at least), and the forms of energy they consume (petrol and diesel) are sufficiently specialised (and again of fiscal importance), that at least gross figures of stocks and flows are commonly available. Indeed the annual sale of motor-cars has almost the status of a general economic indicator. Nevertheless, for the most part such information on end-use and type of appliance is not available.

Some compensation is gained from the availability of energy consumption data according to the economic function of the consumer. It becomes possible to examine the relationship between the total use of energy in the sector to which the consumption corresponds and the general economic development of the sector. Provided that changes in the end use of energy and in the types of appliance used by consumers in the sector are proceeding smoothly, one may expect to observe a stable pattern of dependence over time between its energy consumption and its economic 'progress'. This dependence can be expressed as a coefficient of elasticity in a regression model and its numerical value estimated by ordinary statistical procedures, just as in any other statistical investigation of economic behaviour. The resulting estimates are particularly useful for making forecasts of energy consumption that are to be consistent with independently-made projections of economic development.

However, it must not be forgotten that the numerical values of such coefficients are statistical estimates. They are the effects of changes in the final use to which energy is put and in the types of appliance in which the energy is used and for further analysis one must penetrate to the underlying realities mentioned earlier. This applies particularly to the forecasting of the future values of coefficients in prediction models, and it will involve intuitive as well as purely statistical judgements.

In making a breakdown of energy consumption according to the economic function of the consumer it will not be possible to adhere strictly to one of the common schemes of sectoral division—that used in national income accounting for example. There are several reasons for this. The first is that it is desirable to group all forms of transport together because this is the one end-use of energy for which data are available as has been discussed. The second is that those industries concerned with energy transformation are better treated separately from the main bulk of industry because in respect of energy use they perform a different function from energy-consuming industries. Finally, because information is not sufficiently detailed there will be a large residual block of consumption not exactly identified with a particular sector or group of sectors.

To be specific, the following breakdown of final energy consumption will be adopted:

(i) Industry, excluding electricity and gas undertakings and the use of automotive fuels;

(ii) Transport, including all energy used for inland transport of passengers and goods;

(iii) Agriculture, including only the energy used in specialised agricultural appliances;

(iv) Other Sectors, which includes energy consumption of households, commercial premises and institutions.

The last of these categories is commonly called the Domestic Sector in the technical literature on Energy. The use of energy by this sector is impossible to establish in any direct fashion because consumption data are not available (nor even data relating to sales or deliveries of energy, except for Burning Oil sales because this is a fuel used exclusively for home-heating; there is also some information about the sector's consumption of electricity). Its use of energy can therefore be estimated only as a residual, by subtracting the known consumptions of other sectors from the total. This procedure tends to concentrate all inaccuracies and all the effects of stock changes (in the industrial sector) onto the residual, which becomes in consequence information of very doubtful validity. There is unfortunately no alternative.

In the following paragraphs attention will be paid to each of these sectors of consumption in turn, and to the patterns of energy consumption and of competition (in a broad sense) within each sector. Before doing so it is useful to present consumption data by sector in global form and to examine these from a general point of view.

In Table 11 primary energy consumption is broken down according to the sector to which that energy was destined, whether or not it was subject to transformation into gas or electricity in the process. Figures shown under gas and electricity indicate the shares of primary input of energy for the manufacture of these secondary energies that could be attributed to the needs of the sector concerned. This method of disaggregation is suited to an examination of the relative importance of each sector's demands on all commercial primary energy consumption. It will be recalled that a similar analysis, but by type of energy, was used in the previous section (Table 7). The method is not suitable for looking at the consumption of energy within a particular sector because it does not take into account the way energy is used in that sector; the object in this table, however, is not to examine energy consumption within sectors but to compare consumptions between sectors.

Roughly speaking, rather more than a quarter of all commercial primary energy is consumed by Industry, about a sixth by Transport, one thirtieth by Agriculture, and the balance of a little more than half is used by Other Sectors. There have been fluctuations in these proportions during the period but there appears to be a tendency for the consumptions of Industry and of Other Sectors to increase at the expense of consumption of the Transport sector. This has obviously been due almost entirely to the displacement of solid fuels as a (railway) transport fuel with the consequent considerable increase in efficiency and reduced fuel consumption that it involved. If consumption by Transport is neglected, changes over the period are very much less significant although there remains (in the beginning and end of period, five-year averages) a slight tendency for consumption by Industry to increase its share at the expense of consumption by Other Sectors. Although representing only a very small proportion of the total, consumption by Agriculture has increased its share significantly over the period.

Industry and Services

Included in Industry and Services are all those establishments concerned with mining and quarrying, manufacturing, building and service-type industries that are covered by the Census of Industrial Production. In general the Census includes all establishments except those which had, on average, less than 3 persons engaged during the year.

Since 1961, Census Returns (which are made each year by all but the smallest establishments) have shown both the quantities of fuel and power used during the year and their costs. The reporting of quantities consumed had previously been discon-

Table 11: COMMERCIAL PRIMARY ENERGY CONSUMPTION BY SECTOR IN WHICH FINALLY CONSUMED; 1950 TO 1963

10^{12} Btu

Year	Industry					Transport			Agriculture	Other Sectors					Total all sectors
	Solid fuels[1]	Liquid fuels[2]	Gas[3]	Electricity[3]	Total	Solid fuels[1]	Liquid fuels	Total	Liquid fuels	Solid fuels[1]	Liquid fuels[2]	Gas[3]	Electricity[3]	Total	
1950	13·0	4·3	4·8	4·8	22·5 (26·4%)	7·1	10·1	17·2 (20·2%)	1·8 (2·1%)	25·3	4·3	4·5	9·6	43·7 (51·3%)	85·2 (100%)
1951	11·2	5·7	0·4	5·2	22·5	7·1	10·7	17·8	2·3	33·0	5·0	5·1	11·2	54·3	96·9
1952	11·8	6·1	0·4	6·3	24·6	6·8	11·3	18·1	2·6	21·5	3·5	4·8	12·5	42·3	87·6
1953	13·1	6·0	0·5	7·1	26·7	6·1	11·9	18·0	2·9	23·2	3·8	4·9	12·6	44·5	92·1
1954	13·6	6·8	0·6	7·7	28·7	5·8	12·7	18·5	2·9	30·0	3·4	4·9	14·2	52·5	102·6
1955	14·3	7·2	0·6	7·9	30·0	5·2	13·7	18·9	3·4	30·4	5·3	4·9	14·1	54·7	107·0
1956	8·7	7·1	0·6	7·4	23·8	3·1	14·7	17·8	3·7	31·8	7·0	4·9	14·5	58·2	103·5
1957	9·3	5·6	0·6	7·9	23·4	2·6	12·8	15·4	3·0	24·5	7·6	4·8	15·4	52·3	94·1
1958	11·0	7·7	0·6	8·5	27·8	1·5	14·2	15·7	3·4	26·3	6·4	4·8	17·0	54·5	101·4
1959	12·6	8·4	0·7	9·7	31·4	1·3	15·0	16·3	3·7	24·5	5·8	4·7	17·6	52·6	104·0
1960	12·4	9·5	0·7	11·7	34·3	1·3	15·9	17·2	3·7	31·4	7·1	4·9	20·8	64·2	119·4
1961	11·6	9·8	0·7	11·8	33·9	1·0	17·5	18·5	4·2	34·2	7·0	4·4	20·5	66·1	122·7
1962	11·8	12·5	0·7	14·0	39·0 (29·7%)	0·8	18·8	19·6 (14·9%)	3·9 (3·0%)	35·2	7·6	4·3	21·7	68·8 (52·4%)	131·3 (100%)
1963	n.a.	n.a.	n.a.	n.a.	n.a.	0·4	20·3	20·7	4·0	n.a.	n.a.	n.a.	n.a.	n.a.	140·0
5–Years: 1950 to 1954					125·0 (26·9%)			89·6 (19·3%)	12·5 (2·7%)					237·3 (51·1%)	464·4 (100%)
1958 to 1962					166·4 (28·7%)			87·3 (15·1%)	18·9 (3·3%)					306·2 (52·9%)	578·8 (100%)

Notes: [1]The following conversion factors have been used for the coal used in the various sectors: Industry 25·8 m.Btu/ton; Transport 25·8 m.Btu/ton; Other Sectors 27·3 m.Btu/ton.
[2]Conversion factors for gas/diesel and fuel oils: Industry 162,000 Btu/gal; Other Sectors 158,000 Btu/gal.
[3]The quantities in these columns are inputs of primary energy to electricity and gas manufacture, less coke produced in the latter case.

tinued in the early 1950's because the data supplied had been either incomplete or in other ways unsatisfactory, and so for the intervening years only cost data are available. The quantity data for 1961 and for 1962 were by no means complete nor were completed returns entirely reliable—gas consumption was often reported in the wrong units for example—but it was possible to estimate fuel and power consumption from them with fair accuracy. The author was kindly given access by the Central Statistics Office to summaries of the returns for these years for each branch of industry and from them he has prepared the estimates described here. For each branch of industry he scaled up the reported quantities in the ratio of the total cost of each form of fuel to the cost of quantities reported, except in a few cases where this procedure was obviously not applicable because of the relative sizes of the establishments that reported quantity and those that did not.

The basic data, then, are estimated consumptions in 1961 and 1962 and cost data for previous years. There is also some aggregate information on consumption in 1951 in a table published in 1954[8]. The author had no time to follow up this information in C.S.O. records but he has used it to give a fairly firm base to his price indices for the years between 1951 and 1961. For each form of fuel, reported annual costs were divided by estimated average annual prices in order to give consumption. Annual average prices between 1951 and 1961 were extremely difficult to estimate because of the wide fluctuations there have been on account of the Korean War, the Suez crisis, temporary shortages of imported coal, and a number of other factors. Basically, movements in the price of coal were estimated from import price data, and movements in the price of oil from wholesale price data kindly supplied by the Esso Petroleum Coy. (Ireland) Ltd. with some allowance being made for the effects of the increased discounts below published prices given on heavy oil-sales in recent years. Changes in the prices of turf, of gas, and of electricity have been of much less significance.

Until 1961 the consumption of petroleum products had been reported under two headings: heavy oils and light oils: but in that year the classification was extended to show petrol, automotive gas oil, other gas/diesel, and fuel oil separately. Inspection of the aggregate returns showed that in the earlier years firms had tended to report all automotive fuels as 'light oils' and other gas/diesel and fuel oils as 'heavy oils.' This was fortunate because it had been hoped to separate automotive fuels and to deal with them comprehensively within the energy consumption of the inland transport sector. Automotive fuels will therefore receive further attention later. In dealing with the classification of fuels it may be remarked that the technical division between gas/diesel and fuel oils is not followed by reporting firms. It may be that firms (sensibly) show fuels used in stationary engines only as 'other gas/diesel' and all oils that are burnt as 'fuel oil'. From comparing

[8]Journal of the Statistical and Social Inquiry Society of Ireland, 117th Session, 1953-54; the table (page 100) is part of a written answer by Dr. R. C. Geary.

TABLE 12: CONSUMPTION OF FUEL AND POWER; ALL INDUSTRY AND SERVICES*

Type of fuel	1951		1961		1962	
	Quantity	Cost	Quantity	Cost	Quantity	Cost
		£000		£000		£000
Coal th.tons	661	3,727	514	2,287	456	2,023
Coke th.tons	47	373	34	295	32	300
Turf th. tons	291	849	1,546	2,796	1,732	3,522
Heavy oils m.gals	40·5	2,015	117·2	4,357	157·6	5,273
Gas m.cu.ft.	436	136	798	317	860	346
Electricity m.KWh	263	1,377	721	4,284	797	4,622
Other	—	119	—	130	—	181

*Excludes consumption for gas-making, which was as follows (1951 figures not available):—

Type of Fuel	1961		1962	
	Quantity	Cost	Quantity	Cost
		£000		£000
Coal th.tons	281	1,422	264	1,362
Coke th.tons	...	3	4	19
Oil m.gals	4·0	151	5·7	1,591
		1,576		1,591

Source: Census of Industrial Production data: see text.

supply and consumption data it is apparent that quantities of oil in the gas/diesel range are shown as fuel oil and it seems desirable that this should be avoided by more careful definition of the product categories.

For 1951, 1961, and 1962 the quantities of fuel consumed and their costs are shown in Table 12; lubricants have been excluded. By tradition, gasworks consumption of fuel for gas-making is also excluded from the data.

These figures reveal the changes in the pattern of consumption that have taken place over the period and, in particular, the rapid growth in the consumption of turf, oil, and electricity. Total cost figures would be misleading and are therefore not shown in Table 12 because they include some double-counting: both the electricity consumed by industry and the fuel used to generate that electricity are included. The figures used later in this section will exclude these fuels (as well as the fuels used for making towns gas). It should also be noted that the consumption of heavy oils in 1961 and 1962 includes the oil used as refinery fuel at the Whitegate oil refinery.

Table 17 shows the consumption of fuel and power in 1961 and 1962 for each of the major groups of industries. It is clear from this table that fuel consumption was by no means equally divided between the different industrial groups. Coal was of importance to three groups of industries: the Food Group (particularly for Sugar Refining); the Drink and Tobacco Group (particularly for Brewing); and the Clay, Glass and Cement Group (particularly for Cement Production). Turf was used to any extent only by the Food Group (particularly for Flour Milling). Heavy oils were used by most industries. Gas was of very little significance (its apparent importance is magnified by the units in which gas consumption is shown) but small amounts were used by the Food Group (particularly for Biscuit Manufacture) and by the Metals and Engineering Group (particularly for Metal Trades). Electricity is used by most industries, the consumption for Mining and Quarrying and for Cement Production being notably high.

The seventh column of Table 17 gives the estimated effective use of energy by each group of industries in 1961 and 1962. This is the weighted sum of the quantities of fuel and power shown in the previous five columns; in each case the weighting used is the net heat content of the fuel multiplied by its estimated relative efficiency of use (details are given in a note to Table 18). These weightings are rough approximations but they make it possible to see which groups of industries used the most energy. The Food Group was the most important user, followed by the Clay, Glass and Cement Group and then by the Other Manufacturing Group (which includes Oil Refining). Table 13 shows the use of energy by all groups in 1962 measured in proportion to net output; also shown are the average numbers of persons employed, measured in proportion to net output.

The figures in Table 13 reveal a general tendency for employment to be lower in those industrial groups where energy use is higher, with the important exceptions of the Drink and Tobacco and Chemicals Groups. This inverse correlation is a result of the fact that the more an industry is mechanised the more energy it will use and the less labour it will tend to need. But factors like the size of the establishments in a group of industries and the technical nature of the operations carried out must also affect this relationship, and a high correlation is not to be expected. The Drink and Tobacco Group in fact is made up of a relatively small number of larger concerns and this may account for its apparently high productivity both of labour and of energy. The Chemicals Group uses relatively little energy probably because it can make use of the waste products of its basic raw materials to meet its energy needs. The very high use of energy by the Clay, Glass and Cement Group is accounted for by the fact that the process of cement manufacture requires a lot of fuel.

TABLE 13: ENERGY CONSUMPTION AND EMPLOYMENT IN PROPORTION TO NET OUTPUT OF INDUSTRY*; 1962

Industry etc.	Effective energy use: thousand Btu per £ of net output	Employment: persons per £'000 of net output
Mining and Quarrying	65	1·05
Food	148	1·04
Drink and Tobacco	62	0·48
Textiles	65	1·30
Clothing and Footwear	17	1·75
Wood and Furniture	25	1·42
Paper and Printing	97	1·04
Chemicals	45	0·66
Clay, Glass and Cement	564	0·86
Metals and Engineering	43	1·08
Other Manufacturing	238	0·79
Building and Services	31	1·60
All Industries and Services	96	1·12

*Excluding Electricity and Gasworks Undertakings.

In Table 18 are given the quantities of fuel and power estimated to have been used by All Industry and Services in each year from 1950 to 1962 (see Part A of Table 18). Fuel used by Electricity and Gasworks Undertakings and by the Whitegate Refinery is excluded from these figures. Consumption is shown in Part A in original units and in Part B in equivalent heat units. These latter figures are plotted on Chart 2 attached. In Table 14 is shown the percentage breakdown of the total fuel consumption of the whole sector by type of fuel for selected years from 1951 to 1962.

TABLE 14: SHARES OF PRINCIPAL FUELS IN INDUSTRIAL CONSUMPTION; SELECTED YEARS

Fuel	Percentage[1]				
	1951	1954	1957	1960	1962
Coal	56	60	53	51	39·9
Coke	(2)	(2)	(2)	(2)	3·5
Turf	9	6	8	5	4·4
Other gas/diesel	(3)	(3)	(3)	(3)	2·3
Fuel oil	34	33	37	42	48·3
Gas	1	1	2	2	1·6
	100	100	100	100	100·0

Notes: (1) Percentage of total fuel consumption, excluding electricity, of All Industry and Services except Electricity and Gasworks Undertakings and the Oil Refinery.
(2) included with coal above.
(3) included with fuel-oil.

The displacement of coal and coke as the most important source of energy by heavy oils is made clear in Table 14. Electricity is not included in this table because it has a rather different range of uses and does not compete so directly with fuels as fuels do with each other. The growth in the use of electricity is shown comparatively in Part C of Table 18. With 1953 = 100, consumption of fuel had risen to 127 in 1962 while consumption of electricity had risen to 225; the increase in the consumption of electricity was five times as great as the increase in the consumption of fuel.

The substitution of one form of fuel for another is partly a matter of price and partly a matter of technical considerations like ease of storage, handling and control, and, of course, efficiency in use. These technical factors are not easy to weigh against each other because their importance depends upon the purpose for which the fuel is being used and upon the particular characteristics of the plant in which it is consumed. Generally, however, oil compares favourably with coal in respect of each of these factors because it is a more dense form of fuel and because it is liquid, which means that the supply to the appliance can be more closely regulated. Questions of price apart, therefore, fuel-oil will tend to displace the traditional fuel, coal. Unless cheaper as a source of heat other fuels are only used where they bring special advantages due to their chemical composition, burning properties and cleanliness; thus gas is a favoured fuel in some specialised drying operations, in biscuit manufacture for example.

Fuel prices vary considerably according to the quantities purchased, to the rigidity of the technical specifications of the fuel required, and to the long- or short-term nature of the supply contract. The price of coal to an individual consumer can vary from less than £4 a ton to more than £10 a ton, and similarly the price of fuel oil can vary from, say, 6d. to 1s. 1d. a gallon. From the global figures of fuel use presented here it is impossible to draw precise conclusions about the competitiveness of the different forms of fuel. A comparison of average prices will be misleading if, for instance, one fuel is widely used but only in small amounts in individual establishments, whereas the consumption of another fuel is confined to a few establishments each of which uses relatively large quantities. The average prices paid by All Industry and Services in 1962 are shown in Table 15.

TABLE 15: AVERAGE PRICES OF FUELS AND ELECTRICITY TO INDUSTRY IN 1962

Fuel	Average price	Pence per million Btu
Coal	£4·5/ton	42
Coke	£9·3/ton	82
Turf	£2·4/ton	43
Other gas/diesel	16·8d./gal.	108
Fuel Oil	10·1d./gal.	63
Gas	21·2d./therm	212
Electricity	1·34d./unit	393

Note: Data exclude fuel used by Electricity and Towns gas Undertakings and by the Oil Refinery.

The figures in Table 15 are especially favourable to coal and to turf because these fuels are only used to any significant extent by one or two industries while fuel-oils are much more widely used, in smaller quantities and therefore on less favourable terms.

It is possible to add together fuel and electricity if their relative efficiencies of use are estimated. See Part E of Table 18. The resulting quantities are shown in heat units and in relation to 1953 = 100. Immediately below the series based on 1953 = 100 is a volume index of output corresponding to the Industries and Services concerned. This index has been obtained by correcting the volume index of output of All Industries and Services for the omission of Electricity and Gasworks Undertakings. The two series are shown together graphically in Chart 3, and there is clearly a rough correspondence between them. Energy consumption has increased with output except during the 1956–1957 period when output fell. In these two years energy consumption slumped dramatically, only to recover in equally volatile fashion in 1958. During the period of recession not only was there some rationing of oil supplies but prices of both coal and oil had risen to very high levels. In Part D of Table 18 are given the average prices of all fuel (per Btu) in relation to 1953 =100, and it can be seen that fuel prices had risen sharply in 1956 and in 1957. It may also be noted that the average price in 1962 was less than that nine years previously.

From this brief glance at the levels of (effective) energy consumption from 1950 to 1963 it thus appears that either or both volume of output and price may be significant in explaining the variation in energy consumption from year to year; there may also be some secular time effect which is not immediately apparent. To test the importance of these three factors a regression model with three independent variables may be fitted to the set of 13 annual observations. The regression model is similar to that used in Part III in the analysis of the energy consumed by all sectors of the economy, viz:

$$Y=K\,X_1^{\beta_1}\,X_2^{\beta_2}\,e^{\beta_3 T}$$

where Y is the effective energy consumption of All Industry and Services (excluding Electricity and Gas Undertakings and Refinery uses of fuel), X_1 is the volume index of output, X_2 is average fuel price per heat unit, and T is time in years.

The results of the regression analysis are given in Table 16.

With the variables taken singly, volume of output gives much the best explanation of the level of effective energy consumption, with an R^2 of ·81. Given volume of output as an explanatory variable, it proves to be not worthwhile to introduce either price or time as a second explanatory variable. However, price and time together furnish a slightly better overall fit—in reducing the estimated residual variance to a minimum—and the numerical values of the regression coefficients of both these variables are highly significant. The introduction of all three variables together makes the overall fit slightly worse, mainly because one degree of freedom is lost with the third variable while the residual sum of squares is scarcely decreased.

From this evidence it is difficult to draw precise conclusions. Either effective energy consumption can be taken to depend only on the sector's volume of output, with a growth elasticity of about 1·25, or it can be taken to have a natural rate of increase over time of 4% p.a. and to be quite highly elastic to changes in the price of energy. The intercorrelations between the variables are such that it is impossible to distinguish statistically between these alternatives.

The truth possibly lies somewhere between the two extremes. There are technical reasons for expecting energy consumption to be closely related to volume of output, particularly in countries with important heavy industries, like iron and steel production. In Ireland there is no heavy industry to speak of, and energy is principally used by industry for providing motive power and for general heating purposes. Nevertheless the basic relation between energy consumption and volume of output should still hold in countries like Ireland, although there will be more scope for reducing energy consumption by better house-keeping during periods of high energy prices. Again, a time-trend in energy consumption that is at least partly independent of change in volume of output is not to be surprised at; improvements in working conditions, substitution of machines for labour, and greater efficiency of use of energy are all factors which will tend to take effect progressively over time. One can do little at the global level to separate these various influences.

Chart 3 also shows electricity consumption over the 1950 to 1962 period. The use of this form of energy has clearly grown very rapidly indeed, and consistently except for a temporary set-back in 1956; electricity is, of course, the most convenient form of energy for providing motive power. A regression model similar to that used above can be fitted to electricity consumption. No price variable will be brought into the model because electricity prices have varied so little from year to year. The results of the regression analysis are straightforward and need not be set out in a table.

Electricity consumption is growing much faster

TABLE 16: REGRESSION ANALYSIS OF EFFECTIVE ENERGY CONSUMPTION OF ALL INDUSTRY AND SERVICES; 1950 to 1962

DF	b_1 output	b_2 price	b_3 time	Residual sum of squares	S^2	R^2
12	—	—	—	·05998	·00500	—
11	+1·25	—	—	·01111	·00101	·81
11	—	−·65	—	·04615	·00420	·23
11	—	—	+·0137	·02585	·00235	·57
10	+1·17	−·20	—	·00997	·00100	·83
10	+1·36	—	−·0017	·01098	·00110	·82
10	—	−·71	+·0143	·00932	·00093	·84
9	+ ·45	−·51	+·0090	·00890	·00099	·85

CHART 2 (Part IV, Section 2): Consumption of Energy by Industry and Services*; 1950 to 1962.

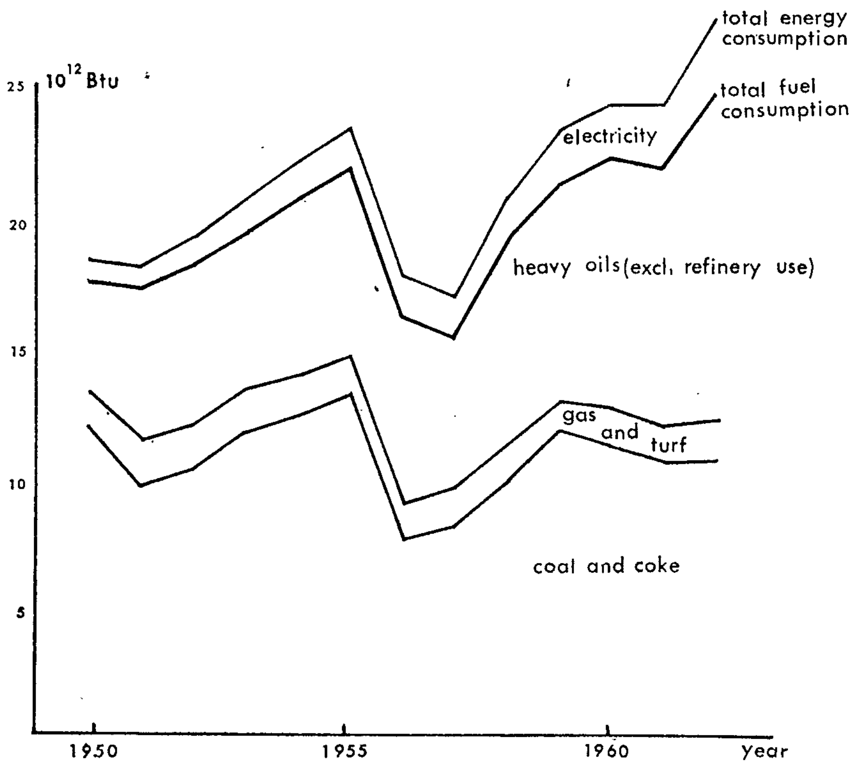
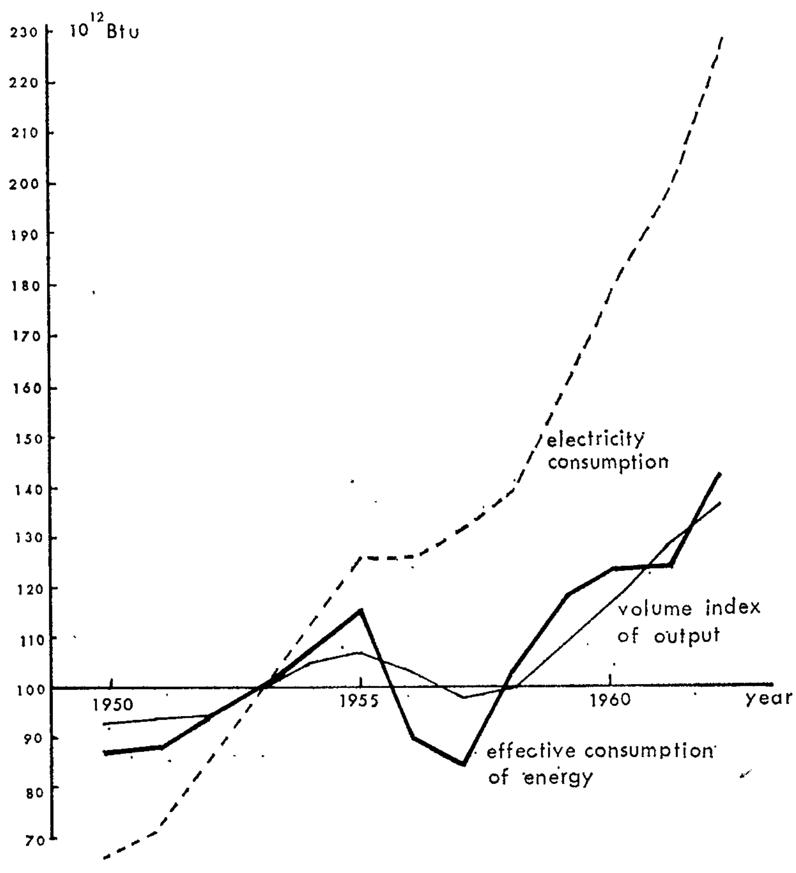


CHART 3 (Part IV, Section 2): 'Effective' Energy Consumption of Industry and Services and Output*; 1953=100



*Note: Electricity and Gasworks Undertakings excluded from all data.

TABLE 17: CONSUMPTION OF FUEL AND POWER[3] BY INDUSTRIAL GROUPS; 1961 AND 1962

Industry	Year	Coal and coke th. tons	Turf th. tons	Heavy oils m. gals.	Gas m. cu. ft.	Electricity m. KWh	Effective use of energy[1] 10^{12} Btu	Value[2] £ thousand	Gross output £ million	Net output £ million	Persons employed thousands
Mining and Quarrying	1961	6·0	—	2·00	4	81·7	0·56	584·2			
	1962	6·5	—	2·15	9	76·0	0·57	561·9	12·4	8·8	9·2
Food	1961	130·1	35·3	22·17	201	155·6	4·98	2,840·4			
	1962	130·9	43·9	24·70	209	189·7	5·43	2,994·2	187·7	36·6	38·2
Drink and Tobacco	1961	43·0	2·2	4·45	11	17·4	1·15	651·8			
	1962	46·8	1·7	5·20	11	20·9	1·29	684·7	68·1	20·7	9·9
Textiles	1961	5·6	0·3	5·17	4	55·8	0·81	639·5			
	1962	5·3	1·3	7·06	8	73·8	1·07	816·3	46·5	16·4	21·3
Clothing and Footwear	1961	3·2	2·0	2·00	43	24·6	0·36	358·1			
	1962	2·5	0·7	0·89	43	19·5	0·21	239·8	28·4	12·7	22·3
Wood and Furniture	1961	0·5	1·5	0·19	15	12·5	0·08	142·4			
	1962	0·8	0·8	0·52	27	16·1	0·13	183·4	11·5	5·3	7·5
Paper and Printing	1961	11·9	13·1	5·97	93	73·6	1·15	809·3			
	1962	17·3	13·5	6·82	117	88·3	1·38	825·9	28·3	14·3	14·9
Chemicals	1961	1·8	0·1	2·23	19	24·9	0·35	296·9			
	1962	1·0	—	2·87	25	21·5	0·39	295·6	23·3	8·7	5·7
Clay, Glass and Cement	1961	170·3	5·5	6·10	67	89·2	3·41	1,336·9			
	1962	163·1	7·0	14·51	93	114·0	4·29	1,647·4	13·4	7·6	6·5
Metals and Engineering	1961	10·9	6·0	3·55	245	85·8	0·93	1,010·9			
	1962	10·7	3·6	5·54	245	92·5	1·14	1,094·6	74·7	26·5	28·7
Other Manufacturing (3)	1961	3·1	1·2	21·83	57	53·1	2·54	914·3			
	1962	3·4	2·0	23·02	45	50·9	2·66	987·6	36·3	11·2	8·8
Total Transportable Goods	1961	386·3	67·1	75·66	759	674·2	16·32	9,584·7			
	1962	388·3	74·5	93·28	832	763·2	18·56	10,351·4	530·7	168·8	173·0
Building and Services	1961	22·6	6·5	3·68	38	42·5	0·90	776·5			
	1962	26·8	7·0	4·12	42	58·4	1·06	791·2	65·0	34·6	55·5
Total All Industries and Services	1961	408·9	73·6	79·34	797	716·7	17·22	10,361·2			
	1962	415·1	81·5	97·40	874	821·6	19·62	11,142·6	595·7	203·4	228·5
Excluding:											
Gasworks Undertakings	1961	283·1	—	4·03	1	4·6	(4)	1,627·7			
	1962	268·6	—	5·72	6	5·0		1,641·3	4·4	2·5	2·2
Electricity Undertakings	1961	137·6	1,472·3	37·87	—	—	(4)	4,051·2			
	1962	72·3	1,649·7	60·39	—	—		5,072·0	25·3	15·6	8·3

Notes: [1]Conversion Factors and Weightings are given in the Notes to Table 18.
[2]Includes the values of small quantities of other fuels.
[3]Includes Oil Refinery use of oil.
[4]Dealt with in detail elsewhere (see Part II and Part IV, Section 1).
Source: CIP Returns for Fuel and Power Data; Irish Statistical Bulletin, September 1964, for output and employment data.

TABLE 18: CONSUMPTION OF FUEL AND POWER BY ALL INDUSTRY AND SERVICES; 1950 TO 1962

Item		1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
A. Consumption:	[2]		[1]										[1]	[1]
—coal and coke	th.tons	460	375	400	455	480	510	295	315	380	455	435	410	415
—turf	th.tons	85	115	115	105	90	85	85	95	95	70	90	75	80
—heavy oils	m.gals.	26·8	35·4	37·6	36·8	41·8	44·3	43·6	34·5	47·8	52·0	58·4	60·3	77·4
—towns gas	m.cu.ft.	410	440	490	590	620	640	660	670	690	730	740	800	870
—electricity	m.KWh	240	260	310	365	410	455	455	475	505	580	655	720	822
B. Consumption in equivalent units (10^{12} Btu):	[3]													
—coal and coke		11·9	9·7	10·3	11·7	12·4	13·2	7·6	8·1	9·8	11·7	11·2	10·6	10·7
—turf		1·1	1·5	1·5	1·4	1·2	1·1	1·1	1·2	1·2	0·9	1·2	1·0	1·1
—heavy oils		4·3	5·7	6·1	6·0	6·8	7·2	7·1	5·6	7·7	8·4	9·5	9·8	12·5
—towns gas		0·2	0·2	0·2	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·4	0·4
Total fuel consumption		17·5	17·1	18·1	19·4	20·7	21·8	16·1	15·2	19·0	21·3	22·2	21·8	24·7
—electricity		0·8	0·9	1·1	1·2	1·4	1·6	1·6	1·6	1·7	2·0	2·2	2·5	2·8
C. Growth in Consumption	1953=100													
Total fuel consumption		90	88	93	100	107	112	83	78	98	110	114	112	127
Electricity consumption		66	71	85	100	112	125	125	130	138	159	179	197	225
D. Value and Price of Fuel Consumed:														
Value of fuel consumed	£'000	4,035	4,785	5,385	5,165	5,345	5,895	5,110	5,455	5,990	6,100	6,100	5,570	5,935
Average fuel price per Btu	1953=100	87	105	112	100	97	102	119	135	119	108	103	96	90
E. Total Effective Energy Consumption incl. electricity	[4] 10^{12} Btu	10·8	10·9	11·6	12·4	13·4	14·2	11·1	10·4	12·8	14·5	15·2	15·3	17·5
	1953=100	87	88	94	100	108	115	90	84	103	117	122	123	141
Volume index of output	1953=100 [5]	92·9	93·7	93·5	100·0	104·3	106·7	102·8	97·5	100·0	108·1	116·6	127·0	135·4

Notes: [1]Figures for these years were estimated from CIP Returns; for other years, value figures have been divided by estimated average prices.

[2]Excludes all automotive fuels, and fuels used by Electricity and Towns gas Undertakings and by the Oil Refinery.

[3]The following conversion factors have been used: coal and coke—25·8 m.Btu/ton; turf—13·4 m.Btu/ton; heavy oils—162,000 Btu/gal.; townsgas—450 Btu/cu.ft.; electricity—3,412 Btu/KWh.

[4]The following weightings, or estimated relative efficiencies, have been used: coal and coke—·55; turf—·50; heavy oils—·65; townsgas—·75; electricity—·95

[5]Index excludes Electricity and Townsgas Undertakings.

in this sector than consumption of all forms of energy. The simple trend rate of increase in electricity consumption is just about 10% p.a., with an R^2 as high as .97. Volume of output is not as useful, as a single explanatory variable, as time; it has an R^2 of .80 (it is interesting to note the very high value of 2.87 of the regression coefficient associated with volume of output, i.e. the simple growth-elasticity). There is a small but valuable improvement in the fit when both explanatory variables are brought into the regression together.

There are grounds, then, for concluding that this sector's consumption of electricity has a high secular rate of growth from year to year whatever the change in volume of output, but that, in addition, it is moderately elastic to changes in the volume of output.

Inland Transport

Inland transport, in the sense in which the term is used here, is the transport of passengers and goods by mechanical means between places located within the national boundaries. It includes road and rail transport, inland and coastal waterways transport, and internal air transport. The latter categories, water and air transport, however, are not very significant in Ireland.

The C.I.E. Report on Internal Public Transport of October, 1963 (Section III, 3), gives a brief account of the history of commercial road and rail transport in Ireland. The important features of that history may be recounted here.

Road transport services began to develop on a large scale in the mid-1920's and to threaten the economic viability of the extensive rail services then operating. These services had been amalgamated in 1924 into the Great Southern Railways Company, which absorbed all railway companies operating exclusively in the Irish Free State. To meet the competition the railway companies were themselves permitted by a 1927 Act to operate road services and the Great Southern Railways subsequently acquired various interests in road passenger services. However, the financial position of the railways continued to deteriorate and further legislation was introduced in 1932 and 1933 to give them additional protection. The 1932 Act prohibited the carriage of passengers by road without licence. The 1933 Act proposed to eliminate competition from road transport of goods completely by bringing road transport services under the monopoly control of rail and water transport companies. To that end carriage of merchandise by road was prohibited except under licence or in an exempted area (now within 10 or 15 miles of five major cities). Licences were granted only to rail and water transport companies and to existing carriers. The former companies were given powers to buy out existing carriers subject to Ministerial approval and on payment of compensation (in the event 387 of the larger carriers were bought out).

Further measures would have been called for in the following years, since railway receipts continued to decline and the rail system was becoming run down for lack of capital, but the outbreak of war and the shortage of oil fuels for road transport brought temporary alleviation. After the war the government set up a new organisation, Córas Iompair Éireann, to replace the Great Southern Railways Company and the Dublin United Transport Company and finance was guaranteed for the re-equipping of the undertaking. The 1950 Act made this organisation a public corporation and merged it with the Grand Canal Company, though it retained its original title.

As part of the programme of capital reconstruction it was decided to replace steam locomotives with diesel-fuelled engines. In 1951 C.I.E. owned 450 locomotives of which all but six were steam engines; by 1964 only 18 steam engines remained out of a total of 240 locomotives. All railway services are now operated by diesel power.

After 1950, the finances of the new organisation showed no signs of being more healthy than those of the companies it replaced and government grants had to be made to meet its revenue losses. The competition which brought this situation about was due to the rapidly increasing private ownership and use of road transport vehicles. Passenger rail traffic was reduced by the growth of private motoring by car and motor-cycle. Goods traffic by rail suffered because both manufacturers and distributors were acquiring fleets of goods vehicles and using them to transport their own products. What was left to the railways was a relatively uneconomic share of goods traffic and the need to keep up public service passenger routes which either had low traffic volumes or which confronted the operators with severe peak-load problems. These problems have not yet been solved.

In 1958 the last of the independent railway companies, the Great Northern Railways Company (or that part of it which operated within the Republic), was absorbed by C.I.E. to give the latter full control over all railways in the state.

The 1958 Act reduced the capital liabilities of C.I.E. and granted operating subsidies for five years, within which time it was hoped that C.I.E.'s operations would become financially self-operating. Permission was also given for the closing down of railway routes that had become uneconomic. Where 528 miles of route had been closed down between 1924 and 1958, a further 621 miles were closed between 1958 and 1964, a total of 1,450 miles of route remained in 1964.

The C.I.E. Report, already referred to, estimates that about half of this remaining mileage of track carries sufficient traffic to break even financially and that a total of only 410 miles of railway is wholly profitable to operate. However, the closing of all unprofitable routes would not necessarily enable the remaining routes to pay their way because of the interdependence of arterial and branch-line traffic. The government now envisages no further whole-scale closing of railway lines, although it does not preclude the possibility that some of the remaining secondary lines will be closed as a result of detailed studies. It recognises that to preserve the railway system an annual subsidy from the Exchequer will have to become a permanent feature of the Budget and a Bill introduced in 1964 proposes an annual payment of £2 million for the next five years, the position to be reviewed at the end of that time.

Reynolds[9] estimated that in 1960 the railways carried about 20%[10] of the total ton-mileage of goods traffic within the State, including both short-and long-distance hauls. Road transport operated for hire or for reward was estimated to account for some 29% of total ton-mileage, the remaining 51% being carriage of their own goods by manufacturers and distributors. Of the ton-mileage carried for hire or for reward, part was carried by licensed operators and part by operators in exempted areas. The part carried by each is difficult to estimate; they operated about the same numbers of vehicles[11], but licensed operators carried all the long-distance traffic and therefore almost certainly took a greater share of the ton-mileage carried for hire or for reward. It is assumed for the sake of argument that licensed operators carried two-thirds of goods traffic for hire or for reward, and this share represents some 20% of the total ton-mileage of goods traffic (i.e. two-thirds of 29%). Of this, Reynolds estimated that C.I.E. accounted for just under half the total transport activities of licensed hauliers. If from this it is inferred that C.I.E. carried half the goods traffic of licensed hauliers, then C.I.E. road haulage operations accounted for about 10% of the total ton-mileage of goods traffic. Thus, in 1960, C.I.E. may have carried by road and rail some 30% of all goods traffic in the State (i.e. 20% by rail; 10% by road).

Reynolds also gave estimates of the sectoral breakdown of passenger transport in Ireland in 1960. Private transport by motor-car (including taxis) and by motor-cycle was estimated to have accounted for about 4,200 million passenger miles, and public transport for 1,150 million passenger miles, just over 20% of the total of 5,350 million passenger miles. Rail passenger transport alone accounted for some 350 million passenger miles, or about 7% of the total; bus transport accounted for the remaining public passenger mileage. CIE has a complete monopoly of passenger transport by rail and an almost complete monopoly of public passenger transport by road, for those road passenger undertakings still operating under licence carry a total traffic of very small proportions.

This paper is concerned with the need for, and use of, fuel and power. It is interested in economic, technical and social developments in Ireland only to the extent that they influence the pattern and the growth of requirements of fuel and power. In the case of transport the consumption of fuel is more or less closely related to the amount of passenger and goods traffic that goes on during a given period, but many other factors intervene to effect the type of relationship that connects the two. Among these factors are the types and sizes of vehicle used, the load or number of passengers carried, the length of journey, and the fuel consumption for each mile of journey. Statistical information about many of these factors is not directly available and considerable use must be made of reasonable inferences and of more or less arbitrary guesses in relating the quantities of fuel consumed to the total volume of transport.

The total volume of transport is itself not easy to quantify nor to relate to exogenous social and economic factors. Nor is the share of transport in the national product identified in the conventional scheme of national accounts. Indeed, for national accounts purposes different types of transport are treated in different ways. Reynolds has dealt with this in a paper to the Statistical and Social Inquiry Society of Ireland (116th Session, 1962–63). The transport of their own goods by industrial concerns is included in National Product as part of Industrial Production; the transport of passengers and goods for reward is included in the product sector Distribution, Transport and Communication, as is the transport of goods by wholesale, retail and distribution concerns. The breakdown of the national income by category of personal expenditure identifies the amounts spent on transport equipment by the final consumer and on travelling within the State. Finally, the amounts spent by Industry, Distribution, Trade, etc. on transport equipment is identified as part of Capital Formation.

It is clear that transport is partly a final good produced for sale to the consumer and partly an intermediate good essential to the production of final goods. As a final good some transport is sold directly to the consumer as seats on buses and on railway coaches and some is sold to him in do-it-yourself

[9]D. J. Reynolds: "Inland Transport in Ireland: A Factual Survey"; E.R.I. Paper No. 10, November 1962; Table 17.

[10]The same figure was used by the Minister for Transport and Power on 30th June, 1964, during the Dáil debate on the Transport and Power Vote.

[11]D. J. Reynolds: "Road Transport: The Problems and Prospects in Ireland"; E.R.I. Paper No. 13, May 1963; Page 7.

form. Thus, a consumer who buys a car transports himself; his doing so adds something to the national product in principle but this contribution, like that of housewives, is not in fact included in the aggregation because of the statistical difficulties of calculating its worth. The net result is that the breakdown of current personal expenditure does not furnish a direct index of the value of the transport element of final demand.

As an intermediate good in the production process even more serious difficulties arise in estimating the contribution of transport. In the price of almost every raw material and manufactured good there is some element of transport payment, which goes ultimately to remunerate the factors of production devoted to making transport equipment, to building roads and railways, and to producing the fuel and lubricants consumed. The contribution of road and rail traffic of goods is obscured because of the lack of separation within the industrial sector of goods transport owned and operated by industry. Even were this problem resolved there would remain the difficult task of eliminating double-counting when transport in final demand is added to transport in intermediate demand: the cost of transport of automotive fuels for sale to the final consumer, for example.

All told, there seems little prospect of finding a simple indicator of the importance of transport in national income accounts.

Transport is separated here as a sector of consumption of fuel and power, in spite of the difficulty of defining and quantifying its economic function, because its fuel consumption is well known. The fuels consumed for road transport purposes are specially prepared petroleum products and they carry distinctive customs and excise duties. Those consumed for rail transport purposes are not so clearly identified, but they are of much less significance (and the total market consists of one single undertaking).

Road Transport

Passengers are carried in cars, taxis, buses and on motor-cycles (and hearses, which are in Ireland a separate category of vehicle). Of these all but the buses use petrol as a fuel. Goods are carried in vehicles that range in size from the light runabout van to heavy goods vehicles of 9 tons or more, sometimes with trailer attached. Some goods vehicles are powered by petrol-engines and some by diesel-engines.

In the following paragraphs some analysis is made of the pattern of fuel consumption of the different types of vehicle. To assist that analysis two preliminary sections are devoted to the size and structure of the populations of private motor-cars and of goods vehicles respectively. Considerable use has been made of Reynolds work on this same subject (in papers already referred to), not all of which is acknowledged in detail.

Private Cars

Table 19 shows the population of private cars in Ireland in August of each year and the number of cars registered for the first time during the twelve preceding months.

TABLE 19: PRIVATE CARS NEWLY REGISTERED AND IN USE; 1950 TO 1963

Year T	Numbers of Cars: Total in August (P_T)	New Registrations Year ended July (N_T)	Cars not re-registered Year ended July $N_T-(P_T-P_{T-1})$
1950	85,140		
1951	96,714	16,087	4,513
1952	104,900	14,005	5,819
1953	108,805	12,404	8,499
1954	117,460	18,764	10,109
1955	127,511	23,688	13,637
1956	135,961	19,302	10,852
1957	135,013	10,709	11,657
1958	143,368	19,041	10,686
1959	154,054	21,455	10,769
1960	169,681	26,534	10,907
1961	186,302	28,102	11,481
1962	207,166	31,177	10,313
1963	229,125	34,775	12,816

Source: Statistical Abstract of Ireland.

Like most economic series relating to Ireland, the population and registration figures in Table 16 show pronounced slackening during the period of recession of 1956 and 1957. It is therefore convenient to distinguish two sub-periods in the series: the period up to 1956 and the period since 1957.

The fitting of an exponential time curve to the population data by the method of Least Squares reveals the following trend rates of growth:—

1950 to 1956:	7·7% p.a.	(R^2=·98)
1957 to 1963:	9·4% p.a.	(R^2=·99)
1950 to 1963:	7·1% p.a.	(R^2=·98)

Quite apart from the effects of the depression on the trend rate of growth over the whole period, there is clearly a tendency for the rate of growth in the private car population to increase, since there has been more rapid growth since 1957 than there was up to 1956.

A number of other interesting questions can be answered in rough fashion using the data in the second two columns of Table 19.

The first question concerns the rate at which cars are being scrapped. To estimate this rate it is necessary to assume that all cars not re-registered each year are consigned to the scrap-heap in that year (shown in the fourth column of Table 1). In fact, some registrations could have been allowed to lapse for a year or more and then renewed, but the available data do not identify these. It is assumed further that, but for random disturbances, the rate of scrapping during the year is a constant proportion (from year to year) of the population at the beginning of the year. This can be represented by the equation

$$N_t - (P_t - P_{t-1}) = sP_{t-1} + u_t \qquad t = 1951 \ldots \text{to } 1963$$

where P_t is the population of cars in August of year t, and N_t is the number of new registrations from August of year $t-1$ to July of year t; s is the scrapping rate, assumed constant, and the u_t are error terms. The equation can be rewritten

$$(P_t - N_t)/P_{t-1} = \alpha + v_t \qquad t = 1951 \ldots \text{to } 1963$$

where $v_t = u_t/P_{t-1}$ and $\alpha = 1 - s$.

The Least Squares Estimator of α is the familiar average

$$1/13 \sum_{t=1951}^{1963} (P_t - N_t)/P_{-1}$$

The estimated values given by this expression are ·919, ·931 and ·924 for the 1950 to 1956, 1957 to 1963 and 1950 to 1963 periods respectively. Subtraction from unity and multiplication by 100 gives estimated average scrapping rates for the three periods of 8·1%, 6·9% and 7·6%. Over the period, therefore, there has been a tendency for scrapping rates to fall; since the last of the pre-war cars on the roads were run until the middle 1950's this tendency was, indeed, to have been expected.

The second question is the rate at which new cars are being registered in proportion to the existing population of cars at the beginning of the year (i.e., in the previous August). Exactly in the same way as scrapping rates were estimated, new registration rates can be calculated under similar assumption of constancy from year to year. The results are set out in Table 20 and compared with population growth rates and scrapping rates for the three periods:—

TABLE 20: NEW REGISTRATION, SCRAPPING AND POPULATION GROWTH RATES OF PRIVATE CARS

Period	Percentage of Population in preceding August		
	New registration rate n	Scrapping rate s	Population growth rate r
	%	%	%
1950 to 1956	16·3	8·1	7·7
1957 to 1963	16·1	6·9	9·4
1950 to 1963	15·6	7·6	7·1

In Table 20 the new registration rates and the scrapping rates are averages of annual rates, while the population growth rates are logarithmic trend rates of growth. In principle, the new registration rate is the sum of the scrapping rate and of the population growth rate, but the different method used to estimate the latter causes small numerical discrepancies (because it attaches different conditions to the errors).

The new registration rate from 1950 to 1956 is very close to that from 1957 to 1963 (both rates lie above the whole period average because so few new cars were registered in 1957). On the whole, therefore, it seems that the rate of growth in the population of private cars has increased over the period not because new cars are being registered at a greater rate but because the rate of scrapping of old cars has fallen.

This leads to the third and final question, of how old cars are when they are scrapped. There is, clearly, a definite relation between car lifetimes, scrapping rates, growth rates and new registration rates. It is easy to write down a set of equations connecting the various elements involved, viz.:—

(i) $$P_T = \sum_{t=1}^{T} N_t - \sum_{t=1}^{T} \sum_{r=1}^{T} S_t^r; \quad r \geqslant t$$

S_t^r is the number of cars first registered in the year ended July of year t that are scrapped during the year ended July of year r.

(ii) $$N_T = \sum_{r=t}^{\infty} S_T^r$$

(iii) $$L_T = 1/N_T \sum_{r=T}^{\infty} r\, S_T^r$$

L_T is the average lifetime of cars first registered in the year ended July of year T.

(iv) $$Z_T = \sum_{t=1}^{T} S_t^T$$

Z_T is the number of cars scrapped in the year ended July of year T.

(v) $A_T = 1/Z_T \sum_{t=1}^{T} t\ S_t^T$

A_T is the average age of cars scrapped in the year ended July of year T.

Note that $P_{T+1} - P_T = N_T - Z_T$ from (i) and (iv).

These equations are simpler than they appear. The first states that the population is the total of all cars ever registered less the total ever scrapped. The second states that all cars registered must at some time be scrapped. The third defines the average lifetime of cars registered in a particular year. The fourth states that all cars scrapped must at some time have been registered. The fifth defines the average age of the cars scrapped in a particular year.

For the 14 years considered here, the values of the P_T and of the N_T are known and, in principle, the values of the S_t^r, the numbers of cars first registered in year t that are scrapped in year r, are unknown. If the practical maximum life of cars is, say, 20 years there are 20×14 unknowns and only 2×14 knowns, and a solution is clearly impossible without simplifying assumptions. A number of approaches are possible, but perhaps the most obvious is to assume that all cars have the same length of life, K years say, which is to be estimated. It is also assumed that populations, new registrations, and scrappings have reached a steady state of development given by the following conditions:—

(vi) $P_T = (1+r)P_{T-1}$;

(vii) $N_T - (P_T - P_{T-1}) = sP_{T-1}$;

(viii) $N_T = (r+s)P_{T-1} = nP_{T-1}$, by subtraction,

where r, s and n are the population growth rate, the scrapping rate, and the new registration rate respectively.

If all cars first registered in the year ended July of year T−K are scrapped in the year ended July of year T+1, then the scrapping rate in that year is

$$N_{T-K}/P_T = s\ ;$$

while the new registration rate in the year ended July of year T+1 is

$$N_{T+1}/P_T = n.$$

Therefore, by division,

$$N_{T+1}/N_{T-K} = n/s.$$

But, from (vi) and (viii) above

$$N_{T+1}/N_{T-K} = (1+r)^{K+1},$$

whence

$$K+1 = (\log n - \log r)/\log(1+r).$$

Substitution of the values of r, s, and n from Table 17 in this expression gives the following estimates of the average ages of the cars scrapped during each of the three periods

1950 to 1956	7·9 years
1957 to 1963	8·6 years
1950 to 1963	8·3 years

These figures show an apparent increase in the average working lifetime of cars from the early part of the period to the later part. This is a necessary consequence of the falling rate of scrapping mentioned earlier, but it is an unlikely result because cars were undoubtedly much older when scrapped in the early 1950's than they have been more recently. The conflict arises from neglecting to consider, for lack of data, the age distribution of the cars scrapped each year. This distribution is almost certainly asymmetrical in form with a long tail, corresponding to the scrapping of very old cars, which has probably become shorter in recent years. The asymmetry would introduce weightings into the calculations.

An interesting reflection concerns the small numbers of cars purchased in the 1956 to 1958 period. If the trend established above for the growth in the total car population is to continue during 1964, 1965 and 1966 and there is no change in the average life of cars then there will be a relative decline in the numbers of cars newly registered in the 1964 to 1966 period. Alternatively and if this does not occur, either cars must tend to be scrapped sooner or the growth in the car population must proceed rather more rapidly for a time.

With a rough idea of the average lifetime of cars it is possible to estimate the structure of the total population of cars by engine size from the detailed figures for new registrations by size of car. It is assumed that the total population of cars in a given year comprises those cars newly registered during the last nine years. A new method of rating horsepower was introduced in 1953, unfortunately, so that figures for earlier years are not comparable with those for 1953 and subsequent years. This makes it impossible to see the changing structure of the car population over a long period, but some information can be derived from the figures since 1953. Table 21

TABLE 21: NEW CAR REGISTRATIONS BY ENGINE SIZE; 1953, 1963 and 1955 to 1963

H.P.	1953		1963		1955 to 1963	
	Number	%	Number	%	Number	%
Small cars:						
up to 8	5,476	38·9	9,727	26·3	84,451	38·5
9 and 10	4,552	32·3	18,749	50·6	80,837	36·8
		71·2		76·9		75·3
Medium-sized cars:						
11 and 12	3,264	23·2	3,036	8·2	32,082	14·6
13 and 14	9	—	4,621	12·5	15,079	6·9
		23·2		20·7		21·5
Large cars:						
15 and over	788	5·6	895	2·4	7,067	3·2
Total	14,089	100	37,028	100	219,516	100

Source: Statistical Abstract of Ireland.

shows new registrations in five ranges of horse-power for 1953, for the period from 1955 to 1963 inclusive, and for 1963.

The percentages of cars in each engine size for the 1955 to 1963 period are taken to indicate the structure of the total car population in 1963. Several interesting trends are revealed. The absolute number of large cars, of 15 H.P. and over, has increased slowly over the period but these cars make up a declining share of the total population. The proportion of medium-sized cars is also tending to fall, but there is a striking shift towards the more powerful family cars of 13 and 14 H.P. Small cars are increasing in relative importance and in 1963 made up over three-quarters of the total population of cars. The increase is due almost entirely to the recently established preference for cars in the 9 and 10 H.P. class, which includes the B.M.C. "Mini".

Goods Vehicles

A similar analysis may be made of the population of goods vehicles. Table 22 shows the population of these vehicles in August of each year and the numbers registered for the first time during the preceding twelve months.

In 1953 it appears that the total population grew by more than the number of new registrations, which implies that a considerable number of vehicles, the licences of which had been allowed to lapse, were brought back into service. Since this is likely to have happened in other years too, it would be well not to rely on the figures in the right-hand column as showing the numbers of vehicles scrapped in the individual years. However, in aggregate over a period of years, lapses and renewals will largely cancel each other out.

TABLE 22: GOODS VEHICLES NEWLY REGISTERED AND IN USE; 1950 TO 1963

Year T	Numbers of vehicles		
	Total in August (P_T)	New Registrations Year ended July (N_T)	Vehicles not re-registered Year ended July $N_T-(P_T-P_{T-1})$
1950	24,726		
1951	26,721	4,469	2,474
1952	27,264	4,054	3,521
1953	33,196	3,482	2,460
1954	37,090	5,588	1,694
1955	40,175	5,821	2,736
1956	41,880	5,457	3,752
1957	43,233	3,233	1,880
1958	43,433	4,744	4,544
1959	43,634	5,030	4,829
1960	43,530	4,965	5,069
1961	43,838	5,459	5,151
1962	44,874	6,779	5,743
1963	45,433	(6,456) est.	5,897

Source: Statistical Abstract of Ireland (includes electrically-driven vehicles).

The total population of goods vehicles has not grown as continuously and consistently as the population of private cars. Having increased rapidly at an average rate in excess of 10% p.a. between 1950 and 1955, the population of goods vehicles increased by only just over 11% over the next eight years.

Annual rates are shown in Table 23, of population growth, new registrations and (apparent) scrappings. The average rate of new registrations over the whole period was 13.6%, and that of scrappings was 8·6% but these averages are hardly representative of any trends that are likely to persist because they indicate a population growth of 5·0% p.a. which is much higher than the rate of growth of recent years. If a shorter, more recent, period is considered the difficulty arises that both the new registration rate and the scrapping rate have been tending to increase and the average rates of the last five years, for instance, will therefore be too low and will underestimate the rates that would obtain in a period of steady change. For the sake of argument, however, it will be supposed that the averages of the last two years are representative of the rates if current conditions were to continue for a lengthy period, viz.:

Population growth rate	1·6% p.a.
Rate of new registrations	15·0%
Rate of scrapping	13·4%

Under the same assumption as those used in the case of private cars, these rates indicate an average vehicle life of 6·1 years, or about three-quarters of the estimated life of the average private car. This, indeed, was to be expected for goods vehicles tend to be used more continuously and under greater strains than private cars.

TABLE 23: RATES OF POPULATION GROWTH, NEW REGISTRATIONS, AND SCRAPPINGS OF GOODS VEHICLES; 1951 TO 1963

Year T	Per cent. Population growth rate $(P_T - P_{T-1})/P_{T-1}$	New Registrations rate N_T/P_{T-1}	Apparent scrappings rate $N_T - (P_T - P)_{T-1}/P_{T-1}$
1951	8·1	18·1	10·0
1952	2·0	15·2	13·2
1953	21·8	12·8	− 9·0
1954	11·7	16·8	5·1
1955	8·3	15·7	7·4
1956	4·2	13·6	9·3
1957	3·2	7·7	4·5
1958	0·5	11·0	10·5
1959	0·5	11·5	11·1
1960	−0·2	11·4	11·6
1961	0·7	12·5	11·8
1962	2·4	15·5	13·1
1963	0·8	14·5	13·7

The structure of population of goods vehicles by size may be considered in respect of the unladen weight of the vehicles, where in the case of private cars engine power was the principal attribute of size. Unladen weight, of course, is related both to carrying capacity and to engine power. Table 24 shows the breakdown of the total population into four ranges of size at August 1956 and at August 1963, and the numbers of vehicles registered in each size range during the 1962 calendar year.

Also shown in Table 24 are the shares corresponding to each size range of the total unladen weights of all vehicles (in order to calculate these shares the average unladen weights of vehicles in the four size ranges had been estimated as detailed in the note below the table). If the carrying capacities of vehicles are related to their unladen weights (as, indeed, they are approximately) then these shares also indicate how the carrying capacity of the total fleet was split up between the four size ranges. Between 1956 and 1963 the significant development was the change from the use of medium-sized vehicles of 2 to 3 tons unladen weight to the use of larger vehicles of 3 tons unladen weight and over.

The average weight of all vehicles increased between 1956 and 1963 from 33 cwt. to 39 cwt., an average rate of increase of 2·4% p.a. Combined with the estimated current trend in the total population of goods vehicles of 1·6% p.a. this means an annual increase of about 4% p.a. in the total weight of goods vehicles on the road. The carrying capacity of the fleet may or may not be growing at precisely this rate. One 6-ton truck can probably carry more than two 3-ton trucks but the single truck is less flexible in operation and may therefore travel longer distances with less than a full load. At all events, speculation about the carrying capacity of the whole fleet of goods vehicles is unlikely to produce meaningful results because a considerable number of the

TABLE 24: GOODS VEHICLES ACCORDING TO UNLADEN WEIGHT; 1956, 1963 AND NEW REGISTRATIONS IN 1962

Unladen Weight	Numbers and shares of total unladen weight: Population August 1956		Population August 1963		Registered 1962	
	Number	%	Number	%	Number	%
Up to 16 cwt. ...	11,889	10·4	12,405	8·5	1,712	11·4
16 cwt. to 2 tons	17,957	36·7	18,475	29·7	2,587	40·2
2 tons to 3 tons	8,293	30·2	4,239	12·2	368	10·2
3 tons and over	3,458	22·7	9,624	49·6	762	38·2
	41,597	100	44,743	100	6,429	100

Average unladen weights were taken as 12 cwt., 28 cwt., 2½ tons and 4½ tons for vehicles in the four size ranges.
Source: Irish Statistical Bulletin.

vehicles included, particularly the lighter ones, are not primarily used for carrying goods as such but as runabout transport for service engineers and in other similar uses.

Of the fleet of goods vehicles, some use petrol and some use D.E.R.V. (Diesel-Engined Road Vehicle) fuel. The capital cost of the diesel-engined vehicle of unladen weight greater than, say, 1½ tons is approximately one-tenth higher than that of a comparable petrol-engined vehicle but this disadvantage is offset by lower operating costs. The fuel consumption of a diesel engine (compression ignition) is roughly two-thirds (by volume) that of a gasoline engine (spark ignition) for the same work, and maintenance costs may be a little lower. This advantage tends to increase with the size of engine. On the other hand, it should be added, the gasoline engine offers quieter and smoother running and a greater speed range.

In April of 1964 the wholesale price of one gallon of DERV was about 90% of that of a gallon of Regular Grade petrol. The former carried a duty of 28·9 pence per gallon and the latter one of 36·2 pence per gallon; this difference between the rates of duty applicable to the two fuels just about equalled the difference between their selling prices. In the early 1950's the two fuels carried the same duty and there was only a very small difference between their wholesale prices. Since 1952, however, the rate of duty on petrol has increased progressively much faster than that on diesel and, correspondingly, the gap between their selling prices has widened.

The difference in price supplements the advantage of lower fuel consumption of the diesel engine and brings the relative operating cost of such an engine down to three-fifths that of a petrol engine. Clearly, relatively few miles need to be run each year to repay the additional capital cost of the diesel engine.

No precise information is available about the breakdown of the goods vehicle fleet by the type of fuel used in the engine. However, for new registrations during the first eleven months of 1963 a breakdown is available and is given in Table 25.

TABLE 25: GOODS VEHICLES BY TYPE OF FUEL

Unladen weight	New Registrations Jan./Nov. 1963			
	Total	Petrol	Diesel	% Diesel
Up to 16 cwt.	1,528	1,524	4	0·3
16 cwt. to 2 tons	2,899	2,590	309	10·7
2 tons to 3 tons	463	87	376	81·2
3 tons and over	1,501	64	1,437	95·7
	6,391	4,265	2,126	33·3

Note: Electrically driven vehicles excluded.
Source: Data supplied by the Central Statistics Office.

The resulting pattern is very much what might have been expected. Petrol engines predominate for the lighter vehicles while diesel engines are the rule for heavy trucks and lorries. This pattern has almost certainly shown some change over the past ten or fifteen years not only because of the widening operating cost advantage of the diesel engine but also because of the fairly recent development of the compression ignition engine. Nevertheless, since 1957 the difference in fuel prices has been considerable and vehicles bought since then (which make up the population of vehicles if the life of a vehicle is about six years) have probably been bought in fairly similar proportions to those shown in the above table. This is even more likely to be true of the heavy trucks, the numbers of which have grown so rapidly in recent years. Somewhat arbitrarily, therefore, the total fleet of goods vehicles in August 1963 may be estimated to be made up of petrol- and diesel-engined vehicles as shown in Table 26.

TABLE 26: ESTIMATED NUMBERS OF DIESEL AND PETROL FUELLED VEHICLES, AUGUST 1963

Unladen Weight	Total	% Diesel	Diesel	Petrol
Up to 16 cwt.	12,405	0	0	12,405
16 cwt. to 2 tons	18,475	10	1,850	16,625
2 tons to 3 tons	4,239	75	3,179	1,060
3 tons and over	9,624	95	9,144	480
	44,743	31·7	14,173	30,570

Other Vehicles

Table 27 shows the totals of vehicles other than private cars and goods vehicles registered under current licence in August of each year:

TABLE 27: OTHER VEHICLES; 1950 TO 1963

Year	Petrol Engines			Diesel Engines	
	Taxis (and hearses)	Exempt vehicles[1]	Motor cycles	Buses	Miscel. vehicles[2]
1950	6,759	2,707	5,801	1,231	515
1951	6,885	3,339	6,405	1,229	524
1952	6,719	2,198	7,980	1,230	500
1953	6,104	3,466	11,317	1,224	615
1954	5,747	3,880	15,052	1,245	803
1955	5,437	3,858	21,436	1,301	832
1956	4,891	3,643	26,539	1,372	871
1957	5,656	3,970	28,571	1,377	861
1958	5,298	4,264	30,568	1,388	809
1959	4,826	4,183	34,059	1,426	992
1960	4,557	4,189	41,467	1,436	937
1961	4,327	4,337	45,594	1,466	1,054
1962	4,274	4,563	48,268	1,478	1,159
1963	4,113	5,059	49,529	1,514	1,236

Notes: [1]"Exempt vehicles" are mainly cars run by government and local government departments.
[2]"Miscel. vehicles" include dumpers, excavators, road-haulage tractors etc.

Source: Statistical Abstract of Ireland.

The number of taxis in the Republic has declined slowly but steadily over the whole period, a consequence of the growing private ownership and use of motor-cars; in recent years the decrease has been about 150 vehicles or some 3½% a year. The number of government or exempt vehicles, on the other hand, has grown fairly rapidly, at about 5% p.a. Similarly, the numbers of buses and of miscellaneous vehicles have also increased, the former by about 1½% p.a. and the latter by nearly 7% p.a.

The motor-cycle is the category of vehicle that has shown the most ebullient growth, particularly in the early part of the period. The following figures show the rates of growth in the number of motor-cycles during the period, obtained by the fitting of exponential time curves to the data:—

1950 to 1955 31·0% p.a. (R^2=·97)
1956 to 1959 8·5% p.a. (R^2=·99)
1960 to 1963 6·0% p.a. (R^2=·94)

1950 to 1963 19·2% p.a. (R^2=·55)

Fuel Consumption for Road Transport

Little detailed information is available about the consumption of automotive fuels by the different types of road vehicles. The total consumption of automotive fuels is given in Table 28 for each year since 1950. Petrol consumption excludes use in agricultural tractors.

TABLE 28: FUELS CONSUMED FOR ROAD TRANSPORT; 1950 TO 1963

Year	Million Gallons	
	Petrol	Automotive diesel
1950	63·0	5·7
1951	67·2	6·3
1952	70·6	6·6
1953	74·2	6·8
1954	78·5	7·8
1955	82·9	8·9
1956	86·0	10·6
1957	70·6	10·5
1958	77·8	12·7
1959	80·5	14·8
1960	84·4	17·2
1961	91·0	20·7
1962	96·3	23·9
1963	104·2	26·2

The figures for petrol consumption in Table 28 include petrol used by visitors to Ireland from abroad who bring cars with them into the country mainly in order to take motoring holidays. In 1962 for example[12], there were some 18,000 cars temporarily imported into Ireland through ports in the Republic. In addition, about 80% of the 27,000 cars temporarily imported into Six Counties' ports are estimated to have passed across the Border into the Republic. Thus in this year visitors from abroad may have brought 40,000 cars into the Republic. A sample survey[13] indicated that each car may cover about 1,250 miles during visits, of which (say) 1,100 miles may be taken to have been run within the Republic. A total of 44,000,000 miles run with an estimated average fuel consumption of 30 miles per gallon would mean a total petrol consumption by car tourists from abroad of some 1·5 million gallons.

In 1962 also, some 3½ million cars crossed the Border into the Republic[12]. Between one-third and one-half of these were cars from the Republic returning home after visits to, or journeys through, the Six Counties. The question that arises is whether on balance more petrol was purchased in the Republic by visitors from the North than was purchased in the North by visitors from the Republic. With such large numbers of crossings, small differences between the average purchases of petrol for each car on the opposite sides of the border could significantly affect the total petrol consumption of cars registered in the Republic. For instance, if cars from the North bought an average of three gallons per car in the Republic while cars from the Republic bought only two gallons per car in the North (a difference in this direction is not unreasonable bearing in mind the larger area of the Republic) then the net sales of petrol to cars from the North could have been 3 to 4 million gallons. These are perhaps greatly exaggerated figures since much of the cross-border traffic is local movement of vehicles; the other factor is that, until 1964 at least, petrol was more expensive in the Republic, which makes it unlikely that visitors from the North would make a habit of buying petrol here.

However, this brief discussion is sufficient to show that the petrol consumption figures in Table 28 may over-estimate by only some four to six per cent the quantities of petrol used by cars registered in the Republic.

Without knowledge of the average number of miles run each year by the different types of vehicles or of their average fuel consumption per mile it is impossible to split up the figures in Table 28 precisely between the different categories of vehicle. Detailed knowledge is lacking but, by guessing average fuel consumptions and by assuming certain relations between the average miles covered each year by the different vehicles, some approximate results can be obtained. Although they will lack precision these results may make it possible to see the general trends in vehicle use. In the following paragraphs an attempt is made to compare what happened in 1963 with what happened in 1953.

[12]Bord Failte Annual Report, 1962/63.
[13]From information given by Bord Failte.

Petrol-engined vehicles will be discussed separately from diesel-engined vehicles.

Private cars, taxis, government ("exempt") vehicles, and motor-cycles may be collected together and labelled "car transport". It is assumed that taxis run three times as many miles each year as other cars and motor-cycles only half as many. The average fuel consumption per 'unit' of car transport is shown in Table 29 for 1953 and 1963; fuel consumptions for each car size have been guessed. Motor-cycles are shown at the bottom of the table.

TABLE 29: AVERAGE FUEL CONSUMPTION OF CARS; 1953 AND 1963

Type of Vehicle	Numbers, in '000		Average fuel consumption	
	1953 (est)	1963	m.p.g.	gals./ mile
Private Cars, H.P.:				
up to 8	42·4	91·6	40	·025
9 and 10	34·8	80·2	33	·030
11 and 12	25·0	36·7	30	·033
13 and 14	0·0	11·4	25	·040
15 and over	6·6	9·2	20	·050
	108·8	229·1		
Taxis (x 3)	18·3	12·3	25	·040
Exempt Vehicles	3·5	5·1	25	·040
Motor-cycles (x ½)	5·7	24·8	100	·010
Total 'units' of car transport	136·3	271·3		
Weighted average fuel consumption				·031 (1953) ·028 (1963)

Much of the lighter commercial traffic is in vehicles with petrol engines. In Table 30 the average fuel consumption of a petrol-engined goods vehicle is calculated assuming all sizes of vehicle have the same average annual mileage. The actual numbers of vehicles which used petrol are not known exactly. The estimates for 1963 derived earlier are used for that year; for 1953 the numbers of these vehicles have been guessed assuming that only a very small proportion of the goods vehicles fleet had diesel engines in that year.

In 1953 the vehicles listed in Tables 29 and 30 together consumed 74,200,000 gallons of petrol, and in 1963 104,200,000 gallons (neglecting deductions on account of visitors and tourists). Let the average annual mileages of "Car Transport", and "Goods Transport, Petrol" be M_c, and M_{pg} respectively, then the following equations can be formed—one for 1953 and one for 1963:

1953:— $(136{\cdot}3 \times {\cdot}031)\ M_c + (31{\cdot}4 \times {\cdot}52)\ M_{pg} = 74{,}200$
1963:— $(271{\cdot}3 \times {\cdot}028)\ M_c + (30{\cdot}6 \times {\cdot}045)\ M_{pg} = 104{,}200$

Direct solution of these equations, with no account given to the possibility that average mileages may have changed, leads to the values: $M_c = 10{,}300$ miles a year; $M_{pg} = 18{,}800$ miles a year. The latter is an unlikely figure because it is so high. The assumption that $M_c = M_{pg}$ leads to the common values of 12,700 miles a year in 1953 and of 11,600 miles a year in 1963. These seem to be more reasonable figures though still high by UK standards[14]. A few trial solutions for different ratios of M_{pg} to M_c reveal, moreover, that unless this ratio has decreased substantially between 1953 and 1963 then annual car mileages must have declined e.g.:—

TABLE 30: AVERAGE FUEL CONSUMPTION OF PETROL-ENGINED GOODS VEHICLES; 1953 AND 1963

Type of Vehicle	Number, in '000		Fuel Consumption	
	1953 (est)	1963	m.p.g.	Gals./ mile
Petrol-driven goods vehicles, unladen weight				
Up to 16 cwt.	10·0	12·4	30	·033
16 cwt. to 2 tons	15·0	16·6	20	·050
2 tons to 3 tons	5·1	1·1	12	·080
3 tons and over	1·0	0·5	9	·110
	31·1	30·6		
Miscel. vehicles	0·3	0·0	15	·066
Total "goods transport, petrol"	31·4	30·6		
Weighted average fuel comsumption				·052 (1953) ·045 (1963)

Year	Ratio of M_{pg} to M_c			
	0·5	1·0	1·5	1·8
M_c in 1953, miles p.a.	14,710	12,710	11,120	10,300
M_c in 1963, miles p.a.	12,570	11,600	10,780	10,300

These figures clearly point to a decline between 1953 and 1963 in the average number of miles covered each year by motor-cars. It has been the common experience of many countries that growth in the ownership of motor-cars is associated with declining annual mileages.

The average fuel consumption per mile of diesel vehicles is shown in Table 31, assuming that all goods vehicles run the same number of miles each year.

The fuel consumed by the vehicles listed in Table 31 may be estimated by subtracting from the total diesel fuel used for road transport purposes an estimate of that used by buses. In 1953, 1,200 buses ran some 44.7 million miles of journeys and consumed some 4.47 million gallons of fuel at 10 miles to the gallon; the corresponding estimate for 1963 is 4·56 million gallons, with the same average fuel consumption per mile. Thus, by subtraction, 2·33

[14]Reynolds *op. cit.* (see footnote (9) above).

Table 31: AVERAGE FUEL CONSUMPTION OF DIESEL-ENGINED GOODS VEHICLES; 1953 AND 1963

Type of Vehicle	Number, in '000		Fuel Consumption	
	1953 (est)	1963	m.p.g.	Gals./mile
Diesel-driven goods vehicles, unladen weight				
Up to 16 cwt.	0·0	0·0	—	—
16 cwt. to 2 tons	0·0	1·9	22	·045
2 tons to 3 tons	1·5	3·2	14	·070
3 tons and over	0·7	9·1	10	·100
Miscel. vehicles	0·3	1·2	13	·075
Total "goods transport, diesel"	2·5	15·4		
Weighted average fuel consumption				·079 (1953) ·085 (1963)

million gallons in 1953 and 21·64 million gallons in 1963 were consumed by the vehicles shown in Table 31.

By simple division, the average annual mileages run by diesel driven goods vehicles in 1953 and in 1963 were 12,000 miles and 16,500 miles respectively. Susceptible to a wide margin of error as these estimates are, they do suggest that the average vehicle is being used more now than ten years ago. This, indeed, one might have expected now that the declining importance of railway goods traffic has favoured longer-distance road traffic in goods.

Fuel Consumption for Rail Transport

Table 32 gives some selected statistics of railway traffic for 1953/54, for 1957/58, and for the six years from 1958/59 to 1963/64. For the first two years data corresponding to Córas Iompair Éireann and to the Great Northern Railways Board are shown separately. From the beginning of October 1958, the GNR's operations within the Republic were absorbed by the CIE. It is difficult for this reason to make an accurate comparison with years before 1958.

In terms of the number of miles run by locomotives rail traffic has declined by some 30% over the ten years from 1953/54 to 1963/64, on the assumption that GNR locomotives ran about one-third of their total mileage in the Republic in 1953/54. However, rail traffic has not suffered to this extent. Between 1953 and 1957 the total number of miles travelled by CIE rail passengers increased by more than 10%; the increase continued after the amalgamation with the GNR, until 1960, and only since that year has there been sign of a slow decrease

Table 32: SELECTED STATISTICS OF RAILWAY OPERATIONS: 1953/54, 1957/58 and 1958/59 to 1963/64

From 1958/59 includes ex-GNR operations in the Republic[2]

Financial year[1]		1953/54	1957/58	1958/59	1959/60	1960/61	1961/62	1962/63	1963/64
Engine miles run; thousands:									
Steam engines	CIE	8,242	2,500	2,549	2,116	1,781	1,392	928	0
	GNR	4,441	2,630						
Diesel locomotives	CIE	118	5,228	5,813	6,270	6,512	6,546	6,632	6,930
	GNR	0	37						
Diesel railcars	CIE	1,290	1,716	2,184	2,141	2,007	1,735	1,732	1,582
	GNR	1,927	2,765						
Total	CIE	9,650	9,445	10,546	10,526	10,229	9,674	9,292	8,512
	GNR	6,368	5,514						
Traffic carried; million passenger or ton miles:									
Passengers	CIE	231	261	325	344	352	344	337	331
Goods[3]	CIE	217	182	202	209	222	218	217	220
Fuel consumption; thousand tons:									
Coal	CIE	n.a.	61·9	58·7	53·8	43·9	35·2	26	0
Oil	CIE	n.a.	21·9	24·0	27·2	27·2	24·9	29·2	29·7
Specific consumption; tons of fuel per thousand miles run:									
Coal	CIE	—	24·8	27·4[4]	25·4	24·6	25·3	28	0
Oil[5]	CIE	—	3·60	3·57[4]	3·71	3·62	3·36	3·89	3·85
Locomotives; numbers:									
Steam	CIE	399	264	347	193	140	132	53	18
Diesel locomotives	CIE	7	135	139	139	154	154	210	212
Diesel railcars	CIE	53	68	94	93	89	86	86	86

Notes: [1]CIE financial year runs April to March; GNR October to September.
[2]GNR operations in the Republic were absorbed by CIE in October 1958; 1958/59 data include corresponding GNR figures for the full year however.
[3]Total receipts from goods and livestock carried divided by average receipts per ton-mile of goods only.
[4]Calculated from mileage of CIE engines only.
[5]It is assumed that diesel railcars consume half as much oil per mile as diesel locomotives.
Source: CIE and GNR Annual Reports; fuel consumption data supplied separately by CIE.

in passenger mileage. Goods traffic has probably declined slightly. The CIE carried in 1963 slightly more ton-miles of goods than in 1953 but the increase is less than the additional business brought to it by the amalgamation.

The closing of uneconomic lines and the cutting-off of uneconomic services have contributed to an improvement in the use of rail services. The number of miles of first track railway lines in use fell from 2,008 in March 1954, to 1,458 in March 1964, despite the acquisition of 230 miles of track from the GNR. The average distance of a passenger journey has increased from 28·5 miles in 1953 to 34·2 miles in 1963.

The replacement of steam locomotives by diesel-fuelled locomotives has continued throughout the period, and there were corresponding changes in the numbers of miles run by the two types of engine, and in the quantities of fuel consumed. Coal consumption fell to below 30,000 tons in 1962/63,[15] less than half the amount used in 1957/58, while between the same two years oil consumption increased by one-third. The greater relative efficiency of oil is apparent from the derived estimates of the specific consumption of each type of fuel per thousand miles run by locomotives (see Table 33). Using coal a locomotive would burn about 25 tons for each thousand miles, but using oil it would consume only just over 3½ tons. A ton of oil is worth perhaps 1¾ tons of coal, and after allowing for this it appears that a diesel locomotive uses its fuel nearly four times as efficiently as a coal-burning locomotive. It should be borne in mind, of course, that the steam engines run by CIE are very much older than its diesel engines.

For earlier years it is more difficult to find reliable estimates of railways fuel consumption. CIE records do not reach further back than 1957/58, and for earlier years would not in any case include fuel consumed for rail traffic within the Republic carried by the Great Northern Railways. It is possible to estimate the numbers of engine miles run within the Republic by the GNR and to add these to the numbers of engine miles run by the CIE. Multiplied by estimates of specific fuel consumption per mile the resulting total engine miles run within the Republic yield estimates of fuel consumption for the earlier years of the period. These estimates are shown in Table 33. Alongside them are shown railways fuel consumption figures published by the Organisation for Economic Co-operation and Development (OECD).

Since 1955 at least, there is a general correspondence between the two sets of estimates in Table 33. For earlier years OECD report coal consumption at about 100,000 tons less than consumption calculated from engine mileages. About a quarter of this difference could be explained if the coal used in GNR engines had all been bought in the North—in the early 1950's coal prices in the North were less than those in the Republic. The remainder is difficult to account for. For the sake of argument, the consumption figures estimated from engine mileages will be adopted, less 25,000 tons in the years from 1950 to 1954.

[15]Little, if any, coal was used in 1963/64.

TABLE 33: RAILWAYS FUEL CONSUMPTION; 1950 TO 1963

Year	Thousand tons			
	Estimated from engine miles run [1 2 3]		Published by O.E.C.D. [4]	
	Coal	Oil	Coal	Oil
1950	300	1	160	n.a.
1951	300	1	190	n.a.
1952	290	2	180	n.a.
1953	260	4	140	n.a.
1954	250	5	180	n.a.
1955	200	11	240	n.a.
1956	150	18	120	n.a.
1957	90	23	100	n.a.
1958	65	25	60	n.a.
1959	54[5]	27[5]	50	32
1960	44	27	50	29
1961	35	25	40	26
1962	26	29	30	20
1963	0	30	n.a.	34

Notes: [1]In fact these data relate to financial years.
[2]For years before 1958, GNR mileages have been included according to share of mileage in the Republic in 1958.
[3]Estimated specific consumptions; 25 tons of coal, 3·6 tons of oil per thousand miles.
[4]Oil data: OECD Oil Statistics; Coal data: OECD Industrial Statistics, 1960 to 1962.
[5]Actual consumption data for this and succeeding years supplied by CIE.

Agriculture

In spite of the importance of agricultural production within the Irish economy, the energy consumed by this sector represents only about one-thirtieth part of the total commercial primary energy consumption. This includes only specifically agricultural fuels used in internal combustion engines—for tractors, combine-harvesters, etc.—and neglects electricity used on farms for motive power and heating. The amounts of electricity used for productive rather than purely household purposes in rural areas are almost certainly small and their omission is not therefore of great significance. Also excluded are other household fuels consumed in rural areas, like turf, coal and bottled gas, since again these are mostly used for other than agriculturally productive purposes.

The low relative use of energy in agriculture—for agriculture's share of national income was still more than 20%[16] in the early 1960's—derives from two causes. The first is that agriculture, even at its most heavily mechanised, does not require intensive use of capital equipment; rather it is an intensive user of land and labour. The second cause is that in Ireland conditions are such that the less energy-intensive agricultural commodities are favoured. The production of meat and of store cattle, and that of dairy products tend to require less energy than the production of cereals. At the same time the volumes of output per man and per acre are low in Ireland. Agriculture still provides employment for about a third of the active population of the Republic.

However, with gross agricultural output rising and the number of agricultural workers falling, the productivity of labour has been increasing, and one would therefore expect to see signs of increased mechanisation and of increased use of energy. In Table 34 are given figures relating to the use of energy for agricultural purposes. The second column shows the numbers of agricultural tractors licensed in August of each year. (These tractors incur special licence duties: £2 10s. p.a. for tractors used only for agricultural haulage, and 5s. p.a. for other agricultural tractors only used incidentally for haulage). The succeeding columns show the quantities of fuel consumed for agricultural purposes, and the last column gives a volume index of agricultural output of crops and turf (i.e., excluding livestock and livestock products).

A comparison of total fuel consumption with volume of output (the last two columns of Table 34) reveals little direct relation between the two series, except insofar as they are both tending to increase. This is not at all unexpected, for year-to-year fluctuations in output of crops are mainly determined by the weather; during a year of bad weather, when output falls, the difficulties of ploughing, sowing, and harvesting are increased and a greater proportional mechanical and physical effort is needed per ton of output, which leads to a greater proportional use of energy. Thus there is little or no correspondence between year-to-year variations in output and in fuel consumption.

Fuel consumption increased between 1950 and 1962 at a trend rate of 5·5% p.a. ($R^2 = \cdot77$); in recent years, however, there is some indication of a levelling-off in consumption. Output increased at a trend rate of 1·9% p.a. ($R^2 = \cdot10$). The growth-elasticity between the two series, however, was only 1·4 ($R^2 = \cdot41$), much less than the ratio of their two rates of growth.

There are three types of tractor fuel corresponding to the three different types of engine used in tractors. They are regular-grade petrol, tractor vaporising oil (a fuel in the kerosine range), and tractor diesel oil (a fuel in the gas/oil range). Until perhaps twenty years ago tractors were usually petrol-burning, but ever-increasing tax advantages stimulated the development of a (comparatively inefficient) engine to burn vaporising oil. The ten years up to the early 1950's saw vaporising oil becoming by far the most important tractor fuel. Towards the end of that period the more efficient diesel engine was developed and adapted to use in agricultural and automotive vehicles. This fuel

[16] This and other figures in these paragraphs are taken from Part II of 'Second Programme for Economic Expansion', Chapter I.

TABLE 34: AGRICULTURAL TRACTORS, FUELS CONSUMED AND AGRICULTURAL OUTPUT; 1950 to 1963

Year	Agricultural tractors in August '000	Fuel Consumption; mil. gals				Volume index of output[1] 1953=100
		Petrol	Vaporising Oil	Diesel Oil	Total	
1950	11·3	1·1	8·7	(2)	11·8	84
1951	14·2	2·1	11·0	(2)	15·1	85
1952	16·0	1·9	12·3	(3)	17·2	88
1953	18·4	1·6	12·5	(5)	19·1	100
1954	22·8	1·5	12·8	(7)	21·3	92
1955	16·4	1·2	12·8	(9)	23·0	96
1956	27·9	1·1	12·3	10·7	24·1	99
1957	34·4	1·2	10·7	8·0	19·9	107
1958	33·5	0·9	10·6	11·1	22·6	80
1959	35·3	0·8	10·3	13·3	24·4	103
1960	37·0	0·7	9·1	14·7	24·5	106
1961	39·7	0·6	9·1	17·5	27·2	105
1962	43·1	0·4	7·9	17·3	25·6	113
1963	46·3	(0·3)	7·3	18·3	25·9	—

( ) Indicates estimate.

Note: [1]Crops and turf (mainly hand-won) only.

Source: Tractor and Output data from Statistical Abstract of Ireland, 1963; petrol data derived from information given in Revenue Commissioners Reports; other fuel data from information supplied by the principal oil companies.

retained the tax advantage of vaporising oil, in agricultural uses at least, for the same was not true of its use in road vehicles. (It may be mentioned in passing that petrol used in agricultural tractors and farm machinery was subject to a partial rebate of tax, granted in 1948. The rebate was initially 6d. a gallon of a total tax burden of 1s. 2d., and by 1956 it had risen to 1s. 1¾d. out of a total of 2s. 3½d. This rebate was abolished in April 1963, but by this time only insignificant amounts of petrol were being used on the land.) In recent years diesel tractors have predominated and there has been spectacularly rapid growth in the use of diesel fuel.

Fairly recently a coloured pigment has been added to tractor diesel fuel to distinguish it from automotive diesel fuel (the fuels are technically interchangeable), and this raises some suspicion that part of the spectacular growth in its agricultural use may be more apparent than real. It is possible, that is, that this measure was made necessary because significant quantities of the duty-free agricultural oil were being used in road vehicles.

Some breakdown of the sizes of tractor in use is available from the 1960 Agricultural Statistics Enumeration. The breakdown by size in June 1960, was as follows (Statistical Abstract of Ireland, 1963, Table 64):

35 HP and over	11,328
20–35 HP ...	25,587
Under 20 HP	6,782
Total tractors	43,697

For August of 1963 the comparative figure for the number of vehicles registered as agricultural tractors (see Table 34) was 36,970. The difference relates to the numbers of "untaxed" tractors which do not operate on the public highway.

If the average horse-powers of tractors in the three ranges are taken as 37 H.P., 28 H.P., and 17 H.P. respectively, the total power of all tractors in 1960 was 1·25 million H.P., and the average horse-power was 29 H.P. per tractor. The average hourly fuel consumptions of tractors are roughly as follows:

Petrol	·045 gals./HP/hour
Vaporising oil	·046 gals./HP/hour
Diesel oil	·035 gals./HP/hour
Weighted average	·039 gals./HP/hour

In forming this average the quantities of each of the fuels consumed in 1960 were used as weightings. If 24·5 million gallons of fuel were burnt by 1·25 million H.P. of machinery at an average hourly consumption rate of 0·39 gals./HP/hour then that machinery was used for an average of about 500 hours a year.

It is easy to calculate for other years the average numbers of hours a year that tractors were used, using the same average H.P. per tractor as that given above and the fuel consumption data in Table 34. (For consistency from year to year, the tractor populations of Table 34 will be used.) Annual utilisations for selected years may be estimated as follows:—

1950	800 hours a year
1955	730 hours a year
1960	600 hours a year
1963	500 hours a year

These figures show a considerable decrease in the use of farm tractors. The decrease may be exaggerated to some extent since average fuel consumption has probably decreased with the increasing efficiency of engines as well as with the change to more efficient types of fuel (which has been allowed for). On the other hand there may be a tendency towards the use of more powerful tractors, which would have the reverse effect. On the whole there is no reason to doubt that tractors, like private motor-cars, are being used less as their ownership becomes more widespread. Use of a tractor for 500 hours a year means that on average the tractor is used for one hundred days or five working months at five hours a day. This is not a high level of utilisation. Unfortunately, comparative figures for other countries are not easily available.

In addition to tractors, a large number of road vehicles are used primarily for farm purposes. In 1960, these included nearly 2,000 lorries of 2 tons capacity and over, nearly 12,000 smaller lorries and trucks, and over 46,000 motor cars. The fuels consumed by these vehicles are included with the consumption of transport fuels and are dealt with as part of the transport sector.

Other Sectors

The fourth main sector has been rather inexplicitly termed "Other Sectors"; it includes the energy consumption of the following sub-sectors:—

Commercial Premises:	Shops, Offices and Business Premises, Places of Entertainment, Handicrafts and Home Industry;
Public Institutions:	Administration Buildings, Other Public Buildings, Hospitals, Schools, Public Services (Street Lighting, Telephone, etc.);
Private Households:	Houses, Flats.

Widely disparate as these categories are, they have in common that they are almost all premises where people live and work, and that their use of energy provides for personal comfort and need (with the exception of Handicrafts and Home Industry, but the use of energy associated directly with work of this nature can be of but little account; it is mentioned for completeness' sake).

A full list of all the purposes of personal comfort and need for which energy is used would be long. Electricity in particular has a wide range of uses in a variety of appliances from television sets to electric shavers. These specialised uses of electricity apart, the energy used by the sector as a whole tends to be employed for four main purposes, viz.:

Lighting
Cooking
Water Heating and
Comfort Heating.

The last two of these are sometimes considered together and called Domestic Heating; and, in fact, although they are two different functions they are often difficult to separate even in a single house if one heating system supplies the energy for both.

It has been mentioned earlier that some at least of the energy consumed by Industry is also used to provide lighting and heating, in this case for industrial workers. The sector here discussed does not, therefore, cover exhaustively the *whole* of the energy consumed for these four main purposes. But a complete breakdown both by sector and by end-use would be quite impossible to achieve with available statistical resources; even the simpler breakdown attempted here stretches those resources almost beyond their capacity, as will be seen.

The other important reservation that should be made at once is that it will not be possible to separate the amounts of energy used for each of the four main purposes distinguished above, even within this one large sector. Much of the discussion which follows will thus not be directly related to figures and will permit only qualitative and not quantitative conclusions being drawn. Nevertheless, the distinction between these four uses of energy is sufficiently basic to warrant its introduction, because different technical possibilities and hence different patterns of inter-fuel competition apply in each use. All that can be said about their relative importance is that, as written, they probably lie in inverse order of the amounts of energy they require. Comfort-heating is certainly by far the most important of the four and lighting the least, in terms of energy consumed if not in terms of the satisfactions they bring (who, indeed, would like to be faced with a choice between them).

Artificial light is needed to supplement and to complement daylight. It can be supplied using a variety of appliances and forms of energy. The basic process makes use of a localised high temperature heat source, and is almost always associated with some loss through radiation, convection and conduction of heat. The most modern light sources, however, use the chemical excitation of certain gases and solids (as in fluorescent lamps), they operate at relatively low temperatures, and heat losses are consequently reduced. The production of heat, it may be noted, is essential to the functioning of lamps using liquid and solid fuel, the heat supplying energy to vaporise the fuel and to increase the efficiency and speed of combustion.

Electric light is by far the most convenient, compact, and efficient form of artificial lighting. It is the most universally used where public electricity is supplied, and often in places not so served, small generators are run to provide electricity for lighting. There are two types of electric lamp: the incandescent filament lamp, either in vacuum or in gas-filled tubes (bulbs), and the fluorescent lamp. The latter is about twice as efficient as the former but its installation cost tends to be higher.

The relative efficiencies of the different light sources may be compared in the following figures, which show light output in lumens per 100 Btu of energy input:—

Kerosine	5 to 30
Gas	45
Electricity	350 to 800

The much greater efficiency of electric lighting more than compensates for the higher price of electricity per Btu. The other factor, at least as important, is the low cost of electric lighting appliances once a supply of electricity has been laid on: for example, perhaps 20 or so Hurricane lamps would be needed to give the same light output as one 100 watt bulb. A household may consume some 200 units of electricity a year for lighting (although very wide variation about this figure is possible).

Cooking requires a much lower temperature source of heat than lighting and the range of possible sources of fuel is thereby widened. Not only can electricity, gas and kerosine be used but so also can solid fuels like coal, coke, turf, and wood. Further, because of the lower grade of heat needed, electricity has much less advantage on the grounds of efficiency alone.

Solid fuel and turf cookers have much to be said for them, particularly because of their multi-purpose nature. They can be made to provide hot water and local space-heating as well as heat for cooking. However, they take more trouble to use, they do not respond quickly, and they are relatively expensive to install.

The gas cooker is a more efficient appliance—perhaps by as much as 50%. It is convenient, quick and easy to control and perhaps its only disadvantages are, first, that associated with the toxicity of gas (which will soon be a thing of the past with the change to oil-based gas manufacture) and, second, that a gas cooker becomes dirty after a time and tends to cause condensation on kitchen walls.

Electric cookers are even more efficient than gas cookers and they are easier to clean. They are said to be less flexible than gas cookers and to be slower, but with modern hot-points and fitted saucepans this claim is to be doubted. Rather it is that a different cooking technique is called for, particularly in using the oven—for a gas oven has an air vent while an electric oven is at its most efficient when closed. Hybrid cookers, with electric oven and gas boiling points, have been put on the market; they were in France a few years ago, for instance, with little reported success. Electric cookers are on the whole more expensive to buy and to maintain than gas cookers.

There are in addition cooking appliances that burn kerosine, but these no longer find such a ready market even in areas where there is no public gas or electricity supply because of the growing popularity of bottled gas appliances. Kerosine cookers compare in efficiency with gas cookers, and they can be very cheap, but they tend to be dirtier in use and to smell if not kept very clean.

On the whole, towns gas is probably more widely used than electricity for cooking in urban areas of Ireland, but it would be difficult to say whether electricity is preferred to bottled gas in rural areas. The reputed advantages of electric cooking have been widely advertised recently by the Electricity Supply Board in an attempt to spread the domestic electricity load over a greater number of hours a day. In Table 35 is given a rough comparison of operating costs with the various fuels (applicable to urban areas only):—

TABLE 35: COMPARATIVE COSTS OF ENERGY FOR COOKING

Fuel	Price	Efficiency %	Pence per therm of useful heat
Electricity	1·2 to 1·6d./unit	55	64 to 85
Gas	2s. 5d./therm	40	73
Kerosine	2s. 2d./gallon	40	43
Coal	£12/ton	25	42

The figures in Table 35 illustrate the influence of factors other than cost, for the two most expensive fuels are also the two most popular. In fact, however, the operating cost advantage of coal (and of other solid fuels) in comparison with electricity and gas may be magnified in these figures for ***intermittent*** use of cooking stoves because it is much more difficult to regulate the heat output of a coal-burning appliance. The requirement of heat for cooking for a typical household is equivalent to about 80 therms of gas a year.

Hot water is primarily required for bathing, laundry and washing-up. The domestic water-heater must supply heat to raise water temperatures by about 100°F., more in winter and less in summer, to a temperature of perhaps 150°F. Typical rates of consumption of hot water by a family may vary from 200 to 500 gallons a week; these would require annual heat inputs of from 150 to 350 therms with a heater working at 70% efficiency. The latter is, incidentally, quite a high efficiency for a hot water system; the major cause of lower efficiencies is not the heater itself, which usually works at high efficiency (and particularly if of the immersion type), but the heat losses from the hot water tank and distribution system.

Hot water systems are of three basic types. The first is the instantaneous heater. This is a heater fitted usually to a single outlet which heats up water as it is run off into the sink or bath; it requires a high-powered heat source and tends to favour the use of gas, although electric appliances fulfilling the same function have been designed. Instantaneous gas heaters are not the most efficient appliances as heaters, but in compensation losses of heat from water are eliminated. With a number of outlets to be supplied with hot water, they are comparatively expensive to install if the house is already fitted with pipes for distributing hot water from a central point. If not, and this applies particularly to very old houses, instantaneous heaters may be the most economic way of providing hot water.

The second basic type is the tank storage heater, which usually supplies hot water for the whole house. The most efficient, safest and most easily controlled form is the thermostatically-controlled electric immersion heater. This can be connected to the off-peak supply of electricity and run at fairly low cost. It is also possible to heat only the upper levels of water in the tank using a second heater placed high in the tank, which increases the system's flexibility. Gas can be used for tank storage heating but it is neither as efficient nor as popular. With electricity at 1·3d./unit and gas at 2s. 5d./therm electricity may have a slight cost advantage and is definitely cheaper at off-peak electricity rates. The electric heater is also cheaper to install and to maintain.

The third type of water heating system is that linked to the cooking or comfort-heating system, of which the latter is the more important combination; its use will be covered below in the discussion of comfort-heating.

Comfort-heating is the most important domestic use of energy; it consumes perhaps three times as much energy as the other three uses put together. It is much too large a subject to deal with in any great detail here, but it is important to mention some of its salient points.

Comfort-heating, as is hinted in its name, is not concerned with an objectively-determined supply of a certain quantity of heat to a certain space of living or working room; it is concerned with the comfort of people when indoors. Comfort (one is thinking here of the warmth aspect of comfort) is like any other form of human satisfaction, it varies from time to time, from person to person, and from place to place. It depends among other things upon social customs and habits, upon personal idiosyncrasies, and to some extent, possibly, upon physical differences between people. Physiologically, it seems to have been established that feeling warm and comfortable depends not only on the temperature of the air immediately surrounding the body but also on the rate of circulation of that air, on the spatial distribution of circulation and of temperature, and on the humidity of the air; further, it depends upon the rate at which heat is being exchanged between the body and its more tangible surroundings by radiation. Thus, an air temperature of 70°F. can feel chill if the walls are very cold and the body is radiating heat to them; again, even if the walls are warm one can feel uncomfortable if there is a cold draught of air at floor level; one can feel uncomfortable in any surroundings if one's skin temperature is high and one is sitting in a draught, a common experience with radiant heaters. Some circulation of air, it may be noted, is essential to replenishing the oxygen in the air as it is consumed.

The body can exchange heat by radiation or by direct contact with surrounding air, and can lose heat by one process and gain it by the other at the same time. The ideal heating system, therefore, brings both surroundings and air to independently regulated temperatures, and it supplies a continual flow of fresh air at the required temperature and humidity, circulating that air in such a way as to provide efficient replenishment and variation without causing irritating draughts. Such a system could only be regulated, perhaps, to the satisfaction of a single occupant of the room, but it would be the nearest possible approach to ideal comfort-heating. Its demands could quite easily be met using equipment at present available—basically, a circulating warm air system in combination with wall or floor panel heating, or some similar pairing—but only at considerable expense. Incidentally, the replacement of the moral stimulus of the bright and cheerful open fire is a problem for the architect and the interior designer rather than for the heating engineer.

The open coal or turf fire meets few of the demands of the ideal comfort-heating system. It keeps the air fresh, at the cost of draughts; it supplies radiant heat, when properly attended, but in such a way that only a few square feet of the room is habitable and then only for one side of the body; it is, moreover, highly inefficient as a heating device. Between 65 and 90% of the heat content of the coal disappears up the chimney as smoke and soot, only to reappear later as highly undesirable pollution of the atmosphere. Its day is over but it dies slowly.

Heating appliances can immediately be separated into radiant and into convector heaters, and into a middle variety which are both, on the one hand, and into single-point room heaters and into central-heating systems on the other. Single-point room heaters can have a self-contained energy source or they can be supplied from a central source; they can be fixtures or they can be portable. Thus there is considerable variety. For present purposes the most convenient classification is into room heaters and into partial and full central-heating systems, though from previous discussion it will be apparent that the two may in some ways be complements to each other rather than competitors. It may be decided, for example, to use central-heating for background warmth and room-heaters for local boosting and radiant heat.

Room heaters using a wide range of fuels are available. They include open fires and openable and closed stoves burning any of the solid fuels (not necessarily interchangeably), oil heaters (usually unflued and burning kerosine), gas fires and electric heaters. Oil heaters, gas fires, and electric heaters can be radiant or convector or a combination of the two. Electric heating can be built into wall and floor panels, it can be used in oil-filled radiators, or it can be used in storage heaters running on cheap, off-peak electricity. Electric heating certainly permits the greatest variety but it is comparatively expensive. Efficiencies in use, and therefore operating costs, vary widely but some representative figures are shown in Table 36.

The figures make no allowance for the flexibility of operation of the heating device. On this count, oil, gas and electric heaters (not storage heaters which are very inflexible) have very strong advantages, while the closed coke stove is at a disadvantage because it takes so long before it brings up the temperature of the room.

For intermittent heating kerosine is probably the

TABLE 36: COMPARATIVE COSTS OF ENERGY FOR ROOM HEATING

Appliance	Fuel	Price	Efficiency %	Pence per therm of useful heat
Open fire	Machine turf Turf briquettes Coal Coke	£6 5s./ton 2s. 4d./bale £10 10s./ton £12/ton	20 20 20 30	56 59 48 35
Openable Stove	Coal Coke	£10 10s./ton £12/ton	40 55	24 19
Closed stove	Coke	£12/ton	70	15
Oil heater (unflued)	Kerosine	2s. 2d./gal.	95	25
Gas heater (flued)	Townsgas	2s. 5d./therm	70	41
Storage heaters	Electricity	0·8d./unit	60	39
Other heaters	Electricity	1·2 to 1·8d./unit	100	35 to 53

cheapest fuel, followed by electricity and gas. For continuous heating coke is easily the cheapest but is also the fuel that needs most attention. Appliance and installation costs vary considerably; oil, gas and electric portable heaters are the cheapest and openable stoves the most expensive.

Back-boilers for water-heating can be used with open fires and with stoves, and tend to improve the overall efficiency of operation by utilising heat that would otherwise be wasted. Their disadvantage, unless they are supplemented by immersion heaters, is that they tie the supply of hot water to the use of the fire or stove in question.

Central heating merely removes the generating of heat from the rooms where it is required to some central point in the nether regions of house, block of flats, or offices. There heat can be generated with maximum regard to efficiency and little or no regard to size, shape or appearance. As a medium for distributing the heat either warm air, hot water or steam can be used. The latter is more efficient in larger premises, while warm air is the least expensive and easiest to install in new houses. A warm air system is easily adapted to filtering the air supply and to controlling humidity; it is also easy to incorporate a cooling system for summer use.

A central heating system tends to be operated fairly continuously, at different levels of heat output during day and night, perhaps, but never for an hour or so at a time like a room heater. The system usually supplies heat to a number of rooms, sometimes to a large building, and burns fuel in quite large quantities. It can therefore be designed to burn almost any given fuel at high efficiency, the greater its heat output and the more continuously the system operates the greater the efficiency possible. There is relatively little difference between the efficiencies at which the various fuels can be used—in properly designed appliances, that is. Liquid fuels and gas have certain physical advantages in being easier to supply and to control by automatic means and in the appliance requiring less attention than with solid fuels. Gas-burning plant is easily the cheapest to install since it needs no storage for fuel. Oil-burning plant costs perhaps a little less than a fully automatic solid-fuel appliance but is more expensive than those that are hand-fed or only partly automatic.

It will be appreciated that the comparative costs of different systems depend on a large number of factors, including size, degree of automation, maintenance costs, continuity of operation etc., and representative costs may be misleading. However, for completeness' sake, a rough cost comparison is set out in Table 37. The figures refer to a heating system with a capacity of about 75,000 Btu./hour in a house with 5 or 6 main rooms; and supplying 300 gallons a week of hot water for baths etc. Suppose the central heating system operates for the equivalent of 1,500 hours a year at maximum output, then it might supply 1,050 therms of heat to the building and 150 therms for water heating, a total of 1,200 therms a year. Approximate installation and operating costs are given in Table 37. They show that oil is cheaper than gas to burn but that oil plant is more expensive to install than gas-burning plant; and similarly for anthracite in comparison with gas. The relative advantages of oil and solid fuel are too nicely balanced (particularly if a solid fuel of lower grade than anthracite is used) to be possible to enter into here.

No costs for electricity are shown in Table 37 because electricity is not used for central heating as such. A sufficient number of electric heaters can be

TABLE 37: COMPARATIVE COSTS OF CENTRAL HEATING

Fuel	Price	Efficiency %	Annual Fuel Cost £	Installation Cost £
Domestic Fuel Oil	1s. 5d./gal.	77	71	500
Kerosine	1s. 8½d./gal.	75	92	500
Anthracite	£13 to £17/ton	70	71 to 93	550
Townsgas	1s. 5d./therm	77	110	400

Note: For details of the basis of comparison see text; the data refer to small-bore hot water heating systems only.

installed to give all the benefits of central heating, however, and therefore electricity is in fact a competitor of central heating fuels. Installation costs might be only half that of gas central heating but operating costs would be at least half as much again. With storage heaters both these differences would be reduced.

Very few dwellings in Ireland are equipped with full central heating. It is estimated[17] that at the end of 1963 only 10,000 houses out of the 650,000 homes in the Republic had full central heating, and that the number is increasing by probably over 4,000 a year, of which about half are oil-fired and a quarter electrical heating systems. More precise figures are not available.

Table 40 appended shows the quantities of fuel and power consumed by the group of sectors included here, from 1950 to 1963 (1963 figures are not complete). The figures are not entirely reliable in the case of solid fuels and of heavy oils, for consumption estimates have in these cases been obtained as residuals and they include stock changes that may have taken place in other major sectors of consumption.

Figures are given for each fuel in original units and, for each of the main types of fuel, in equivalent heat units. Total energy consumption is shown in heat units, being the equivalent of nearly 3 million tons of coal in 1962. Until recent years there is little sign of an upward trend in total consumption. In a sense this is a contradiction, since it is undoubted that standards of comfort have been rising rapidly during the period. What has happened is that improvements in the efficiency of use of fuel, and changes to more efficient types of fuel (from hand-won turf to commercial solid fuels, and from solid fuels to liquid fuels and to electricity) have more or less balanced the increased need for the services that the use of fuel provides. The effects of the change to more efficient types of fuel can be eliminated with the device used earlier of guessing the relative average efficiencies of use of each type of fuel and using these to weight each fuel's contribution to the total. The total may be called the 'effective' energy consumption of the sector, and it reveals a marked upward trend, there being an increase of nearly 40% between 1953 and 1962 (see Table 40 for details).

There is no very apt economic indicator with which to compare the energy consumption of this composite sector because it includes energy used by households, by commercial enterprises, and by government departments and public services. The nearest and most useful indicator is personal expenditure on consumers' goods and services at constant market prices. This series may be taken in a broad sense to reveal the increasing material standards of comfort and satisfaction of the community, which are tending to be applied in the office and in other places of work and leisure just as much as in the home. Like the time-series of effective energy consumption just described, personal expenditure hovered uncertainly until 1959 when it begins to grow with some vigour. However, apart from their growth components, there is no strong correlation between year-to-year variations in each series—nor should these be expected given the known shortcomings of the energy data and the tenuousness of the relation between the two series, even on *a priori* grounds.

The relation between effective energy consumption and personal expenditure may be studied in a multiple regression analysis, the other variables being time and (winter) temperature. To measure winter temperatures the same series as that used in Part III in examining the relation between all commercial primary energy consumption and GNP will be used here. The model has the simple equation

$$\log Y = \alpha + \beta \log X + \gamma T + \delta \log Z$$

where Y is Effective Energy Consumption in 10^{12} Btu., X is Personal Expenditure at constant (1953) prices related to 1953=100, T is Time in years and Z is an index of average winter temperatures during the winter extending into the beginning of the year in question. The results of the regression analysis are shown in Table 38.

As expected, the results are not very satisfactory

[17]Irish Times Feature, October 27, 1964 "Heating in the Home" P.14.

Table 38: REGRESSION ANALYSIS OF EFFECTIVE ENERGY CONSUMPTION OF OTHER SECTORS; 1950 TO 1962

D.F.	b Consumption spending	c Time	d Temp.	Residual sum of squares	S^2	R^2
12	—	—	—	·03815	·00318	—
11	+1·70	—	—	·01091	·00099	·71
11	—	+·0107	—	·01742	·00158	·54
11	—	—	+·17	·03784	·00344	·01
10	+1·59 (± ·65)	+·0010 (±·0047)	—	·01087	·00109	·72
10	+1·72 (± ·33)	—	+·25 (±·30)	·01023	·00102	·73
10	—	+·0121 (±·0028)	+·63 (±·36)	·01344	·00134	·65
9	+1·30	+·0035	+·36	·00976	·00108	·74

( ) Standard error.

from a statistical point of view. The best fit is obtained with consumption spending alone; the further introduction of either of the other two variables is not justified on the grounds of lessening the estimated residual variance (S^2) of the energy series, nor are estimates of their associated coefficients significant. The time and temperature variables taken together provide an alternative explanation; admittedly, the estimated residual variance is greater than with consumption spending alone but on the other hand the coefficient of temperature is now almost significant at the 95% level (twice the standard deviation shown in brackets). The coefficient of time is equivalent to an average annual rate of growth of 2·8% p.a. In the final regression with all three variables, none of the coefficients are quite significant numerically.

On this evidence one can either infer that effective energy consumption in this sector is growing at an annual rate 1·7 times the annual rate of growth of consumption spending (which increased at a trend rate of 1·4% p.a. over the period) or that it is increasing, subject to variations in winter temperature, at a steady trend rate of 2·8% p.a. The evidence is marginally in favour of the former.

Because of the unreliability of the energy data, changes in the shares of the different forms of energy can be conveniently presented by comparing aggregate consumption (effective energy consumption) in the first five years of the period with that in the last five years. The results are shown in Table 39.

From Table 39 it appears that coal and coke have lost part of their share of the market although the total quantity consumed has remained steady. The use of turf has expanded rapidly, but it should be noted that growth in consumption of machine turf was mainly confined to the early part of the period, and that of turf briquettes mainly to the later part. Commercial solid fuels as a whole have declined slightly in importance.

The use of burning oil has shown little growth and has fallen in recent years. Oil central heating fuels have increased in importance at a rapid rate, both relatively and absolutely. Consumption of liquefied gases has grown at such a high rate that their average annual rate of increase was of the order of 30% p.a., although this figure is not reliable because consumption during the early years of the period was guessed and because all consumption of these fuels is included within this sector whereas a significant but unknown proportion is undoubtedly used for industrial purposes. The consumption of all liquid fuels together has grown at about 7% p.a. and these fuels have increased their share of the market substantially over the eight years spanning the centre years of the two five-year averages.

Townsgas consumption has remained steady but its relative importance has declined. Electricity has shown rapid and continuous growth and by the later years of the period was supplying nearly one-fifth of all the energy effectively used by the sector. Turf of the non-commercial variety has declined in importance considerably.

It seems likely that all commercial types of energy except townsgas (i.e. kerosine, bottled gas, electricity and coal) have shared between them the loss suffered by hand-won turf. Further, the commercial solid fuels have probably suffered from penetration by oil and by electricity, there being no resultant net change in these fuels' share because the decrease has been balanced by the increases just mentioned. Within the solid fuels, coal has undoubtedly lost some ground to turf; in the early 1950's machine turf sales increased quite rapidly through increasing household use and use by local authorities, and latterly sales of turf briquettes have grown strongly. Within the liquid fuels, the use of burning oil has tended to decline but this has been more than compensated for by the growing use of heavier oils for central heating and that of bottled gas for cooking in rural and even in some urban areas. For each of these fuels details of consumption are given in Table 36 appended.

TABLE 39: EFFECTIVE ENERGY CONSUMPTION BY TYPE OF ENERGY

Type of Energy	Average annual consumption				% p.a. increase
	1950 to 1954 inclusive		1958 to 1962 inclusive		
	10^{12} Btu[1]	%	10^{12} Btu[1]	%	
Coal and coke	7·5	45	7·5	37	0
Machine turf	0·3	2	1·0	5	+15·9
Turf briquettes	0·2	1	0·6	3	+18·4
Solid fuel	8·0	48	9·1	45	+ 1·7
Burning oil	1·4	8	1·5	7	+ 0·5
Gas/diesel and fuel oils	1·0	6	2·2	11	+11·5
Liquefied gases	negligible	0	0·4	2	—
Liquid fuel	2·4	14	4·1	20	+ 6·9
Townsgas	1·4	9	1·4	7	+ 0·3
Electricity	1·9	11	3·6	18	+ 8·5
Hand-won turf	2·9	18	2·0	10	− 4·4
Total	16·6	100	20·2	100	+ 2·5

Note: [1]See Table 40 for details of conversion factors and weightings.

TABLE 40: ENERGY CONSUMPTION OF OTHER SECTORS; 1950 TO 1963

Category	Unit	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Commercial Energy Consumption:															
—coal, coke and anthracite[1]	th.tons	875	1,181	769	770	986	1,000	1,030	777	801	759	957	1,022	1,007	n.a.
—machine turf[1,2]	th.tons	74	30	5	108	175	180	204	200	277	231	267	251	254	n.a.
—turf briquettes[2]	th.tons	24	21	22	38	39	37	49	32	37	35	88	156	228	303
Total solid fuel	10^{12} Btu	25·3	33·0	21·5	23·2	30·0	30·4	31·8	24·5	26·3	24·5	31·4	34·2	35·2	n.a.
—burning oil	mil.gals.	14·3	15·8	15·6	15·6	16·8	16·8	16·7	15·1	17·2	16·9	16·6	15·5	15·8	15·7
—gas/diesel and fuel oils[1]	mil.gals.	13·8	16·5	6·8	9·5	3·6	16·6	27·5	32·4	21·6	17·3	25·0	25·4	28·7	n.a.
—liquefied gases	th.tons	1	1	2	2	2	2	4	6	10	13	15	16	17	18
Total liquid fuel	10^{12} Btu	4·3	5·0	3·5	3·8	3·4	5·3	7·0	7·6	6·4	5·8	7·1	7·0	7·6	n.a.
—townsgas[1]	mil. therms	21·9	24·7	23·3	23·6	24·3	24·3	23·9	23·3	23·4	23·3	24·8	24·0	25·5	n.a.
	10^{12} Btu	2·2	2·5	2·3	2·4	2·4	2·4	2·4	2·3	2·3	2·3	2·5	2·4	2·6	n.a.
—electricity[1]	mil.KWh	483	558	608	644	741	809	897	921	1,013	1,057	1,168	1,242	1,331	n.a.
	10^{12} Btu	1·6	1·9	2·1	2·2	2·5	2·8	3·1	3·1	3·5	3·6	4·0	4·2	4·5	n.a.
Total commercial energy	10^{12} Btu	33·4	42·4	29·4	31·6	38·3	40·9	44·3	37·5	38·5	36·2	45·0	47·8	49·9	n.a.
Non-commercial Fuel: —hand-won turf	th.tons	2,848	3,361	3,221	3,132	2,072	2,647	2,495	2,217	1,622	2,243	2,551	1,832	1,835	n.a.
	10^{12} Btu	28·5	33·6	32·2	31·3	20·7	26·5	25·0	22·2	16·2	22·4	25·5	18·3	18·4	n.a.
Total Energy Consumption[3]	10^{12} Btu	61·9	76·0	61·6	62·9	59·0	67·4	49·3	59·7	54·7	58·6	70·5	66·1	68·3	n.a.
Total effective energy consumption[4]	10^{12} Btu	15·8	19·5	15·0	15·8	16·8	18·9	20·5	18·3	17·9	17·7	21·3	21·5	22·6	n.a.
	1953=100	100	123	95	100	106	120	130	116	113	112	135	136	143	n.a.
Personal expenditure at constant (1953) market prices[5]	1953=100	101	101	97	100	102	107	104	102	104	106	112	117	121	

n.a. indicates not available

Notes: [1]These consumption estimates were obtained by subtracting from total consumption of these fuels the quantities known to have been consumed by (or delivered to) the other main sectors of consumption.

[2]Total sales of briquettes are shown here, although in fact some briquettes (perhaps 10% in 1962 and 1963) were used by industry: Machine turf consumptions are correspondingly too low because the total tonnages of turf used by Industry and Services have been subtracted from them.

[3]The following conversion factors were used: coal, coke and anthracite: 27·3 m.Btu/ton; machine turf: 13·4 m.Btu/ton; turf briquettes: 19·0 m.Btu/ton; burning oil: 149 th.Btu/gal.; gas/diesel and fuel oils: 158 th.Btu/gal.; liquefied gases: 43·7 m.Btu/ton; electricity: 3,412 Btu/KWh; hand-won turf: 10 m.Btu/ton.

[4]The following weightings, or relative efficiencies were used: Solid fuels: ·30; liquid fuels and townsgas: ·60; electricity: ·90; hand-won turf: ·15.

[5]Source of data: National Income and Expenditure, 1962, published by the Central Statistics Office.

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. towns gas.

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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- 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 Co-operation
AER	Americal Economic Review
QJE	Quarterly Journal of Economics
EJ	Economic Journal
UNIPEDE	Union of Producers and Distributors of Electricity
ECE	United Nations: Economic Commission for Europe
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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