THE ELECTRICITY SUPPLY BOARD.

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Introductory.

Within recent years the supply of electricity has moved into a position of a definite importance in our everyday activities. There are many reasons for this, but chief amongst them is its great adaptability for use as a service in industry, and as an agent which in many ways supplants manual labour, directly and indirectly. The world is constantly seeking labour-saving devices, and in electricity has found the most promising potentialities towards this objective. The gradual improvement in the standard of living in the twentieth century has carried with it increasing demands for comfort and convenience. In consequence, the demand for electricity has tended to exceed supply, and the evidence of this is now almost universal. Under normal conditions this situation might not have developed, but war has had the effect of slowing down the delivery of electrical plant, and at the same time, by reason of labour scarcity, of pressing forward the demand for electricity. The service, although so apparently simple, has an exceedingly complex background.

There are some well-known characteristics about the business. In the first place the service provided involves an unusually high rate of usage of capital assets and the consequent continuous and increasing investment of large blocks of capital. Secondly, it is a business of markedly increasing returns and has expanded, on a long-term basis, more rapidly than any other industry. There is every evidence of a continuous and persistent demand, and a possible saturation point has not yet been seriously considered. Thirdly, there are serious fluctuations in the demand over the twenty-four hours of the day, and with the seasons of the year. The peak demand rises sharply during short daylight hours of winter and the maximum peak, to meet which the available plant must be adequate, may last only a few minutes. Fourthly, electricity has the unique disadvantage that it cannot be stored.

Growth of Electricity Production.

A study of the rate of output over a period for a number of countries indicates that, in any one country, there is a consistency in the rate of growth. Otherwise there is no direct parallel between any two countries except that where there is a high degree of industrialisation the pattern tends to be somewhat uniform. In the following Tables I and II the figures of production and the consumption per head of population, respectively, are shown. Sometimes the consumption per head is regarded as an index of the progress of a country, but this is not necessarily the case. Norway, Sweden and Switzerland, which head the table, had large resources in water power, and little fuel, so that hydro-electric developments were undertaken on a substantial scale at a very early date. The low costs of production stimulated consumption. The U.S.A., by reason of the expansion in the industrial demand, has now moved into the second place. From Table II it is apparent that, not only is the production per head steadily increasing but, taking into account the large difference between the "highly" developed and the "under" developed countries, there is no indication that any of the countries shown are near the point of saturation.

The rate of growth draws particular attention to the relatively short period within which demand doubles. In ordinary industry a doubling of the turnover, which normally cannot be effected in a short period, will usually necessitate additional machinery, and possibly extra accommodation, without any serious change in the capital structure. With electricity, as the demand grows, direct and continuous capital investment is automatically drawn in. Some study

TABLE I

Production of Electricity KWh $\times 10^6$

Year	1920	1925	1930	1935	1940	1945	1950
Denmark ..	206	365	585	884	873	980	2,174
Great Britain	4,150	7,025	11,100	18,150	29,202	37,532	53,657
Holland ..	785	1,385	1,480	2,885	3,624	7,740	7,305
Ireland ..	—	—	100	206	407	406	785
Spain ..	932	1,585	2,560	3,265	3,617	4,236	7,265
Sweden ..	2,715	3,910	5,260	7,180	8,624	13,527	18,270
U.S.A. ..	40,800	64,500	94,200	99,200	180,000	272,000	395,000
Northern Ireland ..	—	—	—	—	—	—	738
Norway ..	—	—	—	6,660	8,975	10,140	17,675
France ..	3,055	10,360	15,280	15,750	18,833	18,074	33,130
Switzerland ..	2,835	3,720	5,140	6,015	8,050	9,600	10,479

TABLE II

Production per Head of Population KWh

Year	1920	1925	1930	1935	1940	1945	1950
Denmark ..	47	83	133	200	198	222	438
Gt. Britain ..	—	150	240	400	600	760	1,110
Holland ..	75	130	205	225	285	130	716
Ireland ..	—	—	—	18	137	136	262
Spain ..	45	75	113	135	140	160	274
Sweden ..	—	630	830	1,100	1,450	1,850	2,500
U.S.A. ..	—	—	990	1,000	1,400	2,060	2,700
Northern Ireland ..	—	—	—	—	—	—	543
Norway ..	—	—	—	—	3,040	3,295	5,760
France ..	—	280	405	420	450	500	795
Switzerland ..	740	950	1,250	1,400	1,905	2,180	2,072

has, therefore, been made of what is known as the redoubling period. This indicates that the period is reasonably constant for a particular country over a long number of years except when affected by unusual world or internal conditions. Even in those countries where the production of electricity is very high the trend in consumption does not show any diminution, and no evidence appears of any stage of saturation.

Figure 1 shows the growth of electricity for a number of selected countries. These were chosen so that it would be possible to observe any similarity between growth of production in countries where the annual production was compatible with or greatly divergent from the production in this country. On this graph lines equally inclined to the base represent equal redoubling periods. The curve for Denmark, for example, indicates that production doubled in a period of eight years over a reasonably long period. An examination of the curves shows in all cases that the redoubling period is reasonably constant for a particular country except when affected by abnormal conditions. In this country, for the years from 1930 to 1940, the redoubling period was 5.75 years, increasing to 5.5 years from 1944 to date. In the case of the U.S.A. the growth of production indicates a normal redoubling period of six to seven years broken seriously only by the slump of 1929-1933 and post-war conditions in 1944-1946. It seems to be reasonable to assume that the trend of production will continue for each country for a considerable time, and although this may be halted by world economic conditions the evidence shows that unstable periods will again be succeeded by reasonably constant redoubling periods.

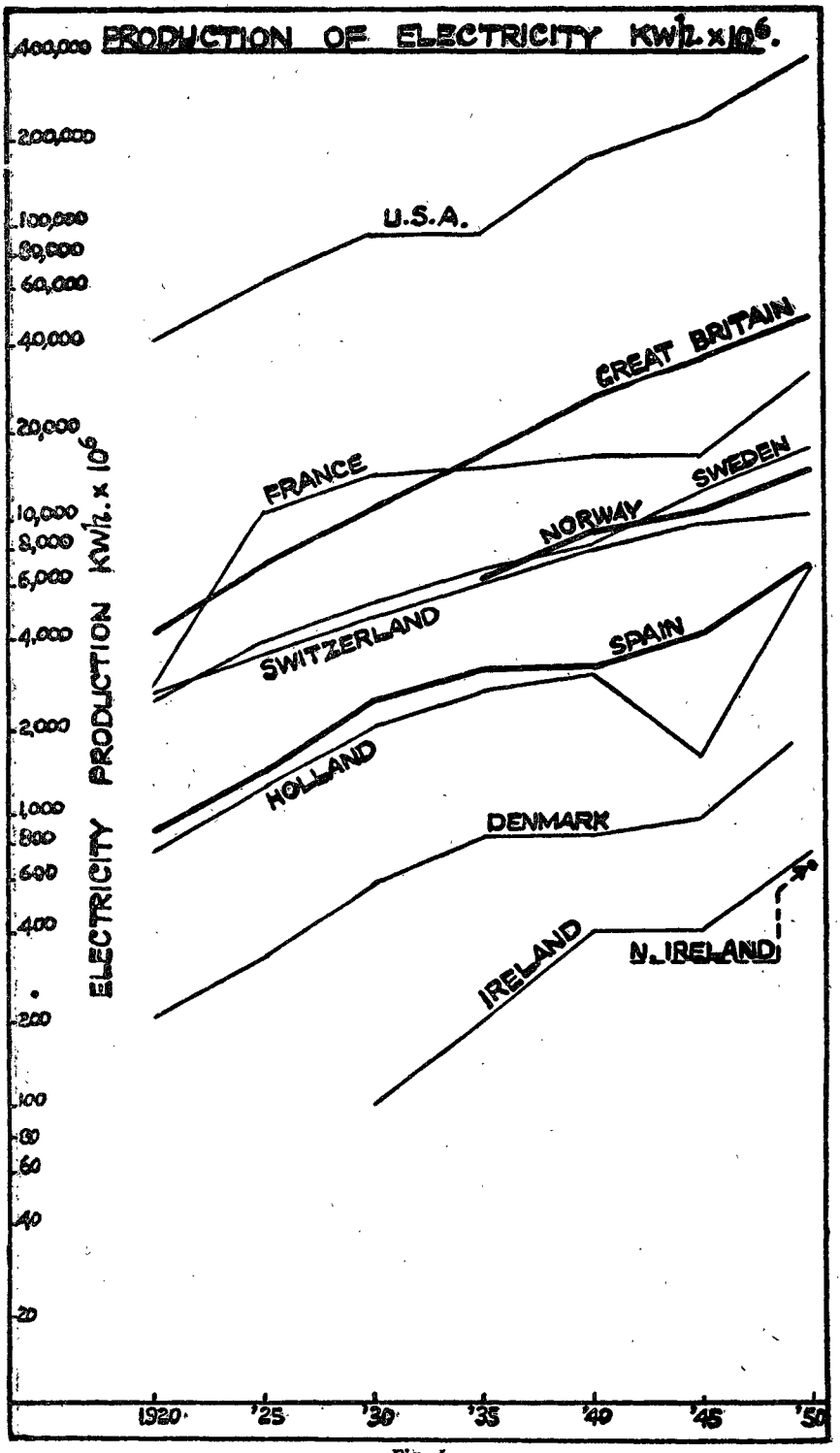
PRODUCTION OF ELECTRICITY KWh. x 10⁶.
ELECTRICITY PRODUCTION KWh. x 10⁶
400,000
200,000
100,000
80,000
60,000
40,000
20,000
10,000
8,000
6,000
4,000
2,000
1,000
800
600
400
200
100
80
60
40
20
U.S.A.
GREAT BRITAIN
FRANCE
SWEDEN
NORWAY
SWITZERLAND
SPAIN
HOLLAND
DENMARK
IRELAND
N. IRELAND
1920
'25
'30
'35
'40
'45
'50

Fig. I

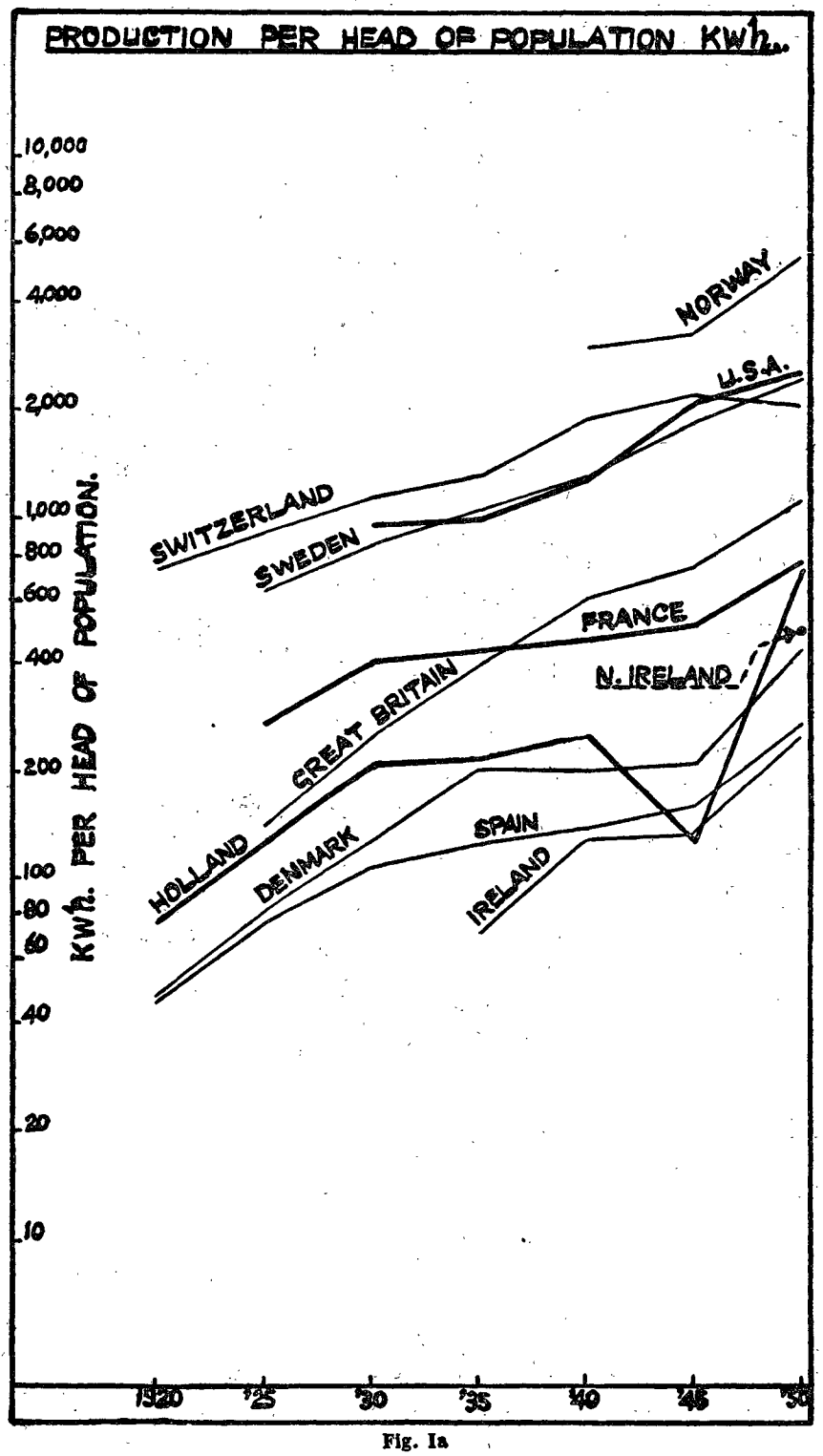
PRODUCTION PER HEAD OF POPULATION KWh.
10,000
8,000
6,000
4,000
2,000
1,000
800
600
400
200
100
80
60
40
20
10
KWh. PER HEAD OF POPULATION.
NORWAY
U.S.A.
SWITZERLAND
SWEDEN
FRANCE
N. IRELAND
GREAT BRITAIN
HOLLAND
DENMARK
SPAIN
IRELAND
1920
'25
'30
'35
'40
'45
'50

Fig. Ia

Growth of Consumption.

Since the establishment of the Electricity Supply Board, some twenty years ago, the consumption of electricity has doubled broadly in each period of five years. During the war, when fuel was scarce, and there was difficulty in securing plant, the output had, of necessity, to be curtailed, and no increase took place. In view of the relatively low consumption per head at the outset this was not unexpected, and the present programme provides for a doubling in five to six years. Much may depend on the rate of expansion of industrial activity because as yet the industrial load is only one-third of the total. In other countries it is rarely less than 50 per cent., and in a country such as Belgium, is over 80 per cent. The marked change which has taken place is in the domestic demand. It will be observed that the percentage has increased from 25 in 1936 to 43 in 1951. Apart from the effects of the difficulty of domestic help, the demand has been strongly stimulated by the scarcity and cost of other fuels, but undoubtedly the greater part of the increase has been drawn by better living standards. The following table shows the pattern of the load at intervals of five years:—

Year	Analysis of units ($\times 10^6$ sold for the year ended 31st March)					
	Motive Power	Domestic	General Lighting	General Heating Cooking and Water Heating	Miscellaneous	Total
1931 ..	29	16	17	10	14	86
1936 ..	62(34%)	47(25%)	24	20	33*	186
1941 ..	139	113	30	35	29	346
1946 ..	50	141	28	40	20	379
1951 ..	257(33%	327(43%)	57	99	31	771

*Includes traction, $\times 10^6$ units, which has now almost disappeared.

Capital Requirements.

The growth in demand carries with it an expenditure in capital, which although not proportionate, is at an exceptionally high rate. The relationship between demand and capital depends largely on the price structure in the sense that the price may be an incentive leading to longer hour use of the existing capital. Tariffs are, therefore, devised to provide for a rapidly declining price with increasing consumption. The revenue from sales will grow at a slower rate than the demand, and the capital requirements have a clearer relationship with the revenue. Broadly, revenue may be measured at from 14 to 20 per cent. of the capital. This range of percentages has tended to drop somewhat. The lower percentage applied to a hydro-electric system by reason of the initial heavy capital costs; a steam station required the higher percentage because of the incidence of the outlay on fuel. Capital investment of the order of from five to six times the increase in the growth of revenue is consequently being absorbed continuously. It can readily be appreciated that the financial structure of the electricity supply industry will, in a relatively short time, begin to tower well above all others.

Plant requirements are usually divided into the three categories of generation, transmission and distribution. Additions to the generating capacity take place annually, and must be planned well in advance because from the date of the placing of the order until the set is finally in commission requires from three to five years. The transmission system, and all its ancillaries, must be constantly strengthened as the load grows. In this country transmission is relatively costly because the natural resources of water and peat are remote from the load centres. The distribution expenditure follows the number of consumers, and also changes in the nature of the load taken. When the River Shannon was harnessed the order of the investment raised some doubts whether it would be remunerative. Time has shown that it was an advantageous investment. Since then the capital expenditure has grown rapidly, and is shown in the following table in £000's under the main headings of generation, transmission and distribution :—

Year ended 31st March	Generation	Transmission	Distribution	General	Total
1931 ..	4,412	2,149	1,544	410	8,515
1936 ..	5,481	2,338	3,102	503	11,424
1941 ..	7,049	3,466	4,569	666	15,750
1946 ..	7,826	3,846	5,205	710	17,587
1951 ..	16,777	5,824	13,040	1,605	37,246

The expansion in generating capacity is marked by the number and variety of the stations.

Original stations	Ardnacrusha	Hydro	60 MW
	Pigeon House.. ..	Coal	21 MW
	Cork	Coal	5 MW
Stations now in commission	Ardnacrusha	Hydro	85 MW
	Pigeon House.. ..	Coal	95 MW
	Cork	Coal	5 MW
	Liffey...	Hydro	38 MW
	North Wall	Oil	12½MW
	Portarlington ..	Turf	25 MW
	Erne	Hydro	55 MW
	Allenwood	Turf	40 MW
Stations under erection	Ringsend	Coal or Oil	90 MW
	Cork	Hydro	60 MW
	Lee	Turf	27 MW
	Boora (Ferbane) ..	Oil	40 MW
	North Wall		25 MW
Stations for which plans are being prepared	Bangor Erris	Turf	40 MW
	Avonmore	Hydro	20 MW
	Clady	Hydro	3½MW
	Cummeragh	Hydro	6 MW

The investigation and implementation of a continuous programme of capital investment of necessity entails a considerable amount of work. Careful studies must be made of the economy of all proposals, of the

selection and suitability of plant and materials, and it is essential to keep abreast with modern practice throughout the world. Much of this work is, in practice, handed over to consultants. The Electricity Supply Board, at the outset, decided to build up its own engineering departments for the planning and execution of capital works. In consequence a trained staff exists to whom ample opportunities are afforded to visit the installations and plants in various countries to ensure that developments here are on the most modern lines. Consultants are engaged only for the purpose of an opinion on a specific problem. The River Erne hydro-electric scheme, which is of a major nature, has been planned and designed by the Board's engineering departments. The Board's own staff has also planned the steam stations at Portarlington, Allenwood, Ringsend, Cork and Ferbane, as well as the hydro development of the River Lee.

The trend of development in capital, revenue, revenue as a percentage of capital, output and number of consumers, is shown in the following table. Revenue as a percentage of capital lacks uniformity for a number of reasons. In the earliest years the returns from the Shannon Scheme had not fully accrued. By the year 1941 the percentage had been growing slowly towards a normal. By 1946 arrears of capital had already accumulated owing to the war, and the incidence of new capital is being shown at the end of the table. The greater proportion of steam plant on the system will now involve an increasing percentage return.

Year ended 31st March	Capital in £ × 10⁶	Revenue in £ × 10⁶	Revenue as % of capital	Output in units × 10⁹	Number of consumers
1931 ..	8·5	0·7	8.5	120	69,000
1936 ..	11·4	1·4	12·3	244	117,000
1941 ..	15·7	2·1	13·4	436	184,000
1946 ..	17·6	3·1	17·7	484	237,000
1951 ..	37·2	5·5	14·8	973	343,000

In Figure 2 capital, revenue, demand and price per unit have been shown in the form of a graph. The marked feature is that demand follows closely the curve for capital. The steep incline in the latter curve in recent years has resulted from the increased cost of plant, which is some three to four times higher than before the war.

Tariff Structure.

Engineers in the industry have always made every effort towards the maximum utilisation of the plant throughout the year. The occurrence of the peak loads, which indicate the total capacity of the plant required, has been a strong incentive towards filling in the demands at other times so that the load factor could be raised as high as possible. Subject, therefore, to avoidance of an increase in the peak demand, the sale of energy at other times showed high returns, and every incentive has been used to attract consumption at such

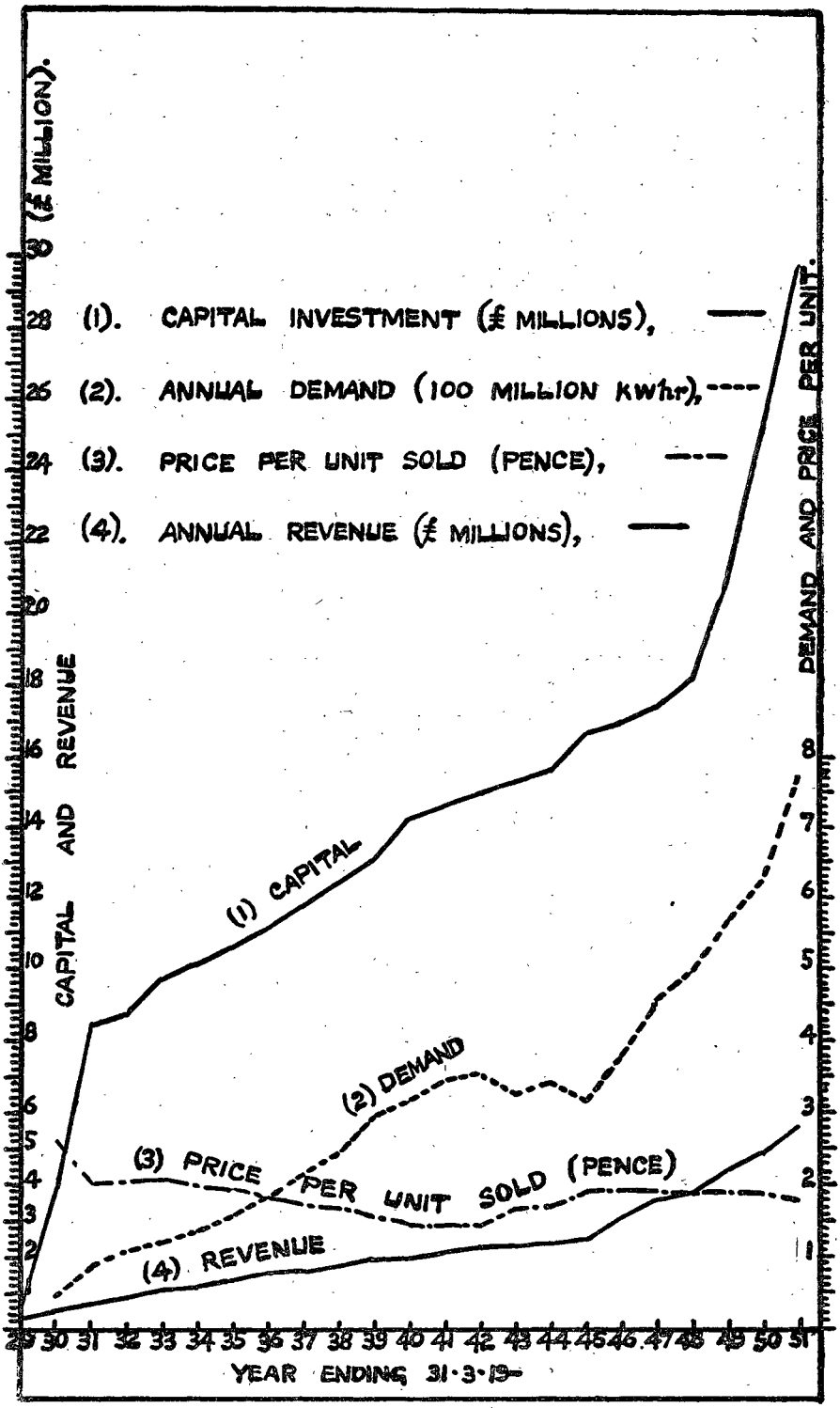
(£ MILLION).
DEMAND AND PRICE PER UNIT.
CAPITAL AND REVENUE
(1). CAPITAL INVESTMENT (£ MILLIONS),
(2). ANNUAL DEMAND (100 MILLION KWhr),
(3). PRICE PER UNIT SOLD (PENCE),
(4). ANNUAL REVENUE (£ MILLIONS),
(1) CAPITAL
(2) DEMAND
(3) PRICE PER UNIT SOLD (PENCE)
(4) REVENUE
YEAR ENDING 31·3·19-

Fig. 2

times. Tariffs had, therefore, two purposes in view. The first was to meet the costs of supply in accordance with the type of the demand, and the second was to create new demands through the attraction of apparently low prices. There is still much difference of opinion as to the correct method of striking prices amongst the various categories of consumption. Broadly, there is the division of costs into (a) energy, (b) capacity and (c) consumer and general. In the case of industries, where there is a heavy demand on capacity, it is usual to have a tariff which charges for the maximum demand on capacity with an added scale for energy costs. Lighting prices have regard to the limited hours of usage, to the emphasis on peak hours, and are, therefore, relatively high. Low tariffs can generally be offered for off-peak requirements, and where there are long hours of usage at a steady load. The structure of tariffs means, in effect, that one element repays the undertaker for costs, more or less fixed, irrespective of the kilowatt hours used, such as capital charges, operation, management, etc., and another element recoups for costs dependent on consumption, e.g., fuel costs. The basis of price for the domestic consumer is a fixed minimum charge with a declining price for the current supplied. The fixed charge ensures that if a consumer has a very low consumption no liability on his account is thrown on to other consumers. The decreasing unit price is the incentive towards increased consumption. Fig 3 shows typical daily load curves.

Prices and Cost of Plant.

Prices for electricity have not followed the change in the general price-level, but have lagged considerably behind. There are two reasons for this. The first is the effect of increasing returns, and the second the continuing availability of plant purchased at a lower level. It is the case, however, that most of the materials used in the supply industry, such as copper, steel, aluminium, rubber, etc., have risen in cost much above the general price-level, and in consequence plant may be three to four times the pre-war figure. Owing to the amount of new plant being brought into commission at this high level it would seem that the price of electricity must be affected. Much will depend on the extent to which increasing returns can neutralise the effect of this high-priced capital. The following figures illustrate the measure of the changes in price of plant which have taken place:—

	Generating plant	*Transformers*	*Transmission per km. of line*
1939	£20 per KW.	£160	£120
1951	£60 „	£770	£310

The supply undertaker in early days was most frequently the municipal authority which, then, could readily find the initial capital necessary. The area was confined, involving little transmission outlay, and gradual additions to distribution, but with a heavy emphasis on capital required for generation. In consequence, a tendency developed to work the generating plant to a maximum and to defer additions. An element of risk was thus introduced which may then have been justified, but which, to the present time, has still somewhat persisted in the industry. By reason of the essential nature of the service,

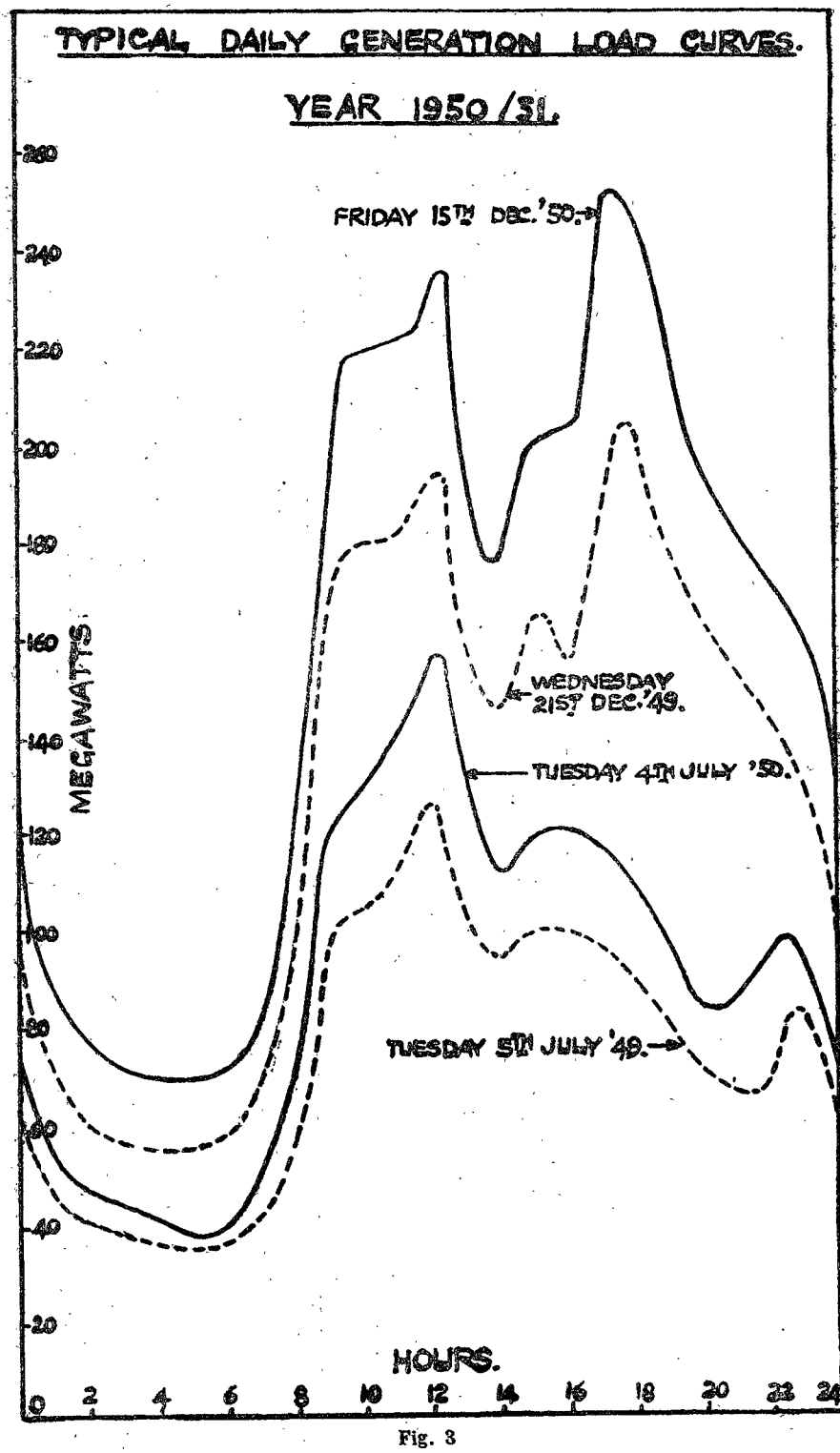
TYPICAL DAILY GENERATION LOAD CURVES.
YEAR 1950/51.
FRIDAY 15TH DEC.'50.
WEDNESDAY 21ST DEC.'49.
TUESDAY 4TH JULY '50.
TUESDAY 5TH JULY '49.
MEGAWATTS.
HOURS.
260
240
220
200
180
160
140
120
100
80
60
40
20
0
2
4
6
8
10
12
14
16
18
20
22
24

Fig. 3

which must meet the demand at all times, day or night, it is probable that a larger element of stand-by generating plant should always be available so that the margin for working would be ample. This provision would affect the price of electricity slightly, but would tend to remove the difficulties of supply which are common to almost all countries from time to time.

There are two further factors which have recently received much prominence, and are not unconnected with the price of electricity. The first is the incidence of the accruing future capital expenditure in the sense that such investments are called for in steps and in large blocks as the existing system becomes fully loaded. A full return on this expenditure cannot be expected for some years, and the point has been raised whether the existing consumer should not contribute in some way in advance for these costs. The second point is the evidence of a certain rigidity in distribution costs, notwithstanding an expansion in consumption. The maintenance of the level of distribution costs is largely attributable to the connection in increasing numbers year by year of the smaller premises with correspondingly lower sales, and to the gradual development into the more sparsely populated areas.

Diversity Factor.

It is a fortunate circumstance that the use of equipment and appliances in the hands of consumers is spread. If all these appliances were utilised at the same time the system of supply would require to be very much larger than it is in fact, and from long experience is found that, at any one time, the demand from equipment is only a fraction of the loading of the total equipment. This is known as the diversity factor. It is strange that in this country there has been one radical departure from this experience. This occurred recently in the case of the heating demand, and was undoubtedly brought about abruptly by the scarcity and cost of other fuels. At the beginning of last year the load was running at a figure 40 per cent. higher than in the previous year. This resulted from a very high proportion of electric radiators being connected to the system at the same time during the cold weather. A rate of growth of these dimensions had, of necessity, to be curtailed because if this continued a doubling of the capacity would be called for within about three years. This has happened also in Great Britain, but not in other countries where the low temperatures of winter are met by systems of central heating.

Cost of Production.

The Electricity Supply Board has not, as yet, published figures of the costs of production at the various generating stations. Until recently more than one-half of the output has been from hydro, and the demands on the steam stations have not been sufficiently sustained and continuous to throw out figures which are reasonably comparable. With the growth of the load, and the consequent long-term running of the steam stations, it is anticipated that the production costs will be published, as a matter of course, in the near future.

Finance.

What are the most suitable arrangements for the financing of the continuous absorption of capital for electricity supply? The original

practice had much to commend it, and was relatively simple, but conditions were then also simple. The undertaker, usually the municipal authority, raised a loan for the purchase of the plant and the term of the loan was determined by the life of the asset. On renewal there was further borrowing. Interest and sinking fund were duly paid, and normally provision existed for the creation of a renewals fund not exceeding 20 per cent. of the capital. Private power companies, which came into existence later, worked on the basis of ordinary industrial financing, and set aside in a depreciation fund sums intended to be adequate to meet the cost of renewals. In recent years the State organisation has been created to absorb other undertakings, and the method of finance, although varying slightly, follows a fairly consistent pattern. Moneys are borrowed, as and when necessary for development, for redemption in a term broadly covering an average life-time of the assets. There is usually provision for a limited renewals fund.

In this country the proposals for the Shannon Scheme originally came forward from the firm of Siemens-Schuckert, in Germany, and in these the method of financing was clearly set out. The proposals were the amortisation of the capital, together with the creation of a complete renewals fund, in the life-time of the assets. In effect, this meant that the consumer would, in a given period, pay broadly double the value of his usage of the assets. The origin of this suggestion probably rested on the custom in Germany, where an undertaker obtained a concession for forty years, at the end of which time he was under a possible obligation to surrender his undertaking in first-class running order. It was therefore necessary for him to recover his capital within this period and to hand over the undertaking with a complete renewals fund. The Government, in the first instance, pressed this system of finance on the Electricity Supply Board. Ultimately a solution was reached on the basis of the Board's setting up a depreciation fund and, in addition, repaying capital advances over a period of fifty years. This latter provision the Board has regarded as in the essence of a contribution towards obsolescence.

There is, as you are aware, much controversy about the inadequacy of provision for depreciation on a cost basis, having regard to the upward movement in the price level. From a pure accountancy viewpoint the problem still remains unsolved except to the extent of recommendations that the depreciation fund should be reinforced by general transfers of such sums as may be reasonably available. In the case of the electricity supply industry, where the provision for depreciation, by reason of the rapid inflow of capital, is continuously increasing, the problem may not be of the same urgency as in industry generally. The question which arises is the ability to finance renewals out of the fund. This will usually be feasible, and will be rendered more likely by the tendency, in the face of high prices, to maintain the assets beyond their scheduled lives.

The majority of State electricity undertakings are on the lines of a statutory corporation, and usually enjoy their own borrowing powers. These are invariably supported by State guarantee. In this country borrowing powers have not been granted under the Electricity (Supply) Act, 1927, to the Electricity Supply Board. Advances are made by the Minister for Finance out of the Central Fund to meet the necessary capital expenditure. There is a provision in the Act for the issue of securities to provide these advances, but so far no

issue has been made. On the basis of estimates submitted by the Board legislative cover is obtained every three or four years for the amount required in a Bill promoted in the Oireachtas for the purpose. The actual cash advances to be made in any year are based on a simple budget submitted to the Government in January showing the requirements for the year commencing on the ensuing 1st April. The rates of interest attaching to the advances are, broadly, the prevailing market rates with a small addition. The rate for any advance continues over the term of fifty years, and the advance is repaid under the form of an annuity covering both interest and sinking fund. The rates vary from 5 per cent. down to 2½ per cent.

The moneys allocated to the depreciation and other funds are utilised by the Board towards meeting capital expenditure. As a result advances from the Minister for Finance are deferred, and in effect this means the investment, for the time being, of the funds with the Government. The Board, under special statutory authority, may borrow the funds accumulating under the Superannuation Schemes and, in fact, does so.

Sources of Power.

The sources from which power is generated here are water, peat, coal and oil. Hydro developments, at present, are the cheapest form of power, and in every country there is concentration on extracting as much as possible from water. It has the merit of being somewhat impervious to external conditions, and perhaps is subject only to the vagaries of the weather. This country has so weathered down that the rivers are flat, and there is no substantial fall for power purposes. Moreover, the saucer-like formation of the central plains renders drainage difficult. The potentialities for hydro-electric development are, therefore, limited.

Water Power.

The River Shannon was the largest river in this country with the greatest catchment area for rainfall, and was in the first instance, harnessed. The output, in an average year, is 300×10^6 KWh., and the cost of production, in terms of existing prices, is relatively low. The second river to be developed was the Liffey. This is a short river of seventy-five miles, with a limited catchment area, but it was possible in the reservoir, artificially created above the dam, to contain one-half of the total flow in the year. Consequently, this scheme, although producing only some 50×10^6 KWh. is very elastic in its possible operation, and is particularly suitable for dealing with peak loads. The cost of production is low compared with fuel costs, although not so low as on the Shannon, which had been built so many years earlier.

The third hydro-electric development is that on the River Erne. This has not yet been completed although it is partly in commission. The falls occur within a distance of five miles upstream from Ballyshannon, and two stations have been erected in this stretch of river. The potential output is about 230×10^6 KWh., but the full utilisation is dependent on the carrying out of certain works in Northern Ireland to allow of water regulation. Arrangements have been made for the execution of these works. The fourth scheme, which is about to commence, is on the River Lee, and the output will be about 40×10^6 KWh.

These four developments absorb some 70 per cent. of the water potential of the country. Broadly, the remainder of the water power is to be found in a large number of small rivers which will gradually be harnessed. The larger of these rivers, with the estimated output in brackets in KWh $\times 10^6$, and which it is probable will be developed within the next ten years, are:—Barrow (50), Boyne (41), Avonmore (40), Nore (30), Flesk (20), Ballysodare (20), Cummeragh (15), Torc (12), Clady (3·5).

Turf.

The first survey of bog-lands of Ireland was made by Commissioners appointed in 1811, and their report indicated that there were 1½ million acres of lowland bog, and it was estimated there was a similar area of mountain bog. Subsequent surveys were made, but the figures of 1811 are still regarded as the best estimates of the reserves of bog. Recently much attention has been drawn to the desirability of using this native fuel as far as possible for the generation of electricity. The bogs suitable for this purpose have been surveyed by Bord na Móna, and it is probable that some seven or eight generating stations can ultimately be built. The two stations already in commission are fuelled by peat in the form of machine-cut sods. This form of production involves extensive preliminary drainage of the bog, and later a good deal of manual labour. Owing to the scarcity of labour some more mechanised form of production has been the subject of investigation. It has now been decided in the new bogs to win peat in milled form, a process which involves much less drainage, and which can be largely mechanised. Two generating stations are being erected to burn milled peat. Peat when originally cut has a moisture content of 90 per cent., and in sod form requires to be dried naturally down to 30 per cent. for generation purposes. It cannot be burned efficiently if the content of moisture is above 45 per cent. In the case of milled peat the moisture content at which it is expected reasonable combustion will be possible is about 55 per cent. The general uncertainty which must accompany imports, such as coal and oil, in times of war or emergency, renders all the more desirable stations which can be fuelled from native resources.

Coal.

The Arigna, Leinster and Tipperary coalfields are regarded as the three workable areas from which coal can be extracted. The Arigna area contains semi-bituminous coal and could be expected to yield about 4,000,000 tons of good quality coal. Present production is at the rate of 80,000 tons per annum. The Leinster coalfield contains anthracite of good quality and has reserves estimated at about 7,000,000 tons. The workable anthracite in Tipperary (Slieveardagh) is about 5,000,000 tons. The Leinster and Tipperary coalfields produce about 50,000 tons of coal and a somewhat similar quantity of duff. The total output of coal for the year 1950 was 169,000 tons, and for the year 1951 is understood to have increased by 10,000-15,000 tons. The whole of this output is readily absorbed on the general market but the Board takes annually 10,000 tons from Arigna. The question of erecting a generating station on any of the coalfields has not been considered in any detail by reason of the demand otherwise

for the present production. A station on the site of any of the coal fields would, of necessity, be small.

Wind Power.

The possibilities of wind power are being explored, but whether these will ever be developed on a large scale is doubtful. A number of wind-measuring instruments have been erected along the west coast, particularly in Donegal. These regions are known to have high winds, and in addition to this the features of the land are of special importance. For instance, a height with concave slopes appears to lend itself particularly to a continuous wind. It will be some little time before the results of the present experiments can be measured.

Tidal Power.

Much has been written about the possibility of utilising the tides to generate power, and all over the world there are sites quite suitable to the purpose. The reason why nothing has yet been done is the prohibitive cost of underwater works, such as a dam, in the sea, especially where there is a wide limit in the rise and fall. The capital costs would be too heavy to permit electricity to be generated at a reasonable cost.

Rural Electrification.

During the war, when this country was forced to thoughts of relying on itself, the desirability of rural electrification came into prominence. A comprehensive report was made on the complete electrification of the country. This contemplated the erection of some 60,000 miles of line, with the possible connection of 280,000 consumers. In an endeavour to make such a scheme economic, because of the difficulties of extensive networks to supply scattered farms and houses, it was proposed that a capital subsidy of 50 per cent. should be granted. There was a precedent for such a method in many other countries, notably Canada. The Government agreed to this subsidy as a broad measure of what was required to make the scheme economic, and this was subject to review at the end of five years. Generally, owing to the increasing costs of materials since the work was started, the subsidy would now seem to be inadequate, but it will not be possible to measure this sufficiently accurately pending a period of further development.

The scheme applied to the rural community in the strictest sense in that it covered all farms, dwellings and cottages outside the towns. The circumstances involved, in effect, individual extension of supply, because rarely were houses clustered together. In this way the conditions differed from the Continent of Europe, where houses tended to be grouped, possibly for their better protection in years gone by. The work started on the basis of the division of the country into ten large areas, and the development of zones within these areas in the order of their financial returns. As the scheme develops the areas will gradually become less remunerative until the very thinly populated, or poor areas, are reached. In the process of time the returns of the Board's undertaking generally should be adequate to carry any financial burden arising from the rural development. The unit of zone is usually an area of twenty-five square miles. About one-quarter of the work has now been completed.

When the scheme was started it was felt that development in the use of electricity by rural consumers would be slow, but that in time expansion would take place as in other countries. Lighting would be the main inducement to take supply. The progress so far made indicates a growing tendency on the part of the domestic rural consumers to purchase gradually various appliances.

To entice the farmer proper to realise what advantages he could gain from a liberal use of electricity has involved considerable propaganda work. A first impression was made by widely publicising a fractional h.p. motor fitted with a special reduction gear capable of giving a large variety of speeds. This motor in effect could drive any machine formerly operated by hand, and the uses included churning, separating, tool-grinding, turnip pulping, sack-hoisting, forge blowing and various other activities. Further progress was made by the introduction of a 3 h.p. grinder. This machine saves the farmer the tedious and expensive process of having to put his grain in a sack, to transport it to the nearest mill for grinding, and re-transfer it back again to his barn. Water-pumping is already being accepted as essential in the farmhouse. A small electric motor coupled to a suitable pump and pressure storage tank with automatic control can give water under pressure on tap at any desired location in the house, around the farmyard or in nearby fields. As a slow but steady process the farmer is beginning to appreciate the many directions in which he may be enabled through the use of electricity to eliminate manual labour, and his mind is turning towards the possible mechanisation of some of his many activities.

Recently considerable interest has been shown in specialised heat applications of electricity in the farmyard. Uses in horticulture had already made considerable advances. It has been found that heating can have definite advantages in, for instance, pig breeding where, through a simple method of heating the floor of the sty, bonhams at eight weeks old are some 30 per cent. heavier than bonhams raised on an unheated floor. Similarly, a strong demand has developed for heating in connection with poultry rearing. The drying of grain through a suitable heating process is a growing requirement.

It has been found that the Electricity Supply Board is being drawn, as a result of propaganda, into a close co-operation in the examination of many agricultural problems, and may gradually help considerably towards improvements in production. Quite apart from the result that the output of agriculture may be influenced, the social aspects of the work of rural electrification may ultimately be of greater benefit than the mere value of the supply of electricity as an amenity. The circumstance that the availability of power in the country may attract industry, and that many dying crafts may be revived, will tend to stabilise the population. Whether all these factors may gradually slow down the exodus of the countryman to the city it is difficult to say, but they must have this tendency.

Industrial Development.

Industry has become closely joined to the availability of adequate supplies of power. One of the first enquiries of the industrialist is what amount of power is available, and where. On the one hand he can choose his site in his best location for labour, and, secondly, he may save capital in regard to his power requirements. The spreading of the supply of electricity implies in the first instance the possible

decentralisation of industries from the thickly populated area. The Governments of this country have all advocated decentralisation to prevent the overloading of the cities. In consequence of this policy the new industries established during the past few years are well scattered throughout the country, and this must have a stabilising effect on the nearby population.

It has been said that in those countries where the power per man in industry is high the productivity is high. This is correct, but the implication possibly not so. It is true that improvements in production technique largely mean greater mechanisation and, consequently, a greater use of power, and it is the case that power requirements automatically follow these improvements. Productivity per man hour in the United States is high because of the intensive effort towards the mechanisation of all operations.

Rationalisation.

Rationalisation in industrial organisation leading to the large merger, or combine, commenced before any move appeared in the electricity supply industry. It may have been that the process was retarded with the supply authorities because they were mainly municipal undertakers operating in their own areas as public utilities. Yet, this was an industry where the economics resulting from unification under a single control were evident. In those countries where large hydro-electric projects were feasible, and where rivers required a substantial measure of water regulation for the purpose, it was obvious that the State must intervene. Consequently State boards appeared in a number of countries, such as Sweden, Norway and Canada. But it was not until developments had taken place in the transmission of energy at high tension—the higher the voltage the smaller the *relative* loss in transmission—that serious attention was drawn to the need to unify supply systems. It was unlikely that any private interests could readily achieve this, and there was clear justification for the State to participate. In the majority of countries electricity supply is under State control, although there are notable exceptions, such as in the U.S.A., where there is State trading jointly with private and other public interests.

In the U.S.A., during the depression following 1929, many public works were undertaken, and the most prominent amongst these were the vast hydro-electric projects such as in the Tennessee Valley, on the Columbia River, and at Boulder Dam. These were strongly opposed by the private interests on many grounds, the chief of which was that the State could not establish such schemes economically. The private undertakers had always been disinclined to extend supply to consumers outside the thickly populated areas, because the business so secured was not so remunerative. The effect of the U.S. Government projects was a large reservoir of power which it has been feasible to distribute throughout wide sections of the country at relatively low prices. It has rendered possible the setting up of the Rural Electrification Administration, which has proceeded steadily with its work in extending supply to farms.

It is curious that in the electricity supply industry the State, having intervened, has been impelled towards initiative and enterprise. It was the case that the State institution could always be backed by strong financial resources, and would undoubtedly be expected to take

steps to supply all types of consumers. General public pressure would insist that this should be done. The process of extension in this way, which could only have been forced very slowly under municipal or private interests, has clearly justified State control. The State, in general, has been regarded as successful in this work, and prices for electricity have been kept at a low level. Many economies were obviously inherent in unified systems under which a generating pool would be formed, with smaller requirements of standby plant, and where a large measure of standardisation could be achieved.

The circumstance that much was to be gained by the unification of the supply system within a country led to the consideration of the advantages of inter-connection between countries. It was clear that a surplus of power available in one country could be absorbed economically by another. Rapid progress has already been made in the export and import of power. Switzerland is linked with France, Germany, Italy and Austria. A submarine cable runs between Sweden and Denmark. Canada, by reason of the large water resources, has been able to export power to the United States. It seems probable that before long the systems in adjoining countries will be interconnected and will ultimately extend continuously through any one continent.

DISCUSSION.

Mr. Arnold Marsh, proposing a vote of thanks, said he was very glad to have the additional information that Mr. Browne had given about the work and the problems of the Electricity Supply Board. The great growth of that organisation, and the effects of its growth on the country, must have made their work extraordinarily interesting. It was obviously, too, of fundamental importance. But he was not satisfied yet with Mr. Browne's information, and he still wanted more. He wished Mr. Browne had looked ahead a bit farther than the next doubling period of five or six years, of which he had spoken. What was beyond?

The most remarkable feature of the graphs showing the growth of electricity production and consumption was that this growth was still as rapid in the most advanced countries as in the most backward. He had been getting some late figures for Canada. Canada, with a consumption of 4,000 units per head per annum, was increasing its consumption at least as fast as we were, but we must expect, if we went on increasing our consumption by only 10 per cent. a year, which was below the actual increase, to reach the present Canadian level in about 26 years. We might do it sooner. That level, however, might involve burning 8 million tons of coal. This would cost £32 million if coal was £4 a ton, or £40 million if it cost £5 a ton, which was just as likely. Even that might soon be doubled again. Where were we to get the coal and how were we to pay for it? £32 million or £40 million would be enough to pay interest at 5 per cent. on £640 million or £800 million of capital. Relying on coal, too, made us more than ever dependent on a growingly scarce import. Could we, by developing any resources of our own, supply a large part of our requirements at a lower cost? Would it not increase our national security if we did so?

The British Electrical and Allied Trades Research Association a couple of years ago had estimated the capital required for wind

power generation at £50 per Kw. installed. That was probably too low now. He would assume a figure one-third higher. 12,000 million units would require an installation of 3 million Kw., and at £67 per Kw. this would cost about £200 million, instead of the equivalent of £640 million or £800 million, plus capital charges, for coal plant. That £200 million would not, of course, be all. Wind power had special disadvantages because of its irregularity, and additional expense would be needed to deal with this. But was the Electricity Supply Board really satisfied that electricity could not be "stored"? The power could be stored to some extent by using surpluses to pump water to high level reservoirs, and these could be situated at any convenient place. Even the Shannon and Erne lakes could be used. Had the Electricity Supply Board engineers made surveys to find reservoir sites of a new kind, not at a level at which water collected itself, but above the water, and perhaps quite high above it? These might cost a good deal, but whatever course of expansion was followed the question of the supply of capital was going to be one of some urgency.

He was very glad to hear Mr. Browne's remarks about the social value of rural electrification, and to know that social considerations were legitimate. Not everything apparently had to be viewed from the purely economic angle. He wished then that they would tell us something about the social possibilities that might arise from a system of special rates for industrial power in the neighbourhood of power plants. Perhaps the country had missed opportunities for stimulating development near Ardnacrusha and the Erne, and might miss more opportunities near the wind and turf power plants of the future, in the Midlands and the West, by not using the bait of cheap electricity to attract industries to their neighbourhoods. For example, they might consider the case of a 20,000 Kw. plant producing 80 million units a year. If half of that was sold to local industry at a halfpenny a unit below the standard price the result would be equivalent to a subsidy of £80,000 a year to local industrialists. Would that be enough to overcome the disadvantage of such sites, and so to bring new population to some depopulated area? In Canada things like this had happened over and over again. A new power plant in an uninhabited region saved capital expense a: transmission losses by selling cheaply nearby, and population assemble around it. He thought electricity could be used to help to solve some of our population problems.

The President, in summing up, expressed the opinion that the Electricity Supply Board was one of our greatest national achievements, and owed much of its success to the work of the reader of the paper as Chairman and General Manager.

The Rural Electrification Scheme was of particular interest and importance. It had led to the use of numerous labour-saving machines and devices which increased output and lessened drudgery on farms. It would be interesting to have a census showing, from time to time, the number of the various types of electric motors and electrically operated machines which are in use on farms. This, however, is only part of a larger, much overdue, census enquiry which would make available a complete survey of all farm equipment of every kind now in use. We would then know our deficiencies in this respect, and could form a closer estimate of the capital cost of reaching some minimum desirable standard in the provision of instrumental capital for agriculture.

It was not quite certain whether the Electricity Supply Board had fully solved the problem of suitable tariff scales for different uses of electric current. In encouraging off-peak consumption by abnormally low tariffs was there not a danger that in fact peak consumption was also inadvertently encouraged, and an excessive strain placed in generating capacity? Should not additional units consumed be charged at a higher price, after a certain period, instead of, as now, at a generally lower price?

Mr. Browne said in reply: As the amount of steam generating plant increases on the Board's system the hydro-plants can be more effectively utilised. The stage has now been reached at which very little water is wasted even during flood periods. Consequently, there is no surplus water power which could be used to pump water back for storage purposes; unless there was a surplus it would not be economic to do this.

With the steady expansion which is taking place the source from which additional power will be obtained after the next ten to fifteen years seems to present a problem. This question the Board will, in the near future, begin to investigate. The problem is not peculiar to this country, and as with all other problems there is no doubt about a solution. The pressure may be such as to speed up experiments with atomic energy from which much, on a manageable scale, may be expected in the next few years.

Energy can be obtained from wind-power, but so far the installations have been small. Moreover, they will tend to be at isolated places. The supply will be of a spasmodic nature, and it will be necessary to have it connected to the main supply system.

Transmission expenditure is becoming relatively heavy because of the spreading of the generating stations. A large number of small stations, throughout the country, is more costly than fewer and bigger stations situated near the main load centres.

The diversity factor with domestic consumers is good, but in recent years the cooking load has added markedly to the mid-day and afternoon peaks. The supplier aims at drawing the demand at times other than peak, and load has been built up on this basis. Care must, however, be taken to ensure that the terms are not so attractive as to create very rapidly a particular demand which, in time, may lead to difficulties. The units per head of population in 1951 were 331.

The load curve shows a special dip in the afternoon, and this is probably accounted for by the day being bright and relatively warm.

Capital investment is at a very high rate, and whether any limitation may be imposed in future is not clear. The expenditure is of a productive nature, and will, therefore, receive priority. The future will also indicate whether the Board may be vested with its own borrowing powers.

Under the Rural Electrification Scheme the Board sells all types of electrical equipment, such as corn grinders, but does not deal in farm machinery as such.

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