STATISTICAL AND SOCIAL INQUIRY SOCIETY OF IRELAND.

THE GROWTH OF ELECTRICITY SUPPLY AND ITS RELATIONS TO CIVILISATION.

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The phenomenal progress of research and invention in the last decade has resulted in the penetration of the social structure by the use of electricity to an extent probably unsuspected even by the members of a learned society such as this. Whether this increased use of the power and properties of electricity has had, and will have in future, a profound influence on the social behaviour of mankind offers a vast field for investigation.

The subject is of great importance to the student of sociology, and incomplete and fragmentary as must be its presentation in a short paper, the facts and figures put before you may at least stimulate some fruitful trains of thought on the developments of the future.

Some cynic is reputed to have said: " When presented with statistics I always ask two questions: Who collected them? and what was his motive?" Now, to-night it is not possible to answer either of these questions, which are really of great importance.

I make no apology for the inaccuracies and discrepancies found in the statistics presented later on; prolonged research and much correspondence would have been necessary to produce statistics on an absolutely comparative basis; the object of this paper is qualitative rather than quantative, so though the figures, except in one or two cases, may only be approximately accurate, and though the derived figures have been obtained with only slide rule accurracy, the general trend of events is sufficiently well indicated. The world statistics indeed must be the roughest of rough estimates, distinguished as may have been the compilers.

An apology, however, is due to this audience for the incompleteness of the statistics in many respects, but two difficulties presented themselves: firstly, the absence of a reference library to my hand, and secondly, the difficulty of selecting what would be of most interest from the considerable amount of miscellaneous statistics which were available.

As to the difficulty of collecting reliable statistics, several instances occur in the paper so they need not be refered to further at this point; these difficulties were also referred to at some length in Mr. Stanley-Lyon's paper on March 3rd, of this year.

As a preliminary to an examination of the electrical situation of to-day a brief survey of the history of electrical research is desirable.

It is perhaps necessary to explain to a non-technical audience that electric magnetic phenomena fall broadly into three categories, the creation or presence of a charge of electricity on the surface of a body; the passage of a current through a conducting medium; and the creation or existence of a magnetic field such as surrounds a magnetised piece of iron.

Though the lodestone or magnetic ore of iron has properties which had been known for many centuries, the first authentic mention of the practical use of these properties in the compass appears in a manuscript of the 12th century, and even in 1616 compasses were of a very elementary type and not in general use. The first scientific study of the magnet was made by Gilbert of Colchester in 1600 in his great work " de Magnete "; Gilbert built up a complete magnetic philosophy on the basis of experiment in place of wild speculations.

Then, in 1671 Otto von Guericke, Burgomaster of Magdeburg, produced the first known electrical machine, a globe of sulphur mounted on a rotating axis and excited by the friction of a cloth, thus acquiring a static charge of electricity; to him also we owe the air pump, an invention which by the possibility of creating a vacuum greatly extended the range of electrical experiments.

Investigations in the production of static electricity culminated in 1745 in the invention of the Leyden jar by Musschenbrook, a professor of Leyden. It is worth mentioning that this was led up to by a physicist, who was experimenting with the electrification of water, accidentally receiving a severe shock from which he did not recover for two days; a prototype of many subsequent bold experimentors who have suffered in their own persons for the advancement of knowledge and the welfare of mankind.

Thus came into existence the electrical condenser, the properties of which play such an important and indispensable part in radio telephony and many other applications of electricity.

Whereas all previous experimenters had only produced intermittent and very transient discharges of electricity, Volta, Professor of Physics at Pavia, in 1792 produced a continuous current from what was in effect a primary battery consisting of discs of zinc and copper in a salt solution.

Applying Volta's method of producing a current Nicholson and Carlisle in 1800 discovered that such a current could decompose water into its constituent gases, and thus present vast electro-chemical industry was born.

Arago in 1820 discovered that an electric current could magnetise iron.

There were many other notable experimenters at work during the years just reviewed, Franklin, Priestly, Galvani, Davy, Wollaston, Oersted, Ampere, Arago, and others.

In the year 1791 a son was born to a blacksmith at Newington Butts near London, and a genius came into the world who was to bring to a more complete fruition the work of his distinguished predecessors. Apprenticed to a bookbinder, Faraday managed to attend lectures by Sir Humphrey Davy and eventually became an assistant in the laboratory of the Royal Institution; in that laboratory in 1831 he made the discoveries on which the whole electrical industry of to-day is based.

I make no apology for dwelling on Faraday, because even though his centenary year has gone by, it is fitting that every learned society, and particularly such a society as this, which deals with social enquiry, should have some reference in its journals to Faraday's great work; firstly, because he was a poor young man of humble origin who made his own career, and secondly, because his experiments and their outcome are a striking illustration of the way practically all inventions are the result of patient and systematic experiment by men with vision to imagine as yet non-existent phenomena, basing their experiments on a complete utilisation of the discoveries and researches of their predecessors.

To sum up the results of Faraday's experiments in the words of * Professor Cramp: "On the 24th of November, 1831, Faraday read his epoch making paper; he sees clearly that he has discovered two sets of phenomena. The first is that in which a varying current in one coil of wire produces transient currents in a second coil; these effects underlie every transformer, every coupled circuit, every induction coil that has since been made. The second set, in which the relative movement between a magnet and a coil produces a current, underlie every dynamo, alternator, and motor since constructed." I quote again from Professor Cramp: "In assessing the work of 1831 we must not hastily conclude that if Faraday had not lived, his work would not have been done. In the natural course of events some other worker would certainly have investigated the same phenomena. The relationship between electricity and magnetism was almost as much in the minds of physicists in 1831 as the composition of the atom is in 1933. World progress is never the work of a man but of a movement which gives to the man his golden opportunity.

Faraday's uncanny grasp of the physical conditions underlying phenomena which he could neither see nor measure, coupled with his untiring zeal and the perfection of his experimental method, enabled him to bring a wide range of observations within the compass of a single law."

I do not propose to trace the history of the development of the electrical industry any further; you have seen how the foundation was laid; a host of able physicists and engineers built continuously on that foundation from 1831 on to the present day.

One further pioneer invention must be mentioned; in 1837 the first electric telegraph was laid down between Euston and Camden Town, and on the 25th July in that year the first messages were sent; that evening saw the birth of a means of communication destined to exert a vast influence on the life and behaviour of mankind. Not till 1866 did the genius of Lord Kelvin make the trans-Atlantic cable a possibility, thus giving a fresh impetus to ease of communication.

The work of giving practical effect to the discoveries of Faraday, Maxwell and Kelvin was immensely accelerated by two important inventions, the incandescent electric lamp developed by Edison and Swan in 1878, and the steam turbine developed by Parsons in 1884.

The first house electrically lit in Great Britain was in November, 1880, when Colonel Crompton used a 3½ h.p. Crossley gas engine to light his own house at 23 Porchester Gardens.

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* "The Birth of Electrical Engineering" (seventh Faraday lecture). Prof. W. Cramp, Proc. Inst. El. Engs. Vol. 69, No. 419, Nov. 1931.

The superiority, convenience and cleanliness of electric light was responsible for the design of prime movers and electric generators continually increasing in size; but there was a limit to what could be conveniently done with reciprocating engines, so that the modern development of electric power practically coincides with the development of the steam turbine in large sizes. The transmission of electricity was also in an undeveloped state. In1903 prime movers of 5,000 h.p. were considered large, and the voltage of transmission was rarely above 11,000. To-day single generators of 150,000 h.p. are being installed, the voltage of transmission has risen to 220,000, and 330,000 may be used in the future.

Before proceeding to discuss the applications of electricity and their influence on civilisation, it is necessary to give some picture of the position of electricity in relation to the power resources of the world.

There are a dozen sources of natural power, the chief ones being coal, oil, water, air, solar radiation, and the tides; only the first three of these can be seriously considered in the light of present knowledge; though in time considerable amounts of energy may be derived from the last two; in passing it is just of interest to note that 5,000 h.p. is required to drive a 5,000 ton cargo boat at 12 knots, and that practically an infinite number of such vessels could be moved without appreciably ~~siderable amounts of energy may be derived from the last two; in~~ the case of tidal power and in many others, is the difficulty of storing electricity cheaply in very large quantities; not even the Drumm battery is likely to solve this problem, though a quickly charged battery of this type, in spite of its weight, may have a considerable field for wireless sets, motor boat propulsion, and particularly for submarines.

In connection with water power schemes, excess of water at certain periods of low load may be pumped to a storage reservoir.

Electricity derived from wind power, for instance, might be used to pump water into a high level reservoir to be subsequently used in turbines. The capital expenditure is usually so high as to be prohibitive.

One recent example of a scheme to utilise tidal power is the Severn barrage; in this case a committee of distinguished engineers and commercial experts report that a feasible scheme would comprise 72—12,000 K.W. turbines on the barrage, delivering 704 million units per annum direct to the English transmission grid; a portion of the output of these turbines during low tide period would be used to pump water to a high level reservoir, the flow from which would produce 906 million units for delivery to the grid.

The whole scheme would cost £38.4 million pounds, and deliver approx. $\frac{1}{13}$ of the total requirements of Great Britain in 1940, at a cost of about £1,000,000 less than these, could be supplied from coal-fired stations.

The following figures give a rough idea of the position of electric power supply in relation to the total power resources of the world in 1927:—

TABLE 1.

Estimated Coal Resources of the World ..	7,397,555	million metric tons
,, Coal Production ,, ..	191,127	,, ,, ,,
,, Oil Production ,, ..	166	,, ,, ,,
,, Electrical Production ,, ..	265,000	,, units
,, Coal equivalent of Electrical Production of the World	265	,, metric tons

The coal equivalent of the world electrical production is, therefore, about $\frac{1}{700}$ of the total world coal production.

The water power resources of the world have not been included because dubious as are the coal figures, the hydro-electric estimates are likely to be even more so.

Some detailed comparative figures of the details making up this total of 265,000,000 units are given in Table 2 for the year 1926.

TABLE 2.—K. W. INSTALLED.

COUNTRY	Hydro Electric	Steam Power	Total	Millions of Units generated per annum
*U.S.A. ..	6,970,000	19,580,000	26,550,000	80,205
*Germany ..	740,000	4,960,000	5,700,000	12,444
Canada ..	2,700,000	120,000	2,820,000	12,093
France ..	1,719,000	4,624,000	6,343,000	11,347
Great Britain	21,000	4,096,000	5,117,000	8,750
Italy	2,570,000	600,000	3,140,000	8,100
Switzerland ..	1,820,000	—	1,820,000	3,350
New Zealand	103,000	35,627	138,915	540
Denmark ..	—	229,000	229,000	422
Tasmania ..	66,000	—	66,000	350
Japan ..	1,960,000	1,240,000	1,240,000	8,000

* 1927.

The world figures cannot have more value than rough estimates, but the figures in Table 2 are probably fairly accurate. Very considerable increases have taken place in the last six years, as will be seen from some later figures referring to Great Britain and elsewhere.

The difficulty in obtaining reliable statistics, however, is well illustrated by the fact that a distinguished colleague of mine in a recent paper gives the French output of electricity in 1928 as 13,000 millions, while a more recent note in the "**Electrical Times**" puts it at 12,000 millions; again the same colleague gives the U.S.A. 1928 production as 113,000 million units, while "World Power" gives 81,868 million as the production for the same year.

The following figures illustrate the development of electric supply in Great Britain, Canada, and the U.S.A. The first Electric Lighting Act passed in 1882, was of such a character as to inhibit development, and it was not till 1909 that some modification in the restrictions, coupled with the new ideas stimulated by the development of the steam turbine and numerous other detail improvements, such as the metallic filament lamp, let to much more rapid development.

The real stimulus, however, came from the war. The four years of war were equivalent in electrical growth to the previous 35 years. This illustrates the possibility that, looked at in perspective war, is not such an outstanding evil as a sentimental world in reaction evaluates it to-day.

The influenza exidemic of 1919 caused far greater misery, loss of property and life than the war, and did infinitely less to stimulate invention and improve the lot of mankind; there can be little doubt that far greater benefits would accrue to mankind if all the energy and money being spent in propaganda against war were spent in research on the prevention of disease or even on electrical developments.

TABLE 3.—STATISTICS FOR GREAT BRITAIN

Year	K.W. Installed	Units Output	Current Expenses on Plant per K.W.	Load Factor
1906..	1,000,000	530 million	£80	14·5%
1925..	3,096,000	4,016 ,,	—	24·9%
1929..	5,801,770	12,812 ,,	£51·3	31·6%
*1932..	7,550,000	13,981 ,,	—	—

* 4,015,000 consumers.

It may be noted that these figures are really not complete, as they do not include many private generating stations. Including these latter, an estimate from the "Electrical Times" is as follows:—

1932: 10,750,000 K.W. installed. 18,113 million units output.

Note.—4,500 private generating stations produced 4,632 million units of the 18,113 million.

Here are two diagrams, acknowledgment for the use of which must be given to the "Electrical Times," that illustrate the relative progress of electric supply in Canada, the U.S.A., and Great Britain. It must be noted that the output of private generating stations is not included in the first diagram.

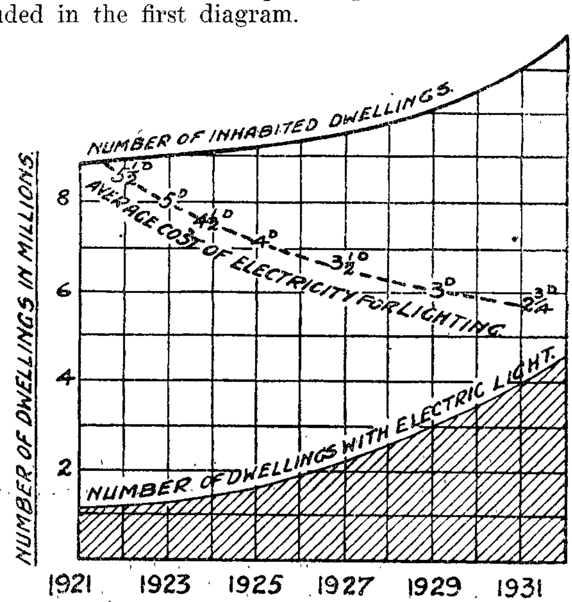
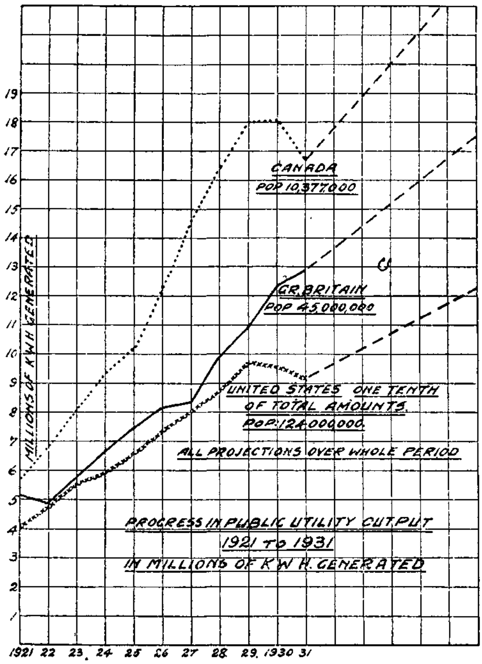


Fig. 1. Domestic Electrification Progress.

The curves show the growth from 1921 to 1931, of the number of inhabited dwellings; the number of dwellings with Electric Light; and the fall in the average cost of electricity for lighting and domestic purposes.

—From "Electrical Times," March 23rd, 1933.



—Reproduced from the " Electrical Times," of 22nd Sept., 1932.

Now follows a table showing the growth of electric supply in the U.S.A.

TABLE 4.

	1922	1928
K.W. of Generators	14,313,000	27,310,000
Units Generated :		
Thermal Stations	.. ..	.. 49,382 millions
Hydro electric	.. ..	.. 32,487 ,,
Total	.. ..	.. 81,869 ,,
Population 118,000,000		
No. of Consumers	12,709,868	23,235,500
Domestic Service :		
Average units per Consumer ..	359	459
Percentage of Homes served by Electricity	39	66

Coal used in 1927 for electric generation, 37,616,000 tons.

Now let us look at two very different and rather backward countries and compare them with the Free State:—

TABLE 5.—PORTUGUESE STATISTICS.

	K.W. Hours Generated		K.W. Installed	
	1927	1930	1927	1930
H H				
Hydro Electric Station	54,735,085	80,351,848	32,000	36,000
Thermal Station ..	132,260,261	170,707,268	101,000	114,000
TOTAL ..	186,995,276	260,059,116	133,000	150,000

The user of these units was as follows, as far as classified:—

	1927	1930
Light, private and public ..	35,000,000	46,000,000
Traction	30,000,000	43,000,000
Power	36,000,000	71,000,000
Chemical Manufacture ..	57,000,000	8,000,000
	158,000,000	168,000,000
Per Inhabitant	26 units	28 units
Private Installation	51,925,000	55,717,000

TABLE 6.—RUSSIAN STATISTICS.

Population	Year	Units Generated	K.W. Installed
147,000,000	1913	2,000 million	——
	1928	5,000 „	1,875,000
	1932	13,300 „	4,600,000

The outstanding figures of these various statistics are brought together below:—

TABLE 7.

Country	Population	Millions of Units Generated	Units per head per annum	No. of Consumers
U.S.A.	118,000,000	81,869 (1928)	690	23,235,000
Great Britain ..	44,000,000	18,113 (1932)	410	4,015,000
Russia	147,000,000	13,300 (1932)	90	——
Portugal ..	6,000,000	224 (1930)	37	——
I.F.S.	3,000,000	153 (1931)	51	——
France	41,000,000	12,000	290	——
Japan	88,000,000	——	——	——

A few figures of Japanese progress in electricity supply indicate the rapid rise of Japan's commercial power. These are the most complete statistics I have been able to obtain for any country. They are taken from a pamphlet entitled "Summary of Progress in Electrical Industry of Japan," by Denki Kyokai Maranouchi Tokyo:—

TABLE 8.—K.W. OF GENERATING PLANT INSTALLED.

Year	Hydro Electric	Thermal	Total
1918 ..	597,124	386,842	983,966
1921 ..	914,744	611,974	1,526,718
1924 ..	1,474,357	763,146	2,237,503
1927 ..	2,111,087	1,356,044	3,467,131
1930 ..	2,797,637	1,601,677	4,399,314
	Under	construction in 1930	
	1,385,454	275,446	1,660,920

It is estimated the hydro-electric resources of Japan can be increased to 2½ times the developed power of 1930.

The demand for electric lighting has naturally increased pro rata, as shown below:—

TABLE 9.

Year	No. of Customers	No. of Lamps
1918 ..	4,860,978	10,317,000
1924 ..	8,976,991	24,447,632
1930 ..	11,352,372	36,839,607

Figures are given showing the number of motors and h p. installed in each industry:—

TABLE 10.

Industry	No. of Motors Installed		H.P. of Motors Installed	
	1926	1930	1926	1930
Textile	47,000	103,500	322,906	737,200
Mechanical	38,600	66,000	269,600	592,000
Chemical	23,300	38,800	365,600	659,000
Food and Drink	101,500	135,100	294,400	341,000
Mining	10,100	17,400	524,200	631,000
Miscellaneous	77,500	137,100	416,000	615,600
	298,900	497,900	2,192,700	3,577,400

Electricity consumption rose from 3,004 million units in 1918 to 10,588 million in 1927.

To conclude the national statistics, here are a few from New Zealand, the State of Victoria, and Denmark compared with the Irish Free State.

New Zealand, with a population roughly half that of the Free State, is more richly endowed with water power than is the case here; it is much more sparsely inhabited, as its acreage is roughly 66 million acres as compared with 17 million of the I.F.S.; though the area under crops and pasture is not any different, about 18 million acres for New Zealand as compared with 14 millions for the I.F.S.

Though in Denmark there is an Electricity Commission to advise the Government, draw up regulations, etc., the supply is principally derived from companies and municipalities. Rural electrification preceded any trunk line transmission. Copenhagen has an 80,000 K.W. station with 60,000 K.W. extensions in progress (1931). Considerable quantities of current are purchased from water power stations in Sweden, reaching Denmark by a 3½ mile submarine cable.

TABLE 11.

	Imports	Exports	Total Acreage	Acreage Cultivated and Grazing	Population
	£	£	millions		
N. Zealand	61,285,000	45,275,000	66.39	18.58	1,527,000
I.F.S. ..	49,889,000	41,185,000	17.02	12.18	2,971,000
Victoria ..	55,559,000	34,682,000	56.24	11.50	1,726,000
Denmark	89,150,000	83,500,000	10.62	6.84	3,550,000

	Units Sold	K.W. Installed	No. of Consumers	£ Capital Expenditure millions	£ Revenue millions
New Zealand	1,000,080,889 (1931)	224,000 (in 41 station)	300,809	29	4 36
Victoria .	379,572,140 (1931)	—	—	18.5	2.54
I.F.S .	† 110,677,196 (1931)	100,000 (in 3 station)	*77,134	8.8	94
Denmark ..	‡ 350,000,000 (1930)	340,000	—	—	—

† About 73,000,000 in Dublin and Cork. ‡ 40% used in Copenhagen.* 46,000 in Dublin and Cork.

The achievement of N.Z. can be realised when it is stated that electricity supply is available to 91 per cent. of the population in a country where the density of population is only 1 per 12.15 acres, as against 1 per 4.1 acres in the I.F.S., both figures being based on the cultivated acres, including grazing. The area under grain crops is 791 thousands of acres in the Irish Free State and 332 thousands of acres in New Zealand. The total length of distribution lines of all the supply authorities in New Zealand is 17,760 miles, the corresponding figure for the I.F.S. is not available.

There were installed in N.Z. 29,480 electric cookers, 42,803 electric water heaters, and 13,656 electric milking machines (another source of information gives this last figure as 18,000); in the I.F.S. there are 29,000 holdings over 100 acres and 1,224,553 milch cows; as the minimum herd of milch cows warranting the installation of a milking machine is about 20, it would appear that in spite of the probably much greater milch cow population of New Zealand there should in time be a large user of these milking machines in the I.F.S.

The charges for electricity in the I.F.S. do not appear to differ materially from those in N.Z. Scales 1 and 2 in the I.F.S., which are those generally applicable to country districts, are 2½ to 2d. for motive power, and ⅓ penny for hot water heating; the N.Z. charge for power for milking machines is 3d. to 4d., and for hot water heating ⅓ penny.

One instance of a N.Z. Power Board's activities is worth quoting; the Hutt Valley, near Wellington, gives the following statistics:—

1925.	Population 27,275	...	Consumers	3,892
1930.	,, 41,500	...	,,	10,467

In 1931 24.5 million units were sold, 2,351 per consumer; there were 1,357 cookers, 1,169 water heaters, 1,018 motors, 1,411 street lamps, 8.4 million units were sold for power, and 10.6 million for light and heat.

Reference has been made to the invention of the electric telegraph and the development of the submarine cable. I do not propose to give you the statistics of the mileage of telegraph and submarine cables which spread in a vast network all over the world, but some figures as to the rate of increase of the use of the telephone and the present position of radio reception are of interest; quite recently all the principal countries and capitals of the world have been put in telephonic communication by means of radio telephony. It may not be so well known that picture transmission by telegraphy has made such progress that most large newspapers have picture sets; close examination is required to detect the received print from the original; the value of the system in transmitting intricate financial sheets and tables is also very considerable.

In 1921 U.S.A. had 63.92 per cent. of world telephones; in 1931, 57.17 per cent; in 1931 67.1 per cent. of world telephones were private companies, 32.9 per cent. State.

TABLE 12.—TELEPHONES PER 100 INHwBITANTS.

	1921	Telephones per 100 Inhabitants in Capital City in 1931	1931	% Increase	Telephone Calls per Inhabitants
Denmark ..	7.7	17	9.9	40	152
Sweden	6.6	32	8.7	38.2	132
Norway	5.0	17.5	6.7	42.2	86
Switzerland ..	3.8	—	7.3	95.6	57
Germany.. ..	3.0	14	5.0	79.5	40
Netherlands ..	2.4	7	3.9	89.3	63
Great Britain ..	2.1	8	4.3	102.5	32
Austria	2.2	7	3.4	75.2	81
Finland	1.3	13	3.5	184.8	47
France	1.2	13	2.8	143.7	20
Belgium	0.8	10	3.6	365.5	27
I.F.S.	—	4	1.0	—	—
Czechoslovakia ..	0.6	5	1.1	113.1	18
Spain	0.3	5	1.0	217.7	26
U.S.A.	12.4	25	16.4	34.0	—
Canada	9.8	28	14.0	63.8	—
New Zealand ..	7.0	10.5	10.2	86.2	—
Japan	0.6	—	1.4	176.2	—

Turning to wireless, it is estimated that there are now 40,000,000 receivers in use in the world:

TABLE 13. 1932.

Country	Population	Receivers per 100 Inhabitants	Telephones per 100 Inhabitants
Denmark	3,550,000	14. 0	17.0
Great Britain	44,750,000	11.75	4.3
Sweden	6,162,000	9.87	8.7
Austria	6,722,000	7.33	3.4
Holland	8,127,000	6.89	3.9
Germany	64,775,000	6.65	5.0
Switzerland	4,080,000	5.67	7.3
Iceland	109,500	4.94	——
Norway	2,847,000	4.34	6.7
Belgium	8,159,000	4.16	3.6
Hungary	8,734,000	3.69	1.3
Czecho Slovakia	14,726,000	3.20	1.1
I.F.S.	2,971,000	1.04	1.0
Poland	31,927,000	0.92	0.6
Esthonia	1,107,000	1.00	——
New Zealand	1,527,000	5.80	10.2
U.S.A.	122,918,000	13.83	16.4
Japan	88,106,000	1.53	1.4

The greatest increase in any country in 1932 took place in Great Britain, where 932,218 new licences were taken out: this was equivalent to 50% of the total increase in Europe (Russia omitted).

The general economics of electric supply may be depicted in a broad manner as follows:—

The generating station may be operated by water power, steam power, or oil engines. Turbines are universally used in the two former; both steam and water turbines are now constructed in very large sizes. Steam turbines run up to 140,000 K.W. or 182,000 h.p.; boiler pressures of 600 lbs. per square inch are common with a steam temperature of 800° F. The thermal efficiency, i.e., the ratio of the calories in the coal to the calories in the units generated reaches as high as 30 per cent.; the voltage of generation is being gradually raised to 33,000.

From the generating stations radiate transmission lines; these lines are being constructed to 330,000 volts; 220,000 volts is a commonly used pressure.

The cost of a steam generating station to-day will not exceed £12 per K.W. installed.

The cost of hydro-electric stations depends on the head of water available and the cost of making a suitable storage to cope with variations in the off-flow of the rainfall. The turbines for use with high heads such as are commonly found in very mountainous countries are small high speed machines compared with turbines for low heads such as those at Ardnacrusha, which are slow speed machines and necessarily very large on account of the huge volume of water that has to be dealt with. Similarly with low heads, enormous storage is required and with high heads small storage; hence the spectacular appearance of Ardnacrusha, which is really a medium sized station much exceeded in size by hundreds of other stations all over the world. In countries with mild winters the water dearth is in summer; in those with cold winters the storage is required for winter use.

As the heating and lighting load is heaviest in winter, in a climate such as ours it corresponds with an ample supply of water.

From the 330,000, 220,000, or 132,000 volt transmission lines radiate lines at lower pressures, till eventually we reach the very low pressure lines which actually feed into consumers houses or factories. The pressure is reduced by transformers which can be built in very large sizes, and at a very low cost, as low as 10/- per K.W.

The cost of generation and high voltage transmission for large powers is very low indeed; a recent test on a medium-sized 25,000 K.W. turbine for a week on a load factor of 45 per cent. resulted in a cost of .118d. for fuel, at 15/9 per ton; in large towns the cost of current per unit sold may be as low as $\frac{1}{3}$ penny, including interest and sinking fund charges.

When we come to the distribution lines at low voltages 400 and under, the capital cost and the loading of the lines has a preponderating influence on the cost of current to the consumer. As an instance consider Manchester figures for 1932 compared with those for New Zealand.

TABLE 14.

	Manchester	New Zealand
Current sold, units	* 431 million	1,000 million
Population	752,000	1.527,000
Capital expenditure, generating stations	£4,620,000	£8,468,000
Transformer stations and mains	£10,673,000	£21,000,000
	£15,296,000	£29,468,000
Revenue	£1,864,000	£2.223,000
No. of consumers	76,375	300,809
No. of cookers	10,779	29,480

* Manchester's trams take about 1/10th of the total units.

Thus out of the total expenditure about 70 per cent. is on transforming stations and mains, and this in a compact town where the mains, even if expensive to instal, will be well loaded with large consumers. As will be seen later, in New Zealand, where an extensive network of mains covers the whole of a sparsely inhabited agricultural country, the cost of the generating stations represents about 34 per cent. of the total expenditure. The similarity of the percentages is due, no doubt, to the much lower cost of overhead lines in New Zealand as compared with the cables in Manchester.

Water power is almost exclusively used in New Zealand and steam power in Manchester.

Till lately the cost of making direct connection for consumers to the very high voltage lines has been quite prohibitive, but quite recently improvements in design have led to the opinion that most rural distribution should be at 11,000 volts.

The development of electric supply in any country is evidently likely to bear some definite ratio to the wealth per head; electricity for domestic use supply is not, however, a necessity, like food, clothing or fuel, so that it is absolutely necessary to persuade the prospective consumer that he gains in pocket or in comfort by the use of electricity. If he spends more on electricity he must spend less on something else unless he is in the possession of a growing income.

Where comfort is not valued, where small economies are despised, or in poor countries, the prospects for the extension of electrical supply are not very good; in general the demand should be greatest where the wealth of a country is neither evenly distributed nor mainly in the hands of a small class, in either of those cases the bulk of the population will be too poor to use electricity.

Climate has a considerable influence on demand; where the summer is hot and the winter cold, a very considerable load can be built up with refrigerators in the one case and heaters in the other.

Certain figures given later on will indicate the high consumption of electricity in towns where institutions, factories, trams and street lighting provide a concentrated load in relation to the mileage of mains compared with the difficulties in extending supply among the agricultural communities who tend to set less value on comfort than the city dwellers, and whose conservative nature resents change; added to these tendencies of the agricultural community is the difficulty of preventing the costs of the distribution lines being out of proportion to the load. A numerical instance may serve to illustrate the point; a 20 mile line serving 20 farms one mile apart might cost, with the necessary transformers, etc., say, £10,000. If 8 per cent. is allowed for interest, maintenance, and depreciation, the standing charges amount to £800 per annum, or 1d. per unit if each farm took 9,600 units per annum. It is clear also that the farmer nearest the tapping point of the main transmission line should pay very much less than the man who is at the far end of the line. Equitable distribution of such charges, however, can be arranged.

The vendors of electricity have devised innumerable different tariffs to attract the consumers custom. It is impossible to go into these here, but in general very low rates are offered to consumers willing to take their supply when the load on the generating is low, due to the natural incidence of the industrial lighting and domestic demand; the tariffs are also devised so as to discourage high consumption for short periods and much apparatus is hired.

A queer instance of this occurs at Preston; the weekly wash day in that town is also cold meat day, and the electric cooker is off duty, so Preston electric supply authority in 1930 hired out 614 electric wash boilers. At Woolwich electric irons are hired out at a penny per week.

There is probably a great future for electric supply to working class houses, and probably 80 per cent. of the houses in most European countries are of this class. An example from Hull is worth quoting.

* Actual data of an estate of 500 houses supplied at 230 volts A.C. from its own sub-station:—

Average rateable value, £13. 4-roomed semi-detached. Equipment of each house: One coal fire and boiler, 7 lights, 1 kitchen plug, 1 4.6 K.W. cooker, 1 8-gallon 3.2 K.W. wash boiler. Wash boiler purchased outright. Rent of cooker, 12s. per annum. Tariff, 15% of net assessment and ½d. per unit.

Direct capital outlay (mains,services and sub-stations)	£9,766
Average No. of units per house per annum	1,140
Income per annum	£2,162
„ „ per house	£4.32
Average income per occupant (estimated)	£200

* *World Power*, January 1933, ½d. 10.

It is interesting to note that the consumption per house per day is higher in summer than in winter; this is due to the use of the coal range in winter for cooking and water heating. This suits the electricity supply.

Another typical example of electric supply to somewhat better class houses is taken from Welwyn Garden City:—

TABLE 15.

Year	Consumers	Units per annum per consumer	Main load K.W.	No. of Cookers	Average Price		Total units sold	Units sold for domestic use
					Industrial	Domestic		
1924 .	661	376	156	8	17.3	3.73	248,245	
1931 .	2,526	2,130	2,160	1,168	10.8	1.62	5,389,756	2,383,436 (44.5%)

A final example of domestic supply. A 10-room all electric house at Oxley, Herts:—

Equipment	K.W.	Consumption	Units
Cooker	7.0	Quarter, March ..	11,000
40-gallon Water Heater	6.0	,, June ..	5,600
Breakfast Cooker	1.5	,, September*	3,600
Sunray Heater	2.5	,, December	6,200
Bowl Fires	2.0		
Bar Fires	5.0		26,400
Lighting	2.5	Tariff $12\frac{1}{2}\%$ on rateable value and $\frac{1}{2}$d. per unit.	
Toaster, Vacuum Cleaner, Iron, etc.	2.5	Annual cost assuming rateable value of £150 per annum, £75.	
	29.0		

Electricity is usually associated in the minds of the public with electric light, but the use of electricity pervades the industrial structure in a way that is but little realised by the non-technical public. Electricity, in the first place, has become a means of making the most delicate measurements; this development has enormously extended the possible fields of research; the advances in our knowledge of the nature of the structure of matter would not have been possible without the use of electrical methods. Electrical pyrometry and thermometry are extensively used in connection with numerous industrial operations; the delicate measurements in connection with the air resistance of aeroplanes and the resistance of ships hulls would be impossible without the use of these methods.

Electrical methods are being used with some success in locating ore bodies, while a triumph of a qualitative kind was the recovery from a Liverpool refuse dump of a minute quantity of radium lost from Liverpool Infirmary.

The world production of aluminium, 226,000 tons is electrolytic, while the production of caustic alkali and chlorine is on such a scale that in 1927 525 million units in U.S.A. and 350 million units in Germany were used for this purpose. Calcium carbide is made in electrical furnaces up to 16,000 K.W. in size; the installed capacity of electric furnaces for making steel approached 2,000,000 tons per annum. The cost of very high grade steel has been appreciably lowered by the use of these processes.

Electric furnaces are used in every industry where accurate heat control is required, and furnaces actually reach 12,000 K.W.

Large amounts of electrical energy are used in making artificial graphite and abrasives.

Electrical welding is coming into universal use, castings being largely replaced by welded steel structures.

It is hardly necessary to mention electro-plating.

The influence on the health of factory workers due to the fine illumination obtainable by electricity and the absence of noise, belts, smoke and dirt, due to the employment of motors is hardly estimable.

At the risk of wearying you, one instance must be given of the fineness complexity of the operations involved in one process alone; in a hundred other branches of the industry equally abstruse and difficult problems present themselves; the manufacture of cables involves the most extensive researches into the qualities of rubber, oil, lead, etc. ; the manufacture of meters has led to research into the quality and causes of wear of privots and jewels; many other examples could be quoted, but to return to my example. The filament of an electric lamp is 6 ten-thousandths of an inch in diameter, the permissible variation must not exceed one-half of 1 per cent., the tolerance is thus less than three-millionths of an inch; the filament consists of a coil of wire, coiled on a mandril not more than three times the diameter of the filament, and its measurement must be more accurate than that of the filament; the variation of the space between individual coils must not exceed five millionths of an inch; the fluidity of the glass used doubles for every 15 deg. c. rise in temperature; the occlusion of gases in any metal parts of the lamp, the purity of the gas used to fill the lamp,etc., all effect the efficiency and life.

The medical profession, whose advances in knowledge have done so much to increase the duration of healthy life, are dependent at every turn on electricity. The use of *x*-rays, diathermy, the lamp for the operating table, and numerous other applications are essential to both medical and surgical treatment.

The domestic applications are well known to all here, but perhaps less well known is their safety. In England 4,000 people lost their lives in their homes last year, 550 fell downstairs, 630 were scalded, 93 choked by food, 200 died as a result of accidental gas leaks, but only five were killed by electricity.

Both road and aerial transport to-day are dependent on electricity for ignition purposes.

Finally in Great Britain a census of 448 electricity supply undertakings made by the "Electrical Times" shows that of 6,547,624 houses in these supply areas 2,820,000 were connected up. The above figures show the large field yet remaining for the development of electric supply. The total number of connections is in the neighbourhood of 4,500,000 for the whole country.

Electricity has been used extensively for traction purposes; tramways have been the principal users, but in the last 20 years there has been considerable development for railway purposes. Briefly the economic justification for railway electrification is density of traffic; for very obvious reasons, which time does not permit me to go into, the ordinary method of using our overhead trolley wire is economical down to a certain density of traffic, about 2,500,000 ton miles per track mile per annum; below this figure battery or Diesel electric traction may be more economical than steam; both these latter methods of traction involve electric motors driving the axles; questions of weight, capital cost, and maintenance will determine the supremacy of one or the other.

11,505 route miles of electrified railway exist to-day. The U.S.A., Switzerland, Italy, France, and Germany account for more than half this total. Electrification of railways is extending steadily but only uses a fraction of the total output of electricity. In France, for instance, 1,300 kms. of railway are electrified out of a total of 40,892 km., and use just about 2½ per cent. of the total electrical output.

Electricity is also being used for ship propulsion, a fair number of ships having been built with comparatively high speed prime movers driving the propellers by slow speed motors.

The influence of electricity on the safety of navigation is very considerable; over 15,000 ships are fitted with wireless in accordance with the provisions of the Safety of Life at Sea Convention; international agreement requires all passenger ships of 5,000 tons and upwards to be fitted with directional wireless for locating their position from numerous wireless beacons. The gyro compass, which is very largely used, is only made possible by the use of electricity.

Other applications are the use of the photo-electric cell which is used for talkies, counting objects, etc.; the examination of metals for flaws; the exact reproduction of motion at any distance; distant control of every kind of apparatus.

Electricity in Agriculture.

The application of electricity to agriculture should be of supreme interest to this country.

It cannot be too often repeated that farming is a basic industry, a staple founded on the basic needs of mankind for food, clothing, and fuel, whereas industrial development is a secondary activity based solely on the surplus production of the farmer, and is of unstable nature, liable to violent fluctuations due to the trend of fashion, invention or politics.

The more extensive use of electricity in agriculture is, therefore, of great importance; yet no field of electrical development offers more difficulty than this one. The difficulties are fairly obvious, the conservatism of the farmer, the long distribution lines, and the small demand for power and light in many cases, and the capital cost of the equipment.

In the U.S.A. there are 6,371,000 farms. In 1928 a count by States showed that 383,730 were served by Electric Light and Power Companies. California, New York, Ohio, Washington, Pennsylvania, and Wisconsin had the largest number of farms, embracing nearly 58 per cent. of the total. In collecting these statistics there was great difficulty in defining a farm and even more in collecting the statistics. The definition arrived in condensed form was as follows:—Any place of three or more acres producing agricultural products: or three acres or less, with a revenue from agricultural products of more than $250, or where the owner or tenant devotes.

his whole time to agriculture. The climatic and social conditions of these States, no doubt have greatly influenced the extent of the user; in Great Britain only 4,000-5,000 farms have an electric supply. In Denmark, in Belgium, in New Zealand practically every village and many farms have supplies of electricity, but definite statistics are lacking.

The different possible application of electric motors, which can be obtained in every size from a fraction of horse-power upwards, are fairly obvious, but to keep down capital expenditure much ingenuity is being expended on producing a very portable motor of a size that can be applied easily to a variety of machines.

In New Zealand electricity on the farm is mostly confined to driving milking machines, cream separators, pumping water and shearing, and water heating in the milking sheds.

Associated industries, quarries, saw-mills, flax-mills, vineyards, freezing works, etc., use a good deal of power.

In Denmark most farms have their own thrashing machines worked by electric motors of an average size of ten H.P. Nearly every farm has electric light.

From the Irish point of view, apart from these and other well-known applications, such as incubators, clipping machines, the most likely fields for a large use of electricity in rural districts are in pumping and in the artificial drying of hay.

In regard to the latter, the important points are that (1) the hay is of increased feeding value and digestibility and (2) no matter what the weather may be the whole crop is saved. I am no agriculturalist, but it seems to me that this latter point is of immense value in a climate such as ours.

The disadvantages are (1) the rather complicated drier which must be of considerable size and necessitates co-operation between small farmers, or the existence of very large farms to ensure economic use.

The cheapest method of all is stack drying, which demands only the use of a fan and motor, but necessitates a high degree of skill and experience in building the stack.

I will give one detailed example of rural electrification: the Puget Sound Power and Light Co. in the State of Washington serves an area of 30,000 square miles, of which only about 8 per cent. is farmed, and in this area over 3,200 miles of rural distribution lines serving 20,000 out of 40,000 farms in the territory have been constructed. The average-size farm is of about 36 acres, and the total annual value of the agricultural products of the area is about £16,000,000. This represents about £400 per farm or about £11 per acre, a much higher figure than is obtainable in Ireland. The average consumption by the farm customers in 1928 was 1,475 units, costing £11 per annum or about 1.8d. per unit. The principal products marketed were milk, poultry, apples, and hay. The large amout of irrigation which is carried out in that part of the U.S.A. accounts for about 30 per cent. of the energy consumption, but if there is no need for irrigation in Ireland there is plenty to be done in the way of drainage. The State of Washington has, however, a much more favourable climate than has this country. Though this and many other illustrations which might be given show that the use of electricity is making headway among farmers, it is evident that the methods of salesmanship adopted have a profound influence on the rate of expansion in rural areas.

In the U.S.A. it has been found that excellent results are obtained by the use of a demonstration wagon circulating in the agricultural districts. I have long advocated the fitting up of one or two agricultural demonstration trains to circulate on the half-disused railways of this country: by actual demonstration and by cinema an immense amount might be done to increase the production of the small agricultural industries and also the use of electricity for these purposes.

The figures and facts that have been quoted so far are not very encouraging in regard to this country. The expert's report, a copy of which I was able to peruse by the courtesy of a friend, foreshadowed a sale of 150 million units and a load of 50,000 K.W. in the first stage: that prophecy has, I believe, been more than fulfilled. It still remains to be seen whether the subsequent developmnt will enable a load of 87,000 K.W. and a sale of 237 million units to be obtained. The sale prior to the establishment of the Supply Board was 55,000,000 units for the whole area comprising in the Irish Free State.

That report set out some statistics of sales of electricity in England which it is worth while reproducing alongside of the latest figures. The 1924 figure is the upper one and the 1933 the lower in each case.

No doubt the establishment of local industries will help considerably in the development in future. Cheap electric power, however, except in electro chemical industry is only of secondary importance: skilled and reliable labour and a steady market are the essentials to development. In fact it is pretty obvious that as the resources of a country are strictly limited by nature, the introduction of labour-saving devices so much facilitated by electricity can only accentuate unemployment and emigration.

TABLE 16.

Town	Population	Units sold per annum	mean load	Yearly Receipts	1932 Load Factor
				£	
Aberdeen ..	175,200	22,146,000	11,200	174,800	32.4
	186,700	40,494,000	17,500	226,100	32.4
Belfast ..	429,000	31,644,000	15,575	320,000	28.1
	415,000	70,807,000	34,400	400,200	
Dublin 1924	310,000	13,028,000	10,173	282,000	23.5
1929	320,000	29,087,000	17.250	319,000	
Chester ..	75,000	3,722,000	2,305	50,000	30.1
	75,000	11,811,000	6,236	85,500	
Kendal ..	14,100	227,000	252	7,300	19.9
	15,600	982,000	758	16,000	
Spenborough ..	12,500	1,700,000	887	16,900	31.9
	12,500	3,227,000	1,320	23,000	
Dundalk 1929	13,200	1.321,000	728	19,200	——

The Dundalk and Dublin figures are for the last year recorded for these as independent undertakings.

It would be interesting to have comparative figures for Dublin and Dundalk for the year 1932. Also compare the following:—

Current	Town	Population	Units Sold	Mean Load	Year's Receipts
£				K.W.	£
32,368,000	1932 Manchester, Liverpool, Glasgow	2,905,000	1,024,000,000	436,700	5,096,000
	Denmark	3,550,000	350,000,000	—	—
8,843,000	E.S.B. 1932 Irish Free State	2,945,000	110,000,000	55,700	938,000

This illustrates very well the difference between the supply to an urban industrialised area and two agricultural countries, each of the latter with a large capital city and no other large towns; the one highly developed agriculturally and the other not.

It will be noted that the mean loads and units sold of the three large towns are nearly nine times and the revenue 5½ times that of the Soarstát, thus illustrating the more economical distribution.

Though it is very dangerous to take average figures, especially having regard to the disgraceful housing conditions in Dublin, the 583,537 inhabited houses in the Saorstát points roughly to an average family of five. The average total income per family would appear to lie somewhere between £200-£300 per annum, based on Kiernan's estimate of April, 1933, in the Economic Journal or, alternatively, on the census of production, I.F.S., 1926-29. On this basis an expenditure on electric current of as much as £4 on the average per inhabitated house should not be out of reach. This would bring the revenue of the E.S.B. to about £2,000,000 per annum and the units sold to about 250,000,000. These figures roughly correspond to the expert's figures for the second stage of the scheme.

It is to be doubted, however, whether such expansion can take place in a country where every expenditure in connection with electricity supply is apt to be dragged into the political arena, where the Board of Control are, however, much theoretically independent, subject to dismissal by the Minister, and where the expenditure on salesmanship and propaganda is limited by the profits of previous years, these profits again being contingent on Finance Department's view as to the rates to be applied to the sinking fund and to depreciation, and where capital expenditure against future developments may be held up for months or years, dependent on the views of officials in the Finance Department without experience of the business of electric supply and on the amount of time over-worked and probably biased Ministers can give to what may appear to them at that moment a minor question without any appreciable influence on the electorate.

The Free State system of supply is unique and not likely to be copied. In no other country except Russia does the Government deal directly with the consumer.

The industrial use of electricity in the I.F.S. is never likely to be large, for the community is too small for the establishment of those types of industry consuming large amounts of power, such as the electrochemical and iron and steel industries.

For instance, a large works that the author controlled for some years employing some 4,000 hands, electrically lit and driven, only took a maximum load of about 1,000 F.W.

And now to conclude, the author may well ask whether the heterogeneous mass of statistics and description presented here can offer any clue as to whether the developments of electricity have had real influence on civilisation, or whether they have merely increased the amenities of life. Culture and civilisation rather differ from one another, so that something that may contribute to civilisation may not add anything to culture. It is noticeable in the statistics presented in regard to the use of electricity that the U.S.A. occupy a foremost place, while the Nordic races occupy the next most prominent places. Whether in the mass the inhabitants of the U.S.A. can be considered as either civilised or cultured is a matter for discussion: if possession of material objects, if the development to an extreme degree of luxury, speed and noise, if the consumption of large quantities and varieties of food, if the commission of crime on a large scale, if the size of newspapers and the influence of the Press are indications of culture and civilisation, then our friends across the water can undoubtedly lay claim to both, and both such culture and civilisation are envied by most of the other nations of the world, particularly the intellectuals of such countries as India, China, and Russia, which are experiencing, or beginning to experience, the stirrings of so-called democracy: electricity has been the powerful agency that has made these things possible. Yet the improvement in manners and morals (I do not mean sexual morals), the milder feelings, or at least, reactions of man to man that has taken place in the last century has been due almost entirely to improved communications, an improvement in which again electricity has played a leading part.

Though many newspapers are sensational and very often inaccurate, still through their medium the pressure of world public opinion, and there is a tendency of public opinion towards improvement, is brought to bear on events happening in even the remotest localities, and their general influence is for good.

In this way full play also has been given to the reactions of the mentalities of different men and nationalities on one another and of the culture and thoughts of the highest types of mentality on those who are willing to listen to them. Broadcasting has been and will be even more so a powerful means to this end: no one who has listened to the broadcasts given in England to innumerable schools all over the country by men like Sir Walford Davies and others can doubt the immense effect that will be produced on those capable of appreciating what is put before them. Unfortunately electricity cannot produce intelligence and the working of the laws of heredity which produce a Bishop Berkeley, a Turner, a Sir William Petty, or a Faraday from obscure parentage also produce at least 80 more or less unintelligent people out of every 100. In many ways it seems that the use of electricity enables the higher aspects of life to be offered to an immensely large audience. The principal rôle played by electricity has been to offer an immense increase in the amenities of life: in most so-called civilised countries the applications of electricity enable the great majority of even the humblest and poorest to enjoy a luxury of life and a variety of pleasures undreamt of fifty years ago. To that development the mass of the workers have contributed nothing except their handicraft: progress has been due, as has been the case since the dawn of civilisation, to a small percentage of individuals drawn from every class, whom heredity either by known or obscure channels has endowed with intelligence, energy, and tenacity of purpose beyond their fellows. It may be concluded that this mysterious agent electricity, which appears to be the ultimate constituent of matter, contributes at least something to culture and a great deal to civilisation.

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