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PROVISION OF ENERGY FOR NON-INDUSTRIAL PURPOSES IN THE UNITED KINGDOM

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Introduction

We presented a paper entitled "Integrated Heat and Power Services for a new City" to the World Power Conference in Moscow in August 1968.¹ This was inspired by the fact that while less than 20 per cent of the 17 $\frac{3}{4}$ million dwellings in Great Britain are either fully or partially centrally heated, the national need to produce dwellings at the rate of about 500,000 a year and a greater awareness of comfort has made engineers, architects, town planners and the public generally think much more seriously about the need for properly heated dwellings. This in turn has given a spur to the more efficient use of fuel and power for non-industrial purposes. The creation of entirely new towns and cities and the redevelopment and extension of some of our older industrial areas has thus given impetus to the idea of district heating and the more rational use of energy resources.

The development of the new or expanded towns in Great Britain are planned and built by development corporations appointed and financed by the Government. The first "New Towns Act" was passed by Parliament in 1946 and there are now 24 new towns in Great Britain in various stages of completion and more being planned. The first of the new towns were planned to take populations of about 60,000 in areas where the population originally was small, but much bigger new towns of 200,000-250,000 are being developed. The expansion of large existing towns is a more recent approach, and in such cases the development is planned and carried out by the existing municipality acting in partnership with a Government-appointed development corporation. In this way the mature towns encourage the further development for industrial and commercial purposes, and the fullest advantage is taken of the existing utilities and communication systems and social facilities.

The climate of Great Britain is equable and cool with no extremes of temperature and a generally high relative humidity. At all seasons the weather may change considerably within a few hours under the influence of the Gulf Stream or Atlantic cyclonic systems from the West or the Euro-Asian continental high-pressure zone in the East. Records of the Royal Observatory at Kew near London covering 20 years indicate that a relative humidity of 100 per cent is possible on any day of the year. The sky is clouded for between 50 and 60 per cent of the time, and in some Western areas of the country summer days are occasionally cooler and damper than the mild winter days. The temperature rarely falls below 30 F in the winter, and exceeds 80 F during the summer for only a dozen or so days in the year.

Table I gives an indication of the way in which the British climate differs from that of other countries in Europe and the various zones of the U.S.A.

The figures are given as guides to the conditions normally existing in the other countries although it is recognized that there are wide differences according to the various parts of the countries concerned. The important fact is that no such extreme differences occur in the whole of Great Britain and that the climate conditions of Great Britain are quite different from those in the other countries (Table II).

The mean annual temperature is 48 F. The difference between the average summer (63 F) and winter (43 F) temperature is only about 20 F.

Table I

Country	Basic design temperature					
	Outside		Inside		Temperature rise	
	Deg F	Deg C	Deg F	Deg C	Deg F	Deg C
U.S.A.						
Zones 1 to 6	-30 to 15	-35 to -9	70 to 75	21 to 24	100 to 60	56 to 33
Canada	-35	-37	70 to 75	21 to 24	110	61
Denmark	3	-16	68	20	65	36
France	20	-7	68	20	48	27
West Germany	10	-12	68	20	58	32
Holland	14	-10	68	20	54	30
Sweden	-4	-20	68	20	72	40
Great Britain	30	-1	65 to 68	18 to 20	35 to 38	19 to 21

Table II—Heating Design Temperatures and Degree Days

Location	Design temperature difference		Deg days per heating season*
	Deg F	Deg C	
London	35	19	4995
New York	70	39	5350
Hamburg	58	32	6085
Paris	48	27	5050
Copenhagen	65	36	6510
Stockholm	72	40	8625

* All degree days are given to a base temperature of 65 F for the nine months September to May.

The absence of any long spells of freezing weather, the equable climate and the cool damp summers, together limit the size and cost of the heating installation and plant required but result in a lengthy annual period of usage. With these important economic advantages the return on investment in heating installations in Great Britain should, therefore, be assured.

Given these conditions, then, it might be thought surprising that much more attention has not been given to district heating in the past in Great Britain. One has to look at this matter in the light of history and appreciate that the industrial revolution first took place in Great Britain and the price paid for this was a very rapid urbanisation and growth in industrial areas accompanied by much atmospheric pollution but all stemming from the availability of cheap coal of high quality. The abundance of cheap coal and of labour for domestic purposes led to the nation wide use of the open coal fire. Despite its low thermal efficiency the open fires were found to be effective in providing a satisfying source of heat and ventilation. The great American, Benjamin Franklin, during his lengthy sojourn in England was particularly struck by the way in which coal was used domestically and by the atmospheric pollution of London and other industrial cities. He did much work in endeavouring to persuade the British of the damage done to property and people by this profligate waste of resources, and introduced his Pennsylvania stove which was designed not only to achieve greater combustion efficiency and the avoidance of smoke but also to produce a rapid circulation of warm air in the room to be heated. It may not be generally known that, consistent with his reputation as a philanthropist as well as an inventor, he refused to patent his design but was a little shocked on returning to London a few years later to find that, in fact, a Cockney ironmonger had done this in his absence and was making a small fortune from it.

In spite of Benjamin Franklin and the Count Rumford of the same period and many other attempts by the great engineers of the past, atmospheric pollution continued at an ever increasing rate so that even as recent as 1952 London experienced a killer smog which lasted for almost ten days and resulted in a considerable number of deaths. It did, however, lead directly to the passage of legislation (namely the Clean Air Act of 1956) which was aimed primarily at reducing smoke emission, especially that from domestic fireplaces. Since the passing of the Act a tremendous reduction in pollution has occurred and yet, it does not appear to have been unduly restrictive; mainly perhaps because the form of legislation avoided the defining of precise limits of contamination in the discharge from chimneys, and so ensured that the degree of control could increase as the advances in technology occur. It should be mentioned here that the smog in London is rather different from that experienced in Los Angeles, since the London smog occurs on cool misty mornings with high humidity in the winter months November to January. It contains sulphur compounds and a high proportion of particulates as well as carbon monoxide and causes severe bronchial irritation. People already suffering from respiratory diseases are particularly prone to severe physical damage caused by such conditions.

Thus we see that clean air legislation produces very much better living conditions, and the real London fogs are largely a thing of the past. Against this historical background, it has been slowly seen that the relatively low standards of space heating in homes and factories, to which the public had largely become accustomed, were not good enough. In recent years higher standards of education, lightweight clothing, perhaps a lighter diet and a greater awareness of comfort standards for social and business purposes, have combined to encourage methods of heating which provide constant equable temperatures and avoid condensation and permit a greater use of accommodation. That this change has been vital to the economy and health of the country can be seen from the fact that the cost of cleaning, maintenance and repairs and the resultant loss of efficiency in industry caused by air pollution amounted, a few years ago, to between £300* and £400 million a year. The cost of absenteeism from work due to medical care and expenses arising from this cause alone, is possibly as great or even greater than the direct loss referred to earlier.

We have calculated that in one city alone with nearly a $\frac{1}{4}$ million inhabitants, the benefits each year of maintaining the best environmental conditions within our reach would result in savings of the order given below:—

By the reduction of cleaning, maintenance and repair costs	£1,500,000
By obviating hypothermia in elderly people and infants	£ 100,000
By preventing loss of production plus medical expenses and care due to bronchitis alone	£1,500,000
By avoiding costs of wasted education and training due to premature deaths caused by pollution and underheated homes	£ 200,000
	<u>£3,300,000</u>

Present Practice in Supply of Energy

Coal

Coal is produced in Great Britain by the National Coal Board by deep-mining and to a lesser extent, by open-cast working. A relatively small amount of coal is produced by privately owned collieries (licensed mines) which operate under license from the N.C.B.

With the closing of uneconomical and worked-out mines the number of producing collieries has fallen from 958 at the end of 1947 to 376 on 31st March

* £ 1 = \$2.40 U.S. (1969)

1968; over the same period the output per man-year has risen from 262 tons to 414 tons with the introduction of mechanized coal-getting, and the total average manpower employed has fallen from 704 thousand to 392 thousand.² The cost of producing deep-mined coal, at the pithead, has risen from 41s.3d/ton in 1947 to 98s.5d/ton in 1966/67.³

Table III shows the total annual output of coal for selected years from 1947 to 1967/68.

The falling production of coal directly reflects the rapidly falling demand in all sectors of consumption except power stations. In 1965 the Government took steps to assist the coal industry by a capital reconstruction and other measures including preference for the use of coal, but the demand continued to fall rapidly. Coal is being replaced by more convenient fuels—oils, gas and electricity—in industry, transport and the home; and in the gas industry it is being displaced by oil or natural gas.

In 1957 consumption started to drop sharply, and it fell by nearly 30 million tons between 1956 and 1959. Competition from oil increased, and the Suez crisis stimulated the rapid development of oil production; oil import restrictions in the U.S.A. led to a flood of cheap oil into the Western European market, and the fall in oil prices encouraged conversion from coal to oil firing in industry.⁴ The Clean Air Act of 1956 gave further impetus to the fall in demand for domestic coal, and the decision by the railways to change from steam locomotives to diesel or electric propulsion further reduced the over-all demand.

At the present time the electricity industry is the largest consumer of coal, taking nearly 42 per cent of the total consumption in 1967-68, but its demand shows little change despite the increasing demand for electricity, because of the replacement of older plants by larger and more efficient units and the growing nuclear generating capacity.

Table IV shows the falling total demand and the pattern of demand by different categories of consumers.

We believe that the over-all demand will continue to fall. The demand for coal-fired domestic central heating we think will decrease, largely because of the inconvenience of fuel storage, and the dirt and labour involved with intermittent stoking and ash removal. The Coal Board and privately-owned marketing firms are doing their best to counter this by projecting a new and modern image for coal-fired boilers, including fluidised bed techniques for large boilers. Nevertheless, in most cases coal still remains marginally the cheapest fuel. The coal authorities are very active in promoting district heating and domestic systems on markets for their products. They have been quite successful in this and have so stimulated growth in district heating.

Table III—Total Annual Output of Coal^a

Year	Output (million tons)		
	*Deep-mined	Open-cast	Total
1947	186.6	10.2	196.8
1952	212.7	12.1	224.8
1957	210.1	13.6	223.6
1962	189.3	8.1	197.4
1967	165.9	7.1	173.0
1968	163.8	7.1	170.9

* Includes licensed mines

Table IV—Annual Coal Consumption in the United Kingdom by Class of Consumer

Year	Consumption—Million Tons ⁴								Total
	Elec- tricity	Gas	Coke Ovens	Do- mestic	Indus- trial	Miscel- laneous	Col- liery	Rail- ways	
1947	27.1	22.7	19.8	36.6	36.0	16.7	11.0	14.6	184.5
1951	35.4	27.4	23.4	38.0	40.9	17.8	10.6	14.3	207.8
1955	42.9	27.9	27.0	37.9	40.7	17.3	8.7	12.8	215.2
1959	46.0	22.5	25.7	33.8	31.6	14.2	5.5	10.2	189.5
1963-64	66.3	21.8	24.0	30.2	25.4	13.3	3.8	5.1	189.8
1965-66	68.1	17.5	25.6	27.5	23.7	13.0	3.3	2.4	181.1
1966-67	66.7	16.1	23.8	25.9	21.2	11.8	3.0	1.5	170.0
1967-68 ^a	69.2	13.6	23.1	24.3	20.0	12.1	2.8	0.6	165.7

Oil

In 1966 oil provided about 37 per cent of Britain's total energy requirements, compared with 15 per cent in 1957.⁵ There is a very small indigenous production of crude petroleum (87,000 tons in 1967) but this represents only about 0.12 per cent of the total supplies of crude and process petroleum.⁶

Both crude petroleum and refined products are imported, but refinery capacity is increasing and thus the proportion of imported refined products to home refinery output is falling.

The rising trends of crude petroleum imports, home production of refined products, and refinery output capacity are shown in Table V.

In the last decade sources of supply of crude oil have changed and diversified: in 1957, 70 per cent of imports were from the Middle East and 29 per cent from the Western Hemisphere, principally South America and the Caribbean; in 1967 only 60 per cent came from the Middle East and 16 per cent from the Western Hemisphere, whilst 20 per cent came from Africa (Libya and Nigeria).⁶

Inland deliveries of oil for energy purposes in the U.K. increased nearly 3½ times between 1957 and 1968—from 21.7 million tons to 74 million tons. Transport and industrial users were the biggest consumers, using between them 67 per cent of the total in 1957 and 62 per cent in 1968. The demand for domestic heating increased three times, though the percentage of total consumption fell from 3.7 per cent to 3.4 per cent. The greatest relative increase in consumption was in oil used by gasworks, which increased 17 times; its share of total consumption rose from 1.8 to 9.2 per cent.

Table VI shows the pattern of the increased demand for petroleum products for energy purposes.

Table V—Supplies of Crude and Refined Petroleum and Refinery Capacity^a

Year	Crude and Process Oils		Refined Products		Refinery Capacity
	Imported	Indigenous	Imported	Refinery Output	
	Thousand tons				Tons × 10 ³ year
1950	9,310	157	9,834	8,562	9,710
1953	25,655	159	6,250	23,393	28,855
1957	28,344	153	10,552	25,171	34,018
1962	52,540	127	14,569	48,131	51,776
1967	71,825	87	23,547	66,893	84,878

Table VI—Inland Deliveries of Petroleum for Energy Purposes⁷
(Million tons)

Year	Transport	Domestic	Gas-works	Industry	Power Stations	Other oil for energy purposes	Total
1957	9.80	0.80	0.4	5.58	0.7	4.42	21.70
1959	12.03	1.32	0.9	8.05	4.2	6.50	33.00
1961	14.60	1.64	1.1	11.64	5.7	7.02	41.70
1963	16.38	2.23	2.1	15.47	5.2	8.82	50.20
1965	18.93	2.19	3.9	19.47	6.3	9.71	60.50
1967	21.26	2.27	5.9	22.33	7.4	10.98	70.14
*1968	22.53	2.48	6.8	23.64	6.4	12.20	74.05
**1975	27.3	2.9	1.7	25.0	11.8	10.6	85.8

* Provisional

** Estimated

The increase in use of oil firing for domestic heating has been mainly among the larger individual central heating systems where it has replaced coal or coke. With the development of smaller vaporizing burners, the range has been extended downwards. Centralized schemes have involved either oil distribution from central storage to individual boilers or more recently, group heating from a central boilerhouse. This latter arrangement is now being fostered by the major oil companies, though it has not yet reached the scale of the Coal Board sponsored projects.

Gas

Gas is made and distributed by 12 Area Gas Boards in Great Britain. The Gas Council has an advisory and consultative responsibility and is also responsible for bulk supplies to the Area Boards of imported gas and North Sea natural gas. Some gas produced in coke ovens by the N.C.B. and the steel industry, and surplus to their own requirements, is purchased by Area Boards.

Although Area Boards set up their own "Gas Grid" pipeline networks to facilitate distribution and the economic use of plant in their own areas, a national bulk transmission system analogous to the electricity Grid System was not considered to be economic until it was required for the transmission to Area Boards of bulk supplies of natural methane imported from Algeria. This system and the additions to it for the transmission of North Sea gas are owned and operated by the Gas Council which purchases the gas from the producers and sells it in bulk to the Area Board.

In Great Britain in 1967-68, there were 192 gasworks in operation¹ at which town gas was made from coal or oil, or reformed from natural gas.

The total gas available in 1967-68 was 4,637.5 million therms, and total sales by the Area Boards amounted to 4,222 million therms. The annual demand for gas is estimated to be nearly nine thousand million therms by 1972-73⁸, stimulated by the availability of natural gas and the rising cost of coal as a primary fuel.

Until recent years, coal had been the major source of town gas, but in the 1950's oil became of increasing importance; with the rising cost of coal, oil is being used to a rapidly increasing extent but will in its turn be displaced by natural gas, either as a feedstock for gas reforming or supplied direct to consumers. The changing pattern of fuel usage is shown in Table VII.

The difference between gas made and gas available is accounted for by gas purchased, either manufactured gas (e.g. coke oven gas from the N.C.B. or the steel industry) or natural gas. Coke oven gas (409 million therms in 1967⁶) is likely as coal gas ultimately to be displaced by natural gas.

Table VII—Fuel Used and Gas Made in Great Britain^o

Year	Fuel Used			Gas Made		Gas Available
	Coal	Coke	Oil	Coal Gas	Total	
	Thousand tons			Million therms		
1943	20,732	731	191	1,427	1,618	1,851
1948	24,445	1,314	462	1,762	2,118	2,415
1958-59	24,179	1,439	669	1,848	2,309	2,839
1963-64	21,807	1,296	1,281	1,638	2,357	3,263
1966-67	15,905	717	3,492	1,152	2,632	4,114
1967-68 ^o	13,500	—	4,600	977	2,865	4,638

Table VIII shows the trends of gas consumption over the years 1961-62 to 1967-68 for Great Britain. During this period, the domestic consumption has very nearly doubled, whilst commercial and industrial consumption have increased by 35 per cent and seven per cent respectively. The high rate of increase of domestic consumption is in the main, the result of substantially increased sales of space heaters and central heating equipment (Table IX). Total demand is expected to rise to nearly 9,000 million therms by 1972-73, of which a little over half will be domestic.⁹ By 1972 the estimated total demand will be 13,300 million therms.⁵

Because of the rising costs of making gas from coal and oil, the Gas Council sought other sources of gas. Large quantities of natural gas (methane) were

Table VIII—Gas Consumption in Great Britain, 1961-62—1967-68^o

Year	Gas Sold—Million Therms			
	Total*	Domestic	Commercial	Industrial
1961-62	2,736	1,346	421	857
1962-63	2,923	1,493	460	852
1963-64	2,978	1,554	451	861
1964-65	3,189	1,727	471	915
1965-66	3,503	2,006	491	928
1966-67	3,774	2,267	521	908
1967-68	4,222	2,652	570	914

* The total includes approximately 60 million therms for Public Administration (including lighting) and a small amount used by Gas Boards for their own purposes.

Table IX—Gas Appliances Sold in Great Britain, 1961-62—1967-68^o

Year	Appliance Sales—Thousands				
	Cookers	Water Heaters	Space Heaters	Central Heating	
				Warm Air	Boilers
1961-62	582.5	207.4	326.4	15	22.5
1962-63	601.7	201.1	533.0	21	35
1963-64	669.0	219.0	744.1	30	60
1964-65	708.4	237.7	920.7	48	90
1965-66	665.0	241.8	991.5	62	123
1966-67	654.7	216.7	852.6	88	143
1967-68	745.1	225.5	879.0	106	177

available in Algeria, and following an experimental shipment of liquefied methane in 1960, a 15-year contract commencing in the autumn of 1964 was signed for the purchase of bulk supplies.

These supply arrangements have been largely overtaken by the discovery of natural gas under the North Sea. Exploration began in 1964, the first natural gas began to flow into the system in 1967, and a nation-wide main gas distribution system should be completed by 1973. This discovery is changing the whole system in U.K. from coal gas to natural gas. The appliances of all 13 million consumers in Great Britain have to be converted over a period of ten years and this will cost in the order of £400 million and the increase in gas-fired central heating has been enormous; approximately 600 per cent in six years. During the late 1950's and early 1960's, the coal, oil, and to a limited extent electricity interests, carried out major advertising campaigns to promote central heating. It was interesting that gas, with very little advertising, made by far the greatest gains; this may be a result of their competitors' promotion. Although the fuel is dearer than coal and oil, the cleanliness, convenience and lack of storage requirements of gas clearly were inducements to most domestic consumers. As yet no large district heating scheme is fired by gas. The bulk tariff for gas is dearer than either coal or oil. It is probable that within a few years gas may be competitive with coal and oil as a basic fuel and will then be used for district heating.

Electricity

In the early days of electricity supply, power was generated by small local stations close to the load centers. Undertakings were privately or municipally owned, and there was little or no interconnection between supply networks; each undertaking generated and distributed enough power for its own consumers. The small generating units were relatively inefficient, and each undertaking had to carry a high proportion of spare plant to cover breakdowns and maintenance. Each generating station had, at all times, to be able to generate the requirements of its own system.

Before the advent of the Grid about 70 per cent of spare generating plant was carried and most of the power used was generated by small and comparatively inefficient sets; larger and more efficient sets were not fully utilized.¹⁰

The original 132 kv Grid was constructed between 1928 and 1933. It was designed to inter-connect selected generating stations so that:

- (1) Spare plant in each area could be pooled
- (2) The most efficient generating sets in each area could be used to the maximum extent.

As a result, spare plant was reduced to 15 per cent and generating efficiency was improved, with consequent reduction in costs.

The construction, operation and maintenance of the National Grid was the responsibility of the Central Electricity Board, but the power stations connected to it were owned by the supply undertakings, who operated them in accordance with the Board's instructions and who also distributed power to consumers. Immediately prior to nationalisation on 1st April, 1948, there were some 560 separate supply undertakings in Great Britain: about two-thirds were owned by local authorities and the remainder by companies.¹¹

With the advent of nationalisation in 1948, the responsibility for generation and main transmission was separated from distribution. Fourteen Area Boards became responsible for distribution in England, Wales and Southern Scotland (the North of Scotland Hydro-Electric Board was responsible for generation and distribution in Northern Scotland), and the Generating Divisions of the British Electricity Authority assumed responsibility for generation and main transmission.

The CEGB transmission system is linked to the Scottish System, but the two are operated independently though in close cooperation.

All following data relate to England and Wales only, unless otherwise stated.

With increasing loads, the 132 kv Grid became inadequate and its extension at that voltage would have brought problems of load-sharing between multiple parallel lines. As a result, the 275 kv Supergrid came into existence in the 1950's with the primary object of permitting the pooling of generating plant on a national basis, rather than the regional basis which was the concept of the 132 kv Grid. It also facilitated the bulk transmission of power from the developing coal fields in the Midlands and the North-East to the areas in the South and North-West, where there was a growing deficiency between coal supply and power demand, and thus saved the higher cost of transporting coal by rail.¹²

With the continuing growth of load, further reinforcement of the transmission system became necessary, and the decision was made in the late 1950's to achieve this by the construction of a 400 kv Grid by the uprating of a number of existing 275 kv lines and the construction of new 400 kv lines. The first section was commissioned in 1965 and the system is now almost complete; it has largely superseded the 275 kv system for bulk power transmission, though the latter voltage is retained as a high power distribution system in large conurbations such as London, Birmingham and Manchester. The 132 kv network serves the same purpose in areas of less concentrated demand.

The 275 kv system is interconnected with the South of Scotland Electricity Board system at the same voltage, and with the 225 kv system of Electricité de France through the cross-Channel 200 kv d.c. link.

The CEGB Grid system is the largest system under unified control in the world.¹³ Table X shows its composition at 31st March 1968.

At 31st March 1948, there were 3,236 route-miles of 132 kv transmission lines and 437 route-miles of 66 kv and lower voltages.¹⁴

During each of the last two decades the demand for electricity has approximately doubled, as shown in Table XI.

Table X—National Grid System¹⁴
Route-Miles of Main Transmission Lines

	Operating Voltage				Total
	400 kv	275 kv	132 kv	66 kv & lower	
Overhead lines	1,294	1,543	6,023	70	8,930
Underground cable	2	105	671	256	1,034
Total	1,296	1,648	6,694	326	9,964

**Table XI—Total Installed Capacity and Maximum Output of
Generating Plant, and Units Sold¹⁵**
(England and Wales)

Year	Generating Plant			Units sold to Area Boards KWH $\times 10^6$
	Total Installed Capacity—MW	Maximum Output Capacity—MW	Maximum Demand Supplied—MW	
1947-48	11,680	10,362	8,607	35,658
1957-58	24,315	22,343	19,311	76,724
1967-68	45,020	41,944	35,818	156,398

In 1967, the demands in 1970 and 1975 for the United Kingdom as a whole were estimated at 207 million kwh and 285 million kwh respectively, compared with actual sales of 160.8 million kwh in 1966.

To satisfy this growing demand, a heavy capital expenditure on generating and transmission plant is necessary. The total net capital expenditure in the U.K. on plant and equipment, and new building and civil engineering work, rose from £136 million in 1950 to £711 million in 1966-67.³ At the end of 1967, a total of 35,000 MW of plant was under construction, of which 25,000 MW was coal-fired, 6,000 MW oil and dual-fired (oil or coal) and 4,000 MW nuclear.⁵

Most of the 25,000 MW of coal-fired plant under construction is situated on the East Midlands and Yorkshire coal fields. The new stations were planned in conjunction with the 400 kv Grid and when completed, they will fully load its north-south transmission capacity. If further generating plant were to be concentrated in this area, then additional transmission capacity would be needed. This need could be avoided by siting future power stations in or adjacent to the area of the demand which they are to meet.

The 6,000 MW of oil-fired and dual-fired plant is being built close to oil refineries. The cost of generation (with oil tax at the current rate of 2.2d/gal.) is expected to be below that of a modern coal-fired station.⁵

The installed capacity of nuclear generating plant at the end of 1967 was 3,635 MW, or two-thirds of the planned capacity of 5,000 MW by the end of 1969. The new stations now planned and under construction will be of the Advanced Gas Cooled Reactor (AGR) type and are expected to generate electricity at a cost less than that of even the most favorably sited coal-fired stations, and lower than the earlier Magnox-type nuclear stations. It is estimated that by 1975 the generating costs of AGR nuclear stations will approach those of a conventional steam station using untaxed oil (Table XII).

Relatively small amounts of electricity are generated by oil engines, gas turbines and hydro-power (mostly in the North of Scotland); with the advent of natural gas its use as a fuel for electricity generation, particularly in summer to reduce the seasonal variation in over-all demand for gas, is being considered, and a trial conversion of one boiler at a coal-fired station has been carried out.

Table XIII shows the output capacity of various types of generating plant and the types of fuel used in the U.K. at the end of 1966, and corresponding estimated figures for 1975.

For the year 1967-68 the total sales of electricity in England and Wales amounted to 150,467 GWh, accounted for by classes of consumer as in Table XIV¹⁴.

All the foregoing shows the tremendous expansion that has taken place in the last 20 years and indicates the great advances made in the technology of power production. It is interesting to reflect on the facts, however, that maximum thermal efficiencies are only approaching 40 per cent and in Moscow last year it

Table XII—Generating Costs of Nuclear and Conventional Power Station—1967^e
(Estimated)

	d/kwh
Nuclear	
Dungeness 'B'	0.52
Hinkley Point 'B'	0.48
Coal	
Cottam	0.53
Drax	0.56
Oil	
Pembroke (with tax)	0.53
Pembroke (without tax)	0.42

Table XIII—Output Capacity of Public Electricity Supply Industry in Great Britain^a

Fuel	Output—MW		Percentage of Total	
	1966	1975	1966	1975
Coal	31,700	53,000	73.7	72.0
Oil and dual-fired	5,300	10,000	12.3	14.0
Nuclear	2,800	6,000	6.5	8.5
Other	3,200	4,000	7.5	5.5
Total	43,000	73,000	100.0	100.0

Table XIV

	CWh	No. of Consumers— thousands
Domestic	56,376	15,803
Farm	2,669	263
Commercial	22,054	1,356
Combined Domestic/Commercial	2,423	221
Industrial	63,565	184
Public Lighting	1,185	5
Street Traction	34	} 0.012
Railways	2,161	
Totals	150,467	17,832

was said in discussion that utilisation is in the order of 40 per cent of the working life of a station. A current implication seems to be that a less advanced technology, coupled with the utilisation of waste heat (total energy), would reduce outage time and increase over-all efficiency. It is not suggested that such an implication is universally applicable but notwithstanding it cannot be overlooked, domestically or industrially.

Domestic Waste

Apart from the materials considered conventionally as fuels, thought is now being given to the use of refuse as a fuel. The spur to this consideration is not shortage of fuel, but primarily the need for alternative means of disposing of refuse. It is estimated that in Britain 18 million tons of refuse per annum is disposed of by local authorities with a heat content of 4000 Btu per lb. The standard method, and the apparently cheapest method of disposal is by tipping; that is dumping the refuse in marshy ground, worked-out quarries, or gravel pits, or land which generally has little economic or amenity value. This practice will probably continue, but in many districts it is becoming increasingly difficult to find any suitable sites for tipping. In a densely populated country like England, there is properly an immediate public outcry against loss of land having farming value or countryside amenity.

To cope with the refuse problem, the following alternatives to conventional tipping are being considered and indeed used:

- (a) Concentration of refuse by tearing, shredding and crushing to reduce the bulk, prior to tipping.
- (b) By treating the refuse to produce compost which can be sold for agricultural and horticultural purposes. Although this may seem logically a sound conception, to return material back to production as happens in the natural world, in practice it is not always economically justified. There are

views that the risk of toxic contamination in the compost makes it unwise to use it.

- (c) The third is incineration. This has the great advantage that the residual bulk is a very small proportion (about 10-20 per cent) of the original; it is sterile and will not contaminate water supplies. The earlier problems of smell and dirt nuisance, frequent breakdown of plant, and short life of plant due to corrosion and wear, have been almost entirely overcome.

In almost all existing refuse incineration plants in Great Britain the waste heat is not utilized. There are installations in Europe, some of which have been working successfully for many years, where the waste heat is produced for district heating. There are firm proposals for a combined refuse incineration-district heating scheme for Nottingham, a large city in the Midlands of England. In this scheme it is proposed to use the refuse (approx. 160,000 tons p.a. now estimated 190,000 tons p.a. in 1980) to provide a source of heat for a large district heating project which will serve shops, offices and dwellings in a large part of the centre of the city. The amount of heat from the refuse is estimated to be between 15 and 17 million therms per annum by 1980, and the waste heat boilers associated with the incinerators are rated at a total of 200 million Btu per hr. This capacity will deal entirely with the summer load, but in the winter will be supplemented by a conventional coal-fired boiler plant of a total capacity of 280 million Btu per hr. It is anticipated that about 60 per cent of the total heat supplied will come from refuse incineration.

Heat Meters

One of the major obstacles to the acceptance of district heating to dwellings has been reluctance on the part of the householder to pay the costs on a flat rate basis or as assessed by meters of dubious accuracy. We have, therefore, recently proposed a device which not only provides the householder with complete control over his expenditure on heat, but would permit of central recording if required.

The device comprises:

- (a) A programmer similar to that used in Britain on small gas boilers for space heating controlling the periods during which they are "ON" or "OFF."
- (b) Two motorised ON/OFF valves; one on the heating flow pipe and the other on the H.W.S.
- (c) Two hour counters to register the number of hours that each of the motorised valves is open.

The hour counters would only be operative while the valves were open, and the programmed hours of operation would be over-ridden by a room thermostat and a hot water supply thermostat on the storage cylinder.

All the equipment required is readily available and well proven in reliability, and the programmer and hour counters would be mounted on a small panel in, say, the kitchen of each house. The householder would be charged on the basis of number of hours recorded against a fixed rate per hour. Such a system would be economically viable for a town or city of say 20-40,000 houses, enabling the units to be mass produced and we estimate the cost to the contractor would then be about £20 each. Of course, the device would impose certain controls over the design and operation of the district heating network but these need not be very onerous.

Use of Resources

The United Kingdom gas and electricity supplies are produced and transported by the Nationalised Industries and, as a consequence, when a supply is made available to provide either fuel to a house, estate or town the capital cost is borne by the Supply Authority and the amortisation and interest on the capital are re-

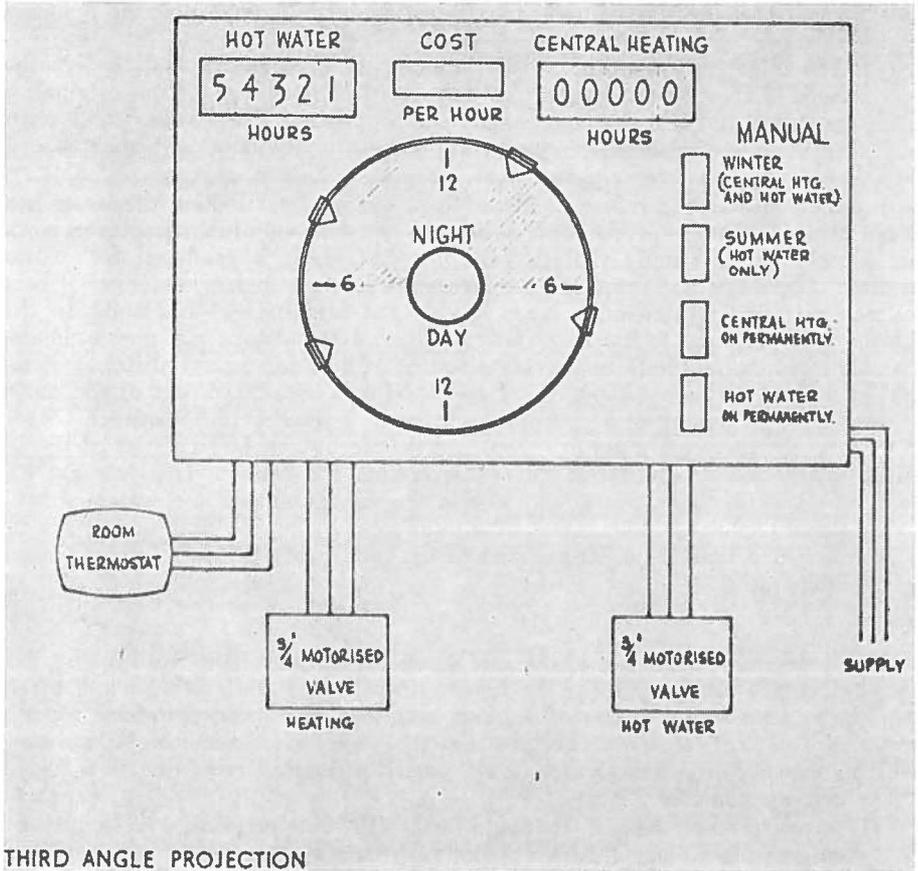


FIG. 1

flected in the tariff to the individual householders or users. On the other hand, if a Local Authority wishes to proceed with district heating to a new conurbation or to the town as a whole, it has to raise the capital for the installation, and this becomes a direct capital charge against the town itself. Again, the interest and amortisation costs would be reflected in the cost of heat to the tenant, but on the other hand the reaction of a Authority could well be that if it has to raise, say, another £1m for district heating it could help solve social problems by the alternative technique of building more houses with the £1m and taking fuel supplies from the Electricity and Gas Authorities where no capital charges are raised against the Town.

These considerations may well have deflected Town Councils and others from adopting the over-all economic solution, when economics are considered in the national as distinct from the parochial sense, and may have resulted in national resources not being properly evaluated. It seems to us that resources demand a great deal more consideration. As an example, normally the use of waste for incineration and the promotion of heat is regarded as a straight comparison between fuels, i.e., waste and coal or gas, whereas, of course, with incineration resources are saved in the conservation of land which in the U.K. can cost between £400 an acre for agricultural land and maybe £10,000 an acre for build-

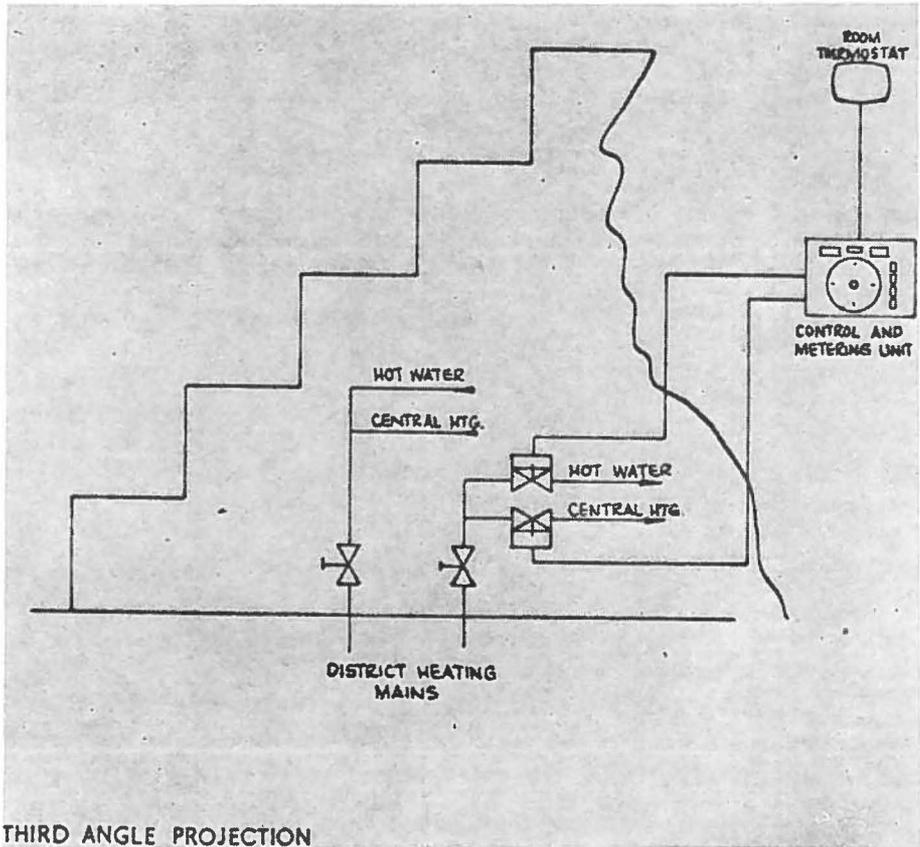


FIG. 2

ing land. If resources were more deeply considered in the context of the use of incineration, it might well be that this would prove to be even more profitable if waste materials were piped to the incineration plant incorporated in common trenches with all other services, thus saving the collection of waste, the use of manpower, and congestion on roads. It seems to us that all these factors are given less consistent consideration than should be the case, and we are motivated in this by the thought that any man in terms of capital expenditure is worth £20,000 or £30,000 equivalent, and that it is incumbent upon us not to waste such a resource but to put it to useful social and profitable activity. Vickers, in November 1968, in a paper to the Institution of Mechanical Engineers entitled "The Engineer in Society" indicated how a proper examination of manpower resources can transform results based on straight financial economic considerations. Table XV abstracted from that paper illustrates what we mean.

The Future—A Rational Approach

The production and use of heat must be considered not as a problem for the individual, but one for the community. It follows, that as electricity and heat are representative of energy and that modern life is sustained by both, neither should be considered in isolation. We further take the view that no source of energy should be wasted and hence domestic waste must be considered as a fuel.

Table XV—Manpower, Money and Productivity Concerning The Generation of 2,400 MW of Electric Power Based on Coal, Nuclear (A.G.R.) and Hydroelectric Energy

	Coal-fired similar to Longannet	Nuclear of A.G.R. type	Hydroelectric as per W. A. C. Bennett
Cost per kilowatt hour	0.57d	0.52d	0.44d (4.4 mills)
Estimated capital cost in:			
£ millions	116	228	310 (\$725 million)
man years	46,400	91,200	86,000
Replacement life of station for purposes of economic appraisal	25 years	20 years	75 years
'Amortization' or replacement requirement per year	1850 men	4560	1150 men
Estimated operating cost in manpower:			
station staff	550 men	600 men	50 men +
fuel supply	10,000 men*	1100 men	0 men
<i>Some "vital statistics"</i>			
Over-all cost in terms of manpower resources required	12,400 men	6260 men	1200 men
Manpower available for increasing G.N.P. by producing goods and services other than electric power	0 men	6140 men	11,200 men
Average output per person in industry	£1,300 p.a.	£1,300 p.a.	£3,300 p.a.
Potential increase to G.N.P. based on full effective employment and use of available technologies is	£0 p.a.	£7,982,000 p.a.	£36,960,000 p.a.
Potential advantage of capital-intensive power generation over 20 years	£0	£159 million	£739 million

* This figure could vary considerably, depending on a variety of factors

+ Initially requires 30 men

We consider that whilst conventional financial economics in the purest sense must always play a part in decision making, the use of resources must come to greater consideration. The time is not ripe yet for wasting the energy and capacity of man on the earth on which we live and so, until that time comes men and materials should be used to the greatest productive end, which might not always be the most financially attractive way.

We suggest too that the time to look at the electricity and heat requirements of a new town is at the inception of planning and if these are associated with other issues—utilities, waste disposal, communications and the like—there are opportunities for rationalisation in services, and economies in capital and maintenance costs.

Acknowledgments

This paper is a personal assessment of the situation in the United Kingdom and the views expressed are solely those of the authors.

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