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CHAPTER 3

Output

IN 1940 THE MANUFACTURED GAS INDUSTRY earned some $379 million from the sale of 390 billion cubic feet of gas to over 10 million customers. Though it still holds a key position in American economic life, it has in recent years been outstripped by natural gas, which in 1940 earned $493 million from the sale of 1,442 billion cubic feet of gas to 7.8 million customers.

Before the two industries can be compared, the limits of each must be defined precisely, for there is a wide area in which they can overlap. Natural gas may be purchased and distributed by plants that also manufacture gas for distribution. Shall such plants be classified as manufacturing or distributing? The Census of Manufactures has attempted to confine its canvass to plants whose activities were deemed to be predominantly manufacturing. With the growth of natural gas production and the practice of distributing manufactured and natural gas mixtures, the Census, especially since 1929, has found it more and more difficult "to obtain figures that did not include data for the distribution and the mixing of gas".[1] Rather than include data for plants whose operations it regarded as nonmanufacturing, the Census of Manufactures stopped canvassing the industry in 1937.

The American Gas Association has defined the manufactured gas industry in such a way as to give a continuous picture of its activities since 1929, when definition became difficult. It classifies a plant as manufacturing if, in effect, about one-quarter of the gas distributed

[1] *Census of Manufactures, 1939*, II, Part I, p. 3.

is manufactured in the plant.[2] The AGA definition allows plants to be included in the manufactured gas industry the Census would classify as 'nonmanufacturing'. The difference in the coverage of the two series in 1929, however, is not great. After 1929, the Census coverage shrank rapidly, until by 1935 its definition proved impracticable. We therefore trace the industry's movements since 1929 with AGA data. The marked tendency since 1929 for plants to cease manufacturing and turn to the distribution of natural gas means that the indexes considered below are for groups of establishments whose number in recent years has declined. Plants taking up the distribution of natural gas as their major activity, in terms of either the Census or the AGA definition of what constitutes a 'major' activity, quit the gas manufacturing industry to enter the natural gas industry.

1 Physical Output in the Manufactured Gas Industry

The relative decline of the manufactured gas industry evident in the difficulties of definition emphasizes the twofold character of its output. Like the electric light and power industry, it is engaged in both manufacturing or processing activities (i.e., the production of gas and the blending of purchased gas) and distribution activities — its 'service' function. The rapid increase in natural gas for urban consumption has favored its distributive function at the expense of its manufacturing. As noted, the Census Bureau recognized this shift in emphasis when in 1937 it dropped the industry from the Census of Manufactures, after having listed it since 1849.

The physical output of the manufactured gas industry is meas-

[2] It is simple to classify a gas plant that is engaged in the distribution of either manufactured or natural gas; difficult when it distributes both. When it distributes both in a pure form (e.g., a manufactured gas plant sells purchased natural gas to a large industrial consumer) the AGA allocates the natural gas sales to the natural gas industry, and also estimates the revenues, employment, etc. associated with such sales. Such a procedure in effect splits the plant into two establishments.

Classification is more complicated when a plant distributes a manufactured and natural gas mixture. The AGA frequently classifies plants as 'manufacturing' if the heat content of the final gas mixture is less than 900 Btu. per cu. ft. Since the heat values of manufactured and natural gas, as determined by the Bureau of Mines, are respectively 575 and 1075 Btu. per cu. ft. (though the Btu. values of gas produced and delivered by utilities may be somewhat lower than the laboratory standards), such a criterion is equivalent to regarding a plant as manufacturing if about one-fourth of its final product is manufactured gas. However, the AGA stressed that such a rule could not be applied mechanically; many decisions had to be based on "an intimate knowledge" of a company's history and current operations.

ured by cubic feet of gas sold (i.e., sold and delivered to the point of consumption). The quality of the unit product may differ widely with respect to both the manufacturing and distributive aspects of the industry's activities. Quality differences in the manufacturing sphere may arise because the heating and illuminating value of various kinds of gas may vary with differences in chemical composition. For example, 41.4 percent of total gas produced or purchased by the industry in 1940 consisted of water gas, 35.5 percent of coke-oven gas, 14 percent of natural gas, and the remainder of small quantities of retort coal gas, oil gas, butane-air gas, oil refinery gas, and reformed natural and oil refinery gas. The chemical differences in these various gases arise mainly from differences in gas-making processes. The choice of process depends in turn on cost rather than demand factors. The several processes call for varying ratios of capital equipment to materials consumed and different kinds of fuel. Gas manufacturers naturally use the methods most suitable to their particular locale and situation. Although the manufacture of several kinds of gas may make for differing unit costs, and therefore presumably differing prices to consumers, we do not have all the value and price data requisite to give each its proper weighting. Price data for 1909–25, collected by the Census of Manufactures, indicate that the differences in the prices charged for the various gases except coal gas were relatively slight. The latter is manufactured by the oldest and generally costliest of gas-making processes, and its selling price may be somewhat higher than the average.[3] However, since 1900 it has not been a large component of total manufactured gas.

In the distribution side of the manufactured gas industry, on the contrary, the quality of output differs widely. As in electric light and power, the differential unit costs occasioned by the different conditions under which service is rendered the several consumer groups (such as variations in the 'load' and 'diversity' factors, see Ch. 1, Sec. 1) are reflected in differential unit prices. Our measures of output take account of these differences (Table 22).

In 1940 gas for domestic use cost the average consumer $1.30 per thousand cubic feet; the rate for gas for house heating, industrial,

[3] E.g., in 1925 straight coal gas was sold at an average rate of $1.68 per th. cu. ft., when other rates reported were water gas, $1.22; mixed coal and water gas, $1.02; oil gas, $1.20; and other gas, $0.82 per th. cu. ft. The average price for all gas sold was $1.10 per th. cu. ft., which reflects the dominant influence of the water gas component (*Census of Manufactures, 1925*, p. 784).

TABLE 22

Manufactured Gas, American Gas Association Data, 1940
Sales for Domestic and Other Uses

	DOMESTIC	HOUSE HEATING	INDUSTRIAL & COMMERCIAL	MISC.	TOTAL
Sales, bil. cu. ft.	199	68	120	2	390
Revenue, $ mil.	258	43	76	1	379
Price per th. cu. ft.,	1.30	0.63	0.64	0.62	0.97
Customers, th.	9,405	305	448	9	10,167
Av. sale per customer, th. cu. ft.	21.1	224.6	268.1	251.1	38.3

American Gas Association, *Statistical Bulletin 44*, Annual Statistics of the Manufactured Gas Industry in 1940, Oct. 1941, p. 3. The above data include 58.7 bil. cu. ft. of natural gas bought for distribution. When the reporting company offers a special rate schedule for cooking and house heating gas together, the AGA usually tabulates such sales as 'house heating', though small quantities of gas for cooking sold at the special house heating rate are included.

commercial, and miscellaneous uses averaged about half as much. Principle uses for gas in the household now include cooking, refrigeration and water-, space-, and house heating. In the past gas was extensively used in residences for lighting, and, for short experimental periods, also in the operation of such laundry appliances as gas irons and gas mangles. New fields for domestic gas are afforded by the modern gas rotary tumbler clothes dryer, a recently developed incinerator, and air-conditioning. Commercial consumption of gas in large quantities is for volume cooking by hotels, restaurants, clubs, hospitals, schools, and industrial kitchens. In addition, manufactured gas is widely used in many industrial processes requiring the application of heat in precise and flexible quantities, e.g., the preparation of foods, firing kilns, and metal processing operations.

The classification of sales as domestic, commercial, and industrial is fairly recent. Total sales have been divided into such categories since 1919 (Table 24) but not until the late 'twenties were differential rates generally set for different consumer groups.

2 Output of Manufactured Gas, 1899–1929

Because of the shift in emphasis from the manufacturing to the distributive function we divide the history of the manufactured gas industry at 1929 (Table 23). As mentioned, the Census tried at all times to exclude from its canvass plants engaged predominantly in the distribution of gas purchased from other companies. But after

TABLE 23

Manufactured Gas, Census Data, 1909–1929

Relation of Gas Purchased to Gas Produced (billions of cubic feet)

		1909	1914	1919	1921	1923	1925	1927	1929
1	Total produced & purchased	152.6	204.8	344.1	334.0	386.5	395.5	445.5	450.7
2	Produced in industry	135.8	176.4	277.0	289.3	295.9	331.0	348.8	347.5
3	Total purchased	16.8	28.4	67.1	44.7	90.6	64.6	96.6	103.2
4	Purchased outside industry	...	...	37.1	14.5	54.4	42.8	77.1	97.9
5	Purchased within industry	...	...	30.0	30.3	36.2	21.7	19.5	5.3
6	Percent purchased to total produced & purchased	11.0	13.8	19.5	13.4	23.4	16.3	21.7	22.9
7	Percent line 4 is of line 1	...	...	10.8	4.3	14.1	10.8	17.3	21.7
8	Percent line 5 is of line 1	...	...	8.7	9.1	9.4	5.5	4.4	1.2

Successive Census of Manufactures reports on Gas Manufacturing.

1919 even plants included in the Census canvass purchased more and more gas. Consequently, we have taken some pains in Table 23 to measure the increasing proportion of purchased gas since 1909, when the Census began to take note of it. Purchased gas rose from 11.0 percent of total gas purchased and produced to 22.9 percent in 1929. Most of it was bought outside the industry, i.e., from coke-oven plants and natural gas companies. Constituting more than one-tenth of the total purchased and produced in 1919, it doubled by 1929. Gas purchased within the industry, that is, from other manufactured gas plants, declined sharply, making up 8.7 percent of the total in 1919 and 1.2 percent in 1929. However, despite its small amount in 1929, gas purchased within the industry complicates the problem of measuring the industry's output because purchases are duplicated in the sales total. Such intra-industry purchases should be excluded from total gas sales, as they are accounted for at the point of sale to ultimate consumers. Accordingly, we have made adjustments to exclude from the industry totals the quantity and value of gas purchased within the industry 1919–29 (Table 24).

We present also Census data showing the movement 1899–1929 of the average price per thousand cubic feet of gas sales for all uses, i.e., domestic, commercial and industrial, including intra-industry (Table 24). Fluctuations in this price reflect factors other than rate schedule revisions; e.g., variations in the proportions sold to different consumer groups and to other plants within the industry. On the whole, the average price, which before 1921 was more often than not less than $1 per th. cu. ft., and in 1921–29 fluctuated somewhat above this level, changed little between 1899 and 1929. Since 1919, when we can isolate the influence of intra-industry sales, no very marked upward or downward trend can be discerned. The

TABLE 24

Manufactured Gas, Census Data, 1899–1929 Sales: and Indexes of Output (1929:100)

	1899	1904	1909	1914	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
Gas, incl. all purchased gas															
Quantity, bil. cu. ft.	67	113	151	204	308		306		357		359		412		408
Revenue, $ mil.	69	113	139	175	282		372		395		396		446		438
Av. price, $ per th. cu. ft.	1.04	1.00	0.92	0.86	0.92		1.22		1.11		1.10		1.08		1.07
Gas, excl. gas purchased within the industry [a]															
Quantity, bil. cu. ft.					281	285	278	296	323	333	339	374	394	397	404
Revenue, $ mil.					267		357		377		386		438		436
Av. price, $ per th. cu. ft.					0.95		1.28		1.17		1.14		1.11		1.08
Gas, by type of use [b], *bil. cu. ft.*															
Domestic					} 204	214	209	220	234	239	242	265	{ 265	261	258
Househeating													{ 11	14	18
Industrial & commercial					66	62	60	68	78	87	91	104	114	118	126
Misc.					11	10	9	8	12	7	6	5	5	3	2
Byproduct coke															
Quantity, mil. sh. t.		1.78	1.64	2.28	2.46		2.03		2.17		2.40		2.98		3.44
Revenue, $ mil.		5.20	5.72	8.72	17.8		17.5		21.5		20.7		25.5		26.9
Av. price, $ per sh. t.		2.91	3.49	3.82	7.25		8.62		9.90		8.64		8.57		7.80
Byproduct tar															
Quantity, mil. gal.		68	92 [c]	126	120		114		109		125		162		164
Revenue, $ mil.		2.1	2.2 [c]	3.2	4.7		5.4		5.0		6.1		8.2		8.2
Av. price, ¢ per gal.		3.1	2.4	2.6	3.9		4.7		4.6		4.9		5.1		5.0
Indexes															
Unweighted [d]	16.4	27.6	36.9	49.9	75.5	76.9	74.9	79.8	87.3	88.3	88.0	96.4	100.9	100.3	10.00
Weighted [d]	15.6	26.6	38.0	52.8	71.2	71.6	69.2	73.2	79.5	82.0	83.6	92.2	97.3	98.2	10.00

The data for 1899, 1904, 1914, 1919, and the odd-numbered years in 1919–29, are from successive Census of Manufactures reports. Data for the even-numbered years in 1920–28 are based on figures published by the American Gas Association, adjusted to conform to Census coverage.

[a] To avoid duplication in the industry sale totals, the quantity and value of gas purchased within the industry have been estimated and excluded. See Appendix Table A9.

[b] The Census of Manufactures did not segregate gas sales by type of use before 1927; for our division, see Appendix Table A10.

[c] Includes 13.8 mil. gal. for which no value was reported, and to which we assigned the unit value reported for other byproduct tar sales.

[d] See Appendix Tables A8, 9, 10, 11, and 12 for details underlying the computations of the output indexes.

average price to ultimate consumers was $0.95 per th. cu. ft. in 1919, rose to a peak of $1.28 in 1921, then declined to $1.08 in 1929.

For the years since 1919, the shifts in gas sales to various consumer groups can be evaluated with the help of American Gas Association estimates of the percentages of total sales to be attributed to domestic and other uses (Table 24 and App. Table A10). In 1919 the low-valued sales for industrial and commercial use were 23.5 percent of total sales, declined to 21.6 percent in 1921 (explaining in part the rise in the average price to all consumers from 1919 to 1921), then increased to 31.1 percent in 1929; meanwhile the over-all average price declined. The high-valued domestic category (i.e., domestic and house heating) moved inversely, declining from 72.8 to 68.5 percent.

These shifts between 1919 and 1929 are reflected by our weighted index of output (Table 24), in which, in the absence of the biennial price data for each consumer group, the average prices prevailing in 1929 are used as weights. The weighted index should also take account of other products of the industry, including byproduct coke and tar, for which we have quantity and value data back to 1904. Such byproducts are not inconsiderable: in 1929 their sale constituted 7.3 percent of the total value (excluding duplications) of the industry's output. Applying the Edgeworth formula, and adding the (weighted) quantities of gas sold for domestic, house heating, commercial and industrial, and miscellaneous uses to the (weighted) quantities of byproduct tar and coke sold, yield an index of weighted output (Table 24), which is interpolated for the even-numbered years between 1919 and 1929 on the basis of AGA annual data.[4] From 15.6 in 1899 the index rises steadily to 100 in 1929; or at an average annual rate of 6.4 percent.

The rapid growth in the production of manufactured gas since 1899 is attributable mainly to the great change in the nature of domestic demand for gas. Throughout the latter half of the 19th century manufactured gas was the chief means of artificial illumination. Since no other large use for gas was then foreseen, gas manufacturers were apprehensive over the increasing threat presented by the Edison electric incandescent lamp. It is easy to see why the electric

[4] A further adjustment was introduced to take account of the output of products not listed in Table (see App. Table A12). The total value of products in 1929, excluding duplications, was $478.2 million.

incandescent lamp quickly commended itself to domestic consumers, for electricity was safer, better, and became even cheaper than gas as an illuminant.[5]

To meet the competition from central electric stations, manufacture of the Welsbach incandescent gas mantle was begun in the last decade of the 19th century. While the incandescent mantle marked a great advance in efficiency, enabling the gas industry to keep pace with electric competition for a time, a new field for gas consumption soon had to be found. With the help of stove manufacturers the industry won the public over to cooking by gas. In 1914 the Census reported over five million gas stoves and heaters in use. Meanwhile the consumption of gas for lighting purposes shrank to negligible proportions, particularly after 1919, when commercial and industrial consumption began to expand rapidly.

Some observers believe the expansion of gas consumption was retarded in the early years of the century because the principle of differential rates was not generally accepted. Until the electric lamp threatened competition, gas was usually sold at straight line rates, which offered little inducement to consumers to increase their consumption. As late as 1914, of 161 companies questioned by the National Commercial Gas Association 48 sold their gas at a uniform rate, i.e., with no premium for bulk consumption.[6]

Differential rates have since been introduced generally. By 1919, when 27.2 percent of total sales went to nondomestic consumers, the industry by and large recognized that the individual requirements of nondomestic gas consumers were sufficient to warrant special discounts. Not until 1927, however, was the Census able to separate the quantity and value data on sales for domestic, house heating, industrial, and commercial purposes.[7] In 1929 the average price of

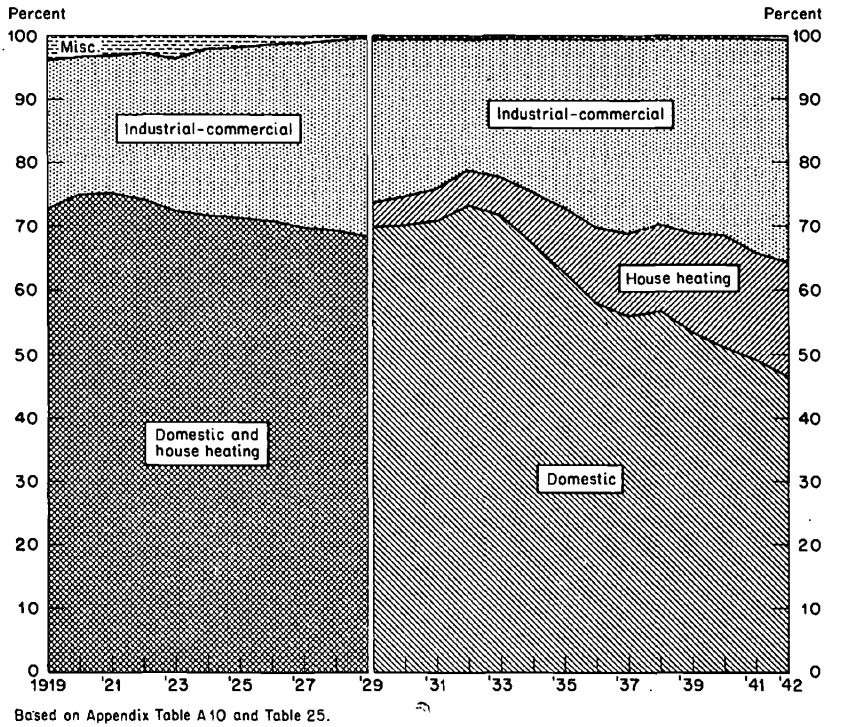
[5] The gas illumination of the closing years of the century has been described as follows: "The burners in use were open jets giving a yellow flame. Gas pressures were neither constant nor consistent. When turned on full, more often than not the gas jet emitted a sharp piercing whistle and the impinging flame cracked globes at a rate that proved a boon to the glassware manufacturers. Incidentally these high pressures boosted the amount of the gas bill to such an extent that a goodly portion of the citizenry, when paying their gas bills, did so with much protest, privately and in public." Louis Stotz and Alexander Jamison, *History of the Gas Industry* (privately published, 1938), pp. 108–9.

[6] *Ibid.*, p. 236.

[7] In constructing the weighted output index for 1919–29 (Table 24) we used 1929 price weights based on AGA rather than Census data, because the division of sales into the several consumer groups is based on AGA estimates.

CHART 11

Manufactured Gas, 1919–1942
Relative Consumption by Domestic and Other Consumer Groups



Based on Appendix Table A10 and Table 25.

gas sold for domestic uses other than house heating was some 40 percent higher than the average price paid by all other consumers (Table 25).

The relatively low-priced industrial and commercial component of total sales had, by 1929, gained at the expense of the domestic and miscellaneous components (Chart 11). The Census of Manufactures did not report many more stoves and heaters in use in 1919 than in 1914; gas cooking had become fairly widespread and further increases in the sale of gas for cooking were held pretty well within the limits imposed by population growth. In addition, gas was not used much in domestic lighting in the '20's, and sales for house heating uses had not yet become large. Nevertheless, because the differential price spread is not very wide, the relative decline of the higher priced domestic component of total sales has slight effect on the *weighted* index of output. Thus, 1929 price weights (which un-

doubtedly overstate the degree of price divergence 1919–29) yield weighted gas sales aggregates that increase 41.8 percent during the decade, as compared with a 43.6 percent increase in total sales (excluding intra-industry duplications). Evidently for these years shifts among the components of total sales do not greatly affect the measurement of output. However, the trends established early in the '20's become, as we shall see, firmly entrenched in the '30's. An unweighted index of output, based on aggregate gas sales 1899–1929, is included in Table 24 in order to evaluate the various refinements underlying the construction of the weighted output index. The two indexes diverge slightly, especially after 1914. The secular trends indicated by the two indexes for the entire 30 years, however, are not dissimilar: the unweighted index rises somewhat less rapidly than the weighted.

3 Manufactured Gas Output since 1929

The output data for the manufactured gas industry since 1929, collected by the American Gas Association (Table 25), may be regarded as constituting an extension of the Census data considered in the preceding section, because, aside from slight differences in coverage in 1929 (see App. Table A15), the Census and the AGA have adhered to a similar basic definition of the industry, in that plants were excluded when they ceased manufacturing and confined themselves to distribution. The AGA, moreover, excluded plants that left the manufactured gas industry not only for the year in which they ceased their manufacturing activity but for all years back to 1929 as well. This reclassification yields, each year, a series the AGA describes as giving "a comparable and consistent picture of the operations of an identical group of companies". Such a group manufacturing gas in, say, 1942, excludes plants no longer manufacturing gas even though they may have been large producers in preceding years. Rather than focus attention on a fixed group of plants, we follow the Census practice and adopt the broader, albeit changing, definition of the industry. Thus, we use the American Gas Association data for successive years, each set of which represents all plants actually engaged in manufacturing in one year regardless what they did before or after (Table 25).

The weighted index of output (Table 25 and Chart 12) shows some evidence of secular decline during the '30's, despite the cyclical upturn after 1939 which does not quite cancel the nearly 20 percent

decline in the middle '30's. However, that a large part of the post-1929 decline is due in part to the inter-industry shift to natural gas is evident from the 8.5 percent increase in the weighted index of output 1929–42 for the fixed group of plants representing the manufactured gas industry of 1942 (cf. Table 25, note).

Another factor contributing to the post-1929 decline is the continuation of the shifts among the components of total sales, already noted for 1919–29 (Chart 11). The percentage of total sales contributed by domestic consumption (mainly for cooking and refrigeration) declined much more precipitously after 1929 than in the preceding period — from 70.1 to 46.4 percent in 1942. Gas sales for house heating emerged as a component in its own right, its share of total sales rising from 3.6 to 18.0 percent. The percentage share of the other relatively low-valued component, industrial and commercial sales, also rose — from 25.8 to 34.8. The effect of these shifts on the weighted output index, reinforced by the widening divergence between the average price for domestic sales and for the other sales groups, is evident when the movements of the weighted output index are compared with an unweighted index based on total sales (Table 25 and Chart 12); the latter increases 9.8 percent 1929–42, while the former falls about 3 percent.

By splicing the indexes constructed for the periods before and after 1929 (Table 26) we can trace the movement of the output of the manufactured gas industry during the entire period under review [8] (Chart 12). A logarithmic parabola fitted to the weighted output index, which helps to summarize the trend of movement, reveals a marked retardation of growth [9] sustained for a period long enough to suggest that the industry, as we have narrowly defined it, has ceased to grow, if it has not already entered a stage of secular decline. Its growth may of course be stimulated by changes in future demand and by the possible ultimate depletion of natural gas resources. As we have seen, the nature of the demand for manufactured gas has changed completely since 1899. While no revolutionary innovations similar to the replacement of lighting by cooking

[8] Splicing the segments before and after 1929 introduces an element of discontinuity due to the different industry definitions underlying the segments. This discontinuity seems unavoidable, but is believed to be slight because of the close agreement between the Census and AGA coverage in 1929 (see note to Table 25).

[9] The annual rate of retardation, as indicated by the parameter b in the formula $y = ka^x b^{x^2/2}$, is −0.29 percent (see note to Table 41 and App. D).

TABLE 25

Manufactured Gas, American Gas Association Data, 1929–1942

Sales and Indexes of Output (1929:100)

Quantity, bil. cu. ft; Revenue, $ mil; Price, $ per th. cu. ft.

		1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
Total	2	401	403	391	359	340	347	354	343	351	349	362	390	406	440
	R	444	447	435	411	378	375	372	358	360	360	365	379	388	411
	P	1.11	1.11	1.11	1.15	1.11	1.08	1.05	1.04	1.03	1.03	1.01	.97	.96	.93
Domestic	2	281	283	277	263	243	233	223	198	195	197	193	199	199	205
	R	340	342	335	325	298	288	279	259	257	258	255	258	260	267
	P	1.21	1.21	1.21	1.24	1.22	1.24	1.25	1.31	1.31	1.31	1.32	1.30	1.31	1.31
Househeating	2	14	18	20	20	21	29	35	41	46	48	56	68	67	79
	R	12	15	16	15	15	19	23	26	29	31	36	43	43	51
	P	.85	.83	.81	.77	.70	.67	.65	.64	.63	.65	.64	.63	.65	.65
Industrial-commercial	2	103	100	92	74	74	84	94	102	107	101	111	120	137	153
	R	90	88	82	69	64	66	68	71	73	70	73	76	83	91
	P	.87	.88	.89	.94	.87	.78	.72	.70	.68	.69	.66	.63	.61	.59
Miscellaneous	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
	R	2	2	2	2	2	1	2	2	1	2	1	1	2	2
	P	.86	.82	.78	.73	.75	.72	.70	.69	.70	.68	.66	.62	.61	.58
Indexes															
Unweighted		100.0	100.5	97.5	89.5	84.6	86.6	88.3	85.6	87.4	86.9	90.3	97.1	101.2	109.8
Weighted		100.0	100.6	98.0	90.6	85.4	85.9	85.9	81.0	81.9	81.9	83.6	88.5	90.9	96.8

NOTES TO TABLE 25

Data for 1932–42 are from successive annual statistical bulletins published by the American Gas Association since 1931; data for 1929–31, from AGA *Statistical Bulletin 10*, October 1932, p. 4. The data for each year are only for plants manufacturing in that year except in 1929, 1930, and 1931, when the data are for plants manufacturing gas in 1931. In *Statistical Bulletin 52* (October 1943, p. 4) the AGA presents similar data for 1929–42 for the group of plants manufacturing gas in 1942, which exclude the operations of any plants that ceased to manufacture gas and so left the industry during 1929–42. The data for the plants defining the manufactured gas industry in 1942 thus "present a comparable and consistent picture of the operations of an identical group of companies over the fourteen year interval". The weighted index of output for these plants, computed in the same manner as the weighted index in the table, is as follows: 1929, 100.0; 1930, 101.0; 1931, 98.6; 1932, 91.2; 1933, 86.4; 1934, 88.0; 1935, 87.9; 1936, 88.9; 1937, 90.0; 1938, 90.7; 1939, 92.7; 1940, 98.5; 1941, 101.3; 1942, 108.5.

The data in Table 25 may be compared with the corresponding data for companies reporting to the Census of Manufactures in 1929, 1931, 1933, and 1935 (see Appendix Table A15). It is evident that the difference between the coverage of the two samples in 1929 was not large. The ratio of the 1929 AGA figure for total sales to the Census, excluding sales to other gas plants, was .994; the ratio for total revenue, 1.019. We would expect the AGA coverage to be somewhat broader than the Census because by definition, the AGA would include some plants whose activities would be deemed by the Census to be mainly distributive (see Ch. 3, note 2).

After 1929 both the AGA and the Census coverage narrowed considerably as plants turned from gas manufacturing to distribution. The decline in the Census coverage was more drastic than in the AGA; the ratio of AGA sales to that of the Census rose from .994 in 1929 to 1.135 in 1935. The Census definition of the industry proved impracticable as the purchase of natural gas by gas manufacturing plants became widespread. On the other hand, the AGA definition, which in practice excluded plants only when they abandoned all gas manufacturing activity, makes for a greater degree of continuity and facilitates the measurement of manufactured gas output in the years after 1929.

The computations underlying the construction of the weighted index are described in Appendix Table A16. The unweighted index is based on total gas sales.

seem imminent, it would be foolhardy to predict flatly that demand for manufactured gas will decline.[10] The wide variety of uses in manufacturing industries suggests that new industrial outlets may in time be opened; e.g., in commercial refrigeration and in domestic and commercial air conditioning.

Since the decline in the consumption of manufactured gas may be traced directly to its replacement in recent years by natural gas, it may well be that its future depends upon what happens in the natural gas industry, to which we now turn. Indeed, it must be emphasized that the 'decline' or retardation of growth indicated by our

[10] Thus, there is no clear-cut evidence of a decline in the demand for manufactured gas in areas where natural gas is not available, as indicated by a weighted output index, 1929–42, computed for a fixed group of companies engaged in gas manufacture in 1942 (see Table 25, note). By 1941 these companies had slightly exceeded their 1929 production.

CHART 12

Manufactured Gas, 1899–1942
Unweighted and Weighted Indexes of Output
(1899:100)

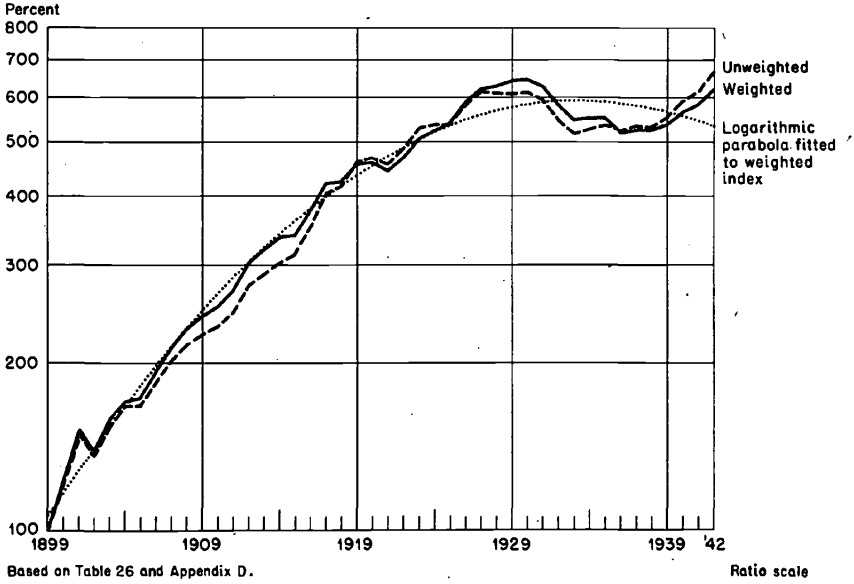


TABLE 26

Manufactured Gas, 1899–1942
Unweighted and Weighted Indexes of Output (1929:100)

	UNWEIGHTED	WEIGHTED		UNWEIGHTED	WEIGHTED
1899	16.4	15.6	1920	76.9	71.6
			1921	74.9	69.2
1900	...	...	1922	79.8	73.2
1901	24.6	23.7	1923	87.3	79.5
1902	22.4	21.6	1924	88.3	82.0
1903	25.6	24.7	1925	88.0	83.6
1904	27.6	26.6	1926	96.4	92.2
1905	27.6	27.0	1927	100.9	97.3
1906	30.5	30.2	1928	100.3	98.2
1907	33.2	33.3	1929	100.0	100.0
1908	35.3	35.9	1930	100.5	100.6
1909	36.9	38.0	1931	97.5	98.0
1910	38.3	39.6	1932	89.5	90.6
1911	40.6	42.2	1933	84.6	85.4
1912	45.2	47.3	1934	86.6	85.9
1913	47.5	50.0	1935	88.3	85.9
1914	49.9	52.8	1936	85.6	81.0
1915	51.3	53.1	1937	87.4	81.9
1916	58.1	58.8	1938	86.9	81.9
1917	66.5	65.8	1939	90.3	83.6
1918	68.3	66.0	1940	97.1	88.5
1919	75.5	71.2	1941	101.2	90.9
			1942	109.8	96.8

Summarized from Tables 24 and 25 and Appendix Tables A13 and 14.

manufactured gas indexes is so much a reflection of the shift to natural gas that the distinction between a manufactured and a natural gas industry may now be too artificial to warrant speculation about the future trends of either. Since the shift to natural gas will undoubtedly continue, judgments about the future should perhaps be based upon the movements of a single combined gas utility industry, which we consider in Section 5.

4 The Natural Gas Industry, 1899–1942

For the purposes of this study, the natural gas industry may be defined to include plants engaged in the transmission and distribution of natural gas. We exclude the activities of companies engaged solely in production, for that is a mining operation; unlike the electric light and power and manufactured gas industries, we are concerned here with a distributive function alone. Sales of plants distributing natural gas in 1940 as reported to the American Gas Association (Table 27) understate natural gas consumption, since

TABLE 27

Natural Gas Sales, American Gas Association Data, 1940

	DOMESTIC (incl. house heating)	COMMERCIAL	INDUSTRIAL	ELECTRIC GENERATION	TOTAL
Sales, bil. cu. ft.	420	122	717	183	1,442
Revenue, $ mil.	283	56	154		493
Price per th. cu. ft.	0.68	0.46	0.17		0.34
Customers, th.	7,212	565	47		7,824
Av. annual sale per customer, th. cu. ft.	58.2	216.9	19,140.8		184.3

American Gas Association, *Statistical Bulletin 45*, Annual Statistics of the Natural Gas Industry in 1940, Oct. 1941, p. 5. Natural gas sold for house heating purposes is usually included with gas sold for cooking and other domestic uses, for, not being separately metered, it can rarely be segregated.

considerable quantities are purchased and distributed by plants in the manufactured gas industry.[11] Moreover, Table 27 does not include natural gas used in field operations and in the manufacture of carbon black, that is, gas consumed at the point of production and requiring no transmission or distribution activity on the part of a utility company. Natural gas statistics collected by the American

[11] In 1940 the American Gas Association reported that plants classified in the manufactured gas industry purchased for distribution 58.7 bil. cu. ft. of natural gas, constituting 15.1 percent of their total sales of manufactured and natural gas (*Statistical Bulletin 44*, Oct. 1941, pp. 3, 8).

Gas Association include the *utility* sales of all natural gas companies, whether public utilities, pipe lines, or producers.

In 1940 3.7 times as much natural gas was sold as manufactured, but the sales revenue was only 1.3 times as great, for its average price was about one-third that of manufactured. The low-valued nondomestic components made up more than 70 percent of natural gas sales in 1940 but only 31 percent of manufactured. Even for similar consumer groups natural gas evidently may be regarded as a lower-valued service; in 1940 the rate for domestic (including house heating) natural gas was about three-fifths that for manufactured gas for domestic and house heating use, in part because it is consumed on a larger scale. The average sale of natural gas for nondomestic use was 1,670 th. cu. ft. at 21 cents per th. cu. ft.; of manufactured gas, 268 th. cu. ft. at 63 cents per th. cu. ft.

The rapid growth of natural gas consumption since 1899 is reflected in statistics collected by the Bureau of Mines (Table 28). These figures, including as they do the consumption of all natural gas, whether sold by a utility company or not, have a wider coverage than our present purpose calls for. However, in the absence of data other than those of the American Gas Association for the period before 1929 we must use them. We first examine them for the trends revealed for the entire period since 1899, then compare them with recent AGA statistics. The weighted index of output, based on Bureau of Mines data, excluding since 1919 natural gas consumed for field use and carbon black manufacture, is 850 percent higher in 1940 than in 1899. The weighted index of manufactured gas output rose only 469 percent.

The growth of natural gas is intimately associated with the American oil industry, although in recent years the relation has become less close. Natural gas formations have usually been discovered and tapped in a search for petroleum; their utilization in the early years, however, depended upon the proximity of markets. In the closing decades of the 19th century, when the oil and gas fields of New York, Pennsylvania, Ohio, and West Virginia were being exploited, the natural gas accompanying the flow of oil was in large part allowed to blow freely into the air, though some was used as fuel in field operations or in nearby refineries. The sale of natural gas as an industry in its own right, not as a troublesome appendage to the oil industry, required the construction of special gas pipe line trans-

TABLE 28

Natural Gas, American Gas Association Data, 1929–1942

Sales and Indexes of Output (1929:100)

Quantity, bil. cu. ft; Revenue, $ mil; Price, $ per th. cu. ft.

		1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
Total															
	Q	954	954	875	804	818	960	1,038	1,231	1,314	1,213	1,328	1,442	1,606	1,768
	R	342	353	335	315	302	328	356	413	441	417	449	493	526	584
	P	.36	.37	.38	.39	.37	.34	.34	.34	.34	.34	.34	.34	.33	.33
Domestic (incl. house-heating)															
	Q	285	297	326	315	288	284	304	344	359	353	373	420	423	476
	R	189	203	221	215	198	197	211	237	246	243	256	283	284	315
	P	.666	.681	.679	.681	.685	.693	.692	.690	.686	.687	.686	.675	.672	.662
Commercial															
	Q	78	81	54	56	61	76	86	98	103	101	109	122	130	153
	R	36.5	39.1	26.0	26.2	29.1	36.2	40.2	46.3	48.2	47.2	50.4	55.1	58.0	64.5
	P	.47	.48	.48	.47	.48	.47	.47	.47	.47	.47	.46	.46	.44	.42
Industrial (incl. electric generating)															
	Q	591	575	495	433	469	599	649	790	852	759	846	900	1,053	1,139
	R	116	111	88	74	75	94	105	129	146	127	143	154	183	204
	P	.20	.19	.18	.17	.16	.16	.16	.16	.17	.17	.17	.17	.17	.18
Indexes															
Unweighted		100.0	100.0	91.7	84.3	85.8	100.7	108.9	129.0	137.8	127.2	139.3	151.2	168.4	185.4
Weighted		100.0	102.3	99.9	94.9	92.1	100.0	107.9	124.8	132.1	126.0	135.8	150.0	159.9	178.4

Data for 1934–42 are from successive annual statistical bulletins published by the American Gas Association since 1934; data for 1929–33, from *Statistical Bulletin 13*, p. 1. The data for each year, except 1929–33, are for plants then engaged in distributing natural gas; in 1929–33 they are for plants distributing natural gas in 1933. The unweighted index is based on total sales; the weighted index, on the above division, using the Edgeworth formula, follows the method described in Appendix Table A16.

mission systems. In 1891 the first long distance, high-pressure gas pipe line was built to connect the gas fields of northern Indiana with Chicago, 120 miles away.[12]

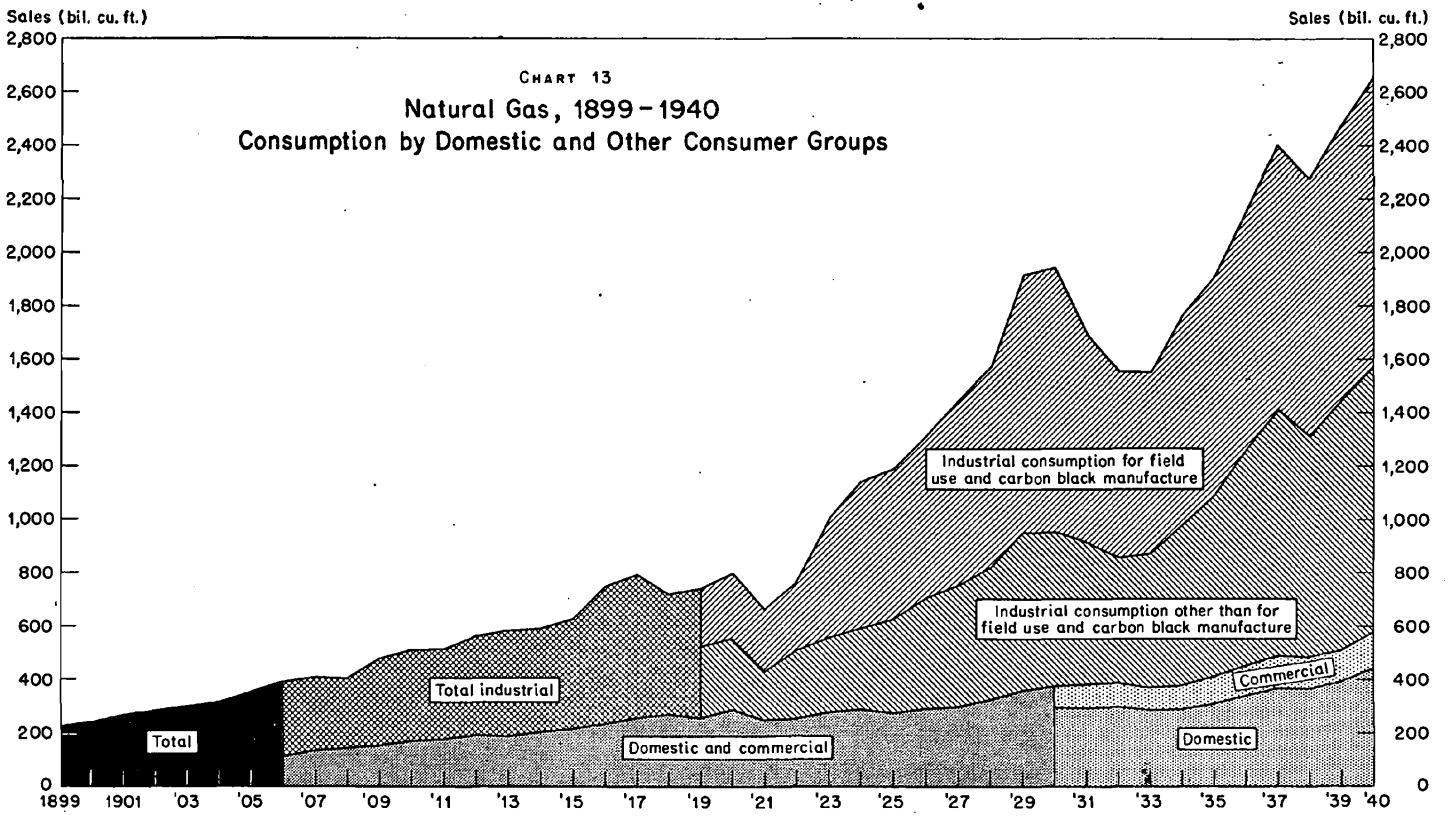
After 1900, with the exploitation of the mid-continent oil and gas reserves of Kansas, Oklahoma, and Texas, pipe lines were constructed more rapidly. Until 1925, however, the greatest expansion in natural gas distribution was in the Appalachian area where industrial consumption was large. But such consumption was pretty much confined to local areas until the late '20's when the newly discovered rich gas fields in California, Texas, and Louisiana began to reach out for distant urban markets. Long distance transmission of gas was facilitated by such innovations as electrically-welded seamless pipe and automatic ditch-digging apparatus. Today natural gas is commonly piped more than 1,000 miles, to serve such large urban areas as San Francisco, Salt Lake City, Des Moines, Chicago, Indianapolis, Memphis, and Washington.[13]

A major stimulant to the long distance transmission of natural gas was the development of industrial consumption, whose high load factor permitted relatively heavy use of pipeline facilities and so encouraged pipeline investment. In the first two decades of the century industrial and nonindustrial consumption probably kept pace, although we cannot deduct from total sales gas sold for field use and carbon black manufacture, which, making up 30 percent of all sales in 1919, constitute the nonutility component of natural gas sales we wish to exclude (Charts 13 and 14). The weighted and unweighted indexes (Table 29 and Chart 15) are parallel despite the lower weight accorded total industrial consumption in the weighted.

From 1919 to 1929 domestic-commercial natural gas consumption, while continuing to increase, did so far less rapidly than industrial. Sales of gas for field use and carbon black manufacture, which in 1929 made up half of all natural gas sales, increased most relatively, reflecting indirectly the growing position of the automobile in the American economy of the '20's. Thus natural gas not only enters into oil producing and refinery operations, but is consumed

[12] J. D. Creveling, A Brief History of the Natural Gas Industry, *Natural Gas*, May 1935, p. 7.

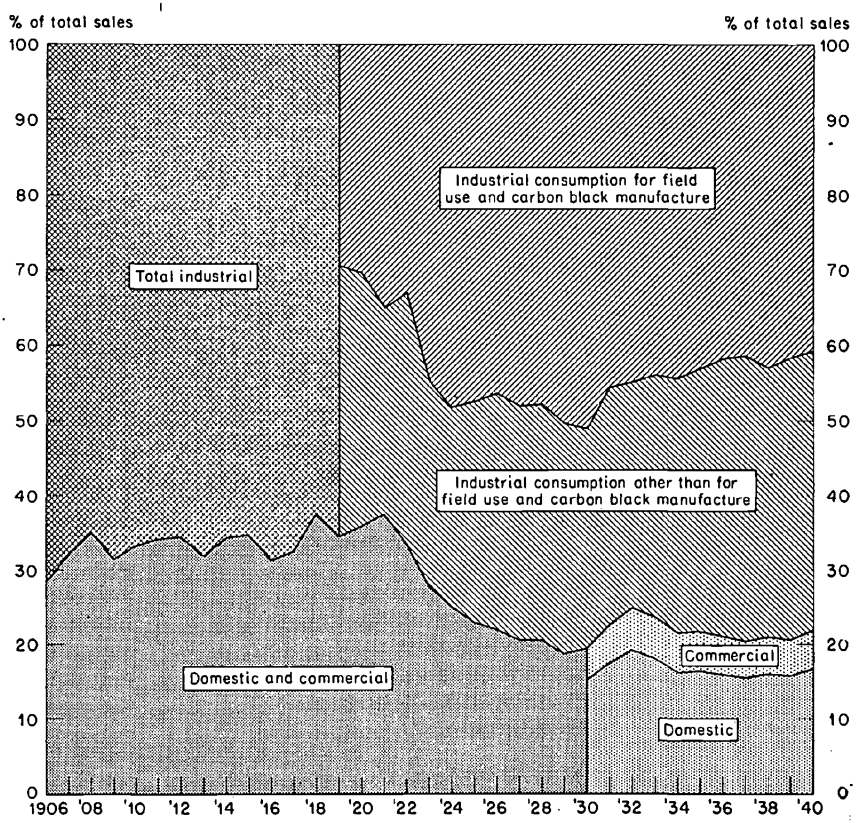
[13] G. L. Wilson, J. M. Herring, R. B. Eutsler, *Public Utility Industries* (McGraw-Hill, 1936), p. 71.



Based on Table 29.

CHART 14

Natural Gas, 1906–1940
Relative Consumption by Domestic and Other Consumer Groups



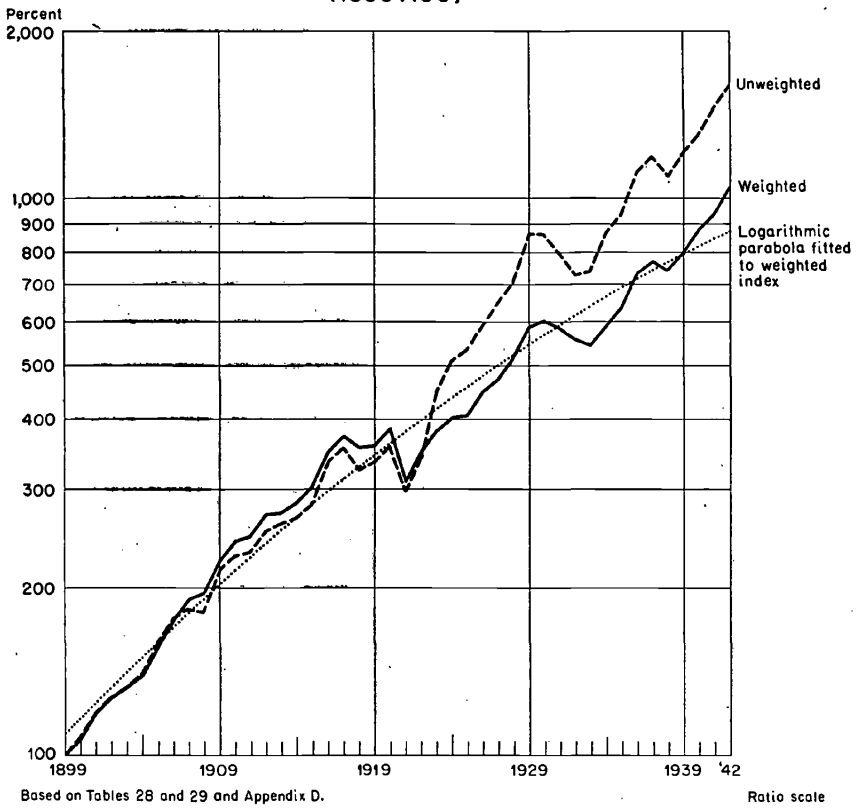
Based on Table 29.

in even greater quantities in carbon black manufacture, which is closely associated with tire manufacturing. However, we exclude such consumption from the weighted index of natural gas output, which therefore advances much less rapidly than the unweighted. From 1929 to 1940 the high-valued domestic-commercial component of natural gas sales advanced slightly at the expense of the industrial components; consequently the weighted index rises more rapidly than the unweighted. This shift after 1929 is in contrast to the sales of manufactured gas for domestic consumption, which continued to decline, relatively and absolutely.

Can the weighted output index in Table 29 be accepted as a

CHART 15

Natural Gas, 1899–1942
Unweighted and Weighted Indexes of Output
(1899:100)



measure of the output of the natural gas industry without some adjustment to exclude sales of natural gas by manufactured gas plants? The natural gas distributed by manufactured gas plants (in the form of natural and manufactured gas mixtures) has already been accounted for in the index of manufactured gas output. As we have seen, the practice of purchasing natural gas for mixed distribution became very widespread during the late '20's. After 1929 we can, without duplication, take proper account of the output of the natural gas industry, as we define it, by considering the data for the companies reporting natural gas utility sales to the American Gas Association (Table 28). The weighted index, which excludes sales of natural gas by manufactured gas plants, rises 50 percent between

TABLE 29

Natural Gas, Bureau of Mines Data, 1899–1940

Distribution to Domestic, Commercial, and Industrial Consumers, and Indexes of Output (1929:100)

Quantity, bil. cu. ft; Price, $ per th. cu. ft.

	DOMESTIC		COMMERCIAL		INDUSTRIAL OTHER THAN FIELD USE & CARBON BLACK MFR.		FIELD USE & CARBON BLACK MFR.		TOTAL INCL. FIELD USE & CARBON BLACK MFR.	INDEXES OF OUTPUT	
	Q	P	Q	P	Q	P	Q	P	(bil. cu. ft.)	Unweighted	Weighted
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1899									223	11.6	17.0
1900									237	12.4	18.1
1901									264	13.8	20.2
1902									281	14.7	21.5
1903									298	15.5	22.8
1904									310	16.2	23.7
1905	Q	P			Q	P			351	18.3	26.8
1906	110	0.23			278	0.08			389	20.3	29.7
1907	131	0.24			275	0.08			407	21.2	32.5
1908	141	0.24			262	0.08			402	21.0	33.2
1909	151	0.24			329	0.08			481	25.1	38.1
1910	170	0.24			339	0.09			509	26.6	41.2
1911	175	0.25			338	0.09			513	26.8	41.9
1912	193	0.26			369	0.09			562	29.3	46.1
1913	185	0.27			397	0.09			582	30.3	46.2
1914	203	0.28			389	0.10			592	30.9	48.4
1915	217	0.28			411	0.10			629	32.8	51.6
1916	235	0.29			518	0.10			753	39.3	59.5
1917	258	0.31			537	0.12			795	41.5	63.7
1918	271	0.31			450	0.15			721	37.6	60.5

1919		256	0.35		270	0.20	220	0.08	746	38.9	60.8
1920		286	0.38		270	0.23	243	0.10	798	41.6	65.4
1921		248	0.44		181	0.22	233	0.10	662	34.5	52.3
1922		254	0.50		257	0.25	252	0.12	762	39.8	59.4
1923		277	0.51		278	0.24	452	0.07	1,007	52.5	64.7
1924		285	0.54		306	0.22	550	0.06	1,142	59.5	68.2
1925		272	0.56		352	0.22	564	0.06	1,188	62.0	69.2
1926		289	0.58		415	0.22	608	0.07	1,313	68.5	76.4
1927		296	0.61		456	0.21	694	0.06	1,445	75.4	80.2
1928		321	0.62		498	0.20	749	0.08	1,568	81.8	87.3
1929		360	0.62		591	0.20	966	0.08	1,918	100.0	100.0
1930	296	0.68	81	0.48	575	0.19	990	0.07	1,942	101.3	102.1
1931	294	0.71	86	0.48	537	0.18	767	0.06	1,684	87.8	100.7
1932	299	0.75	87	0.50	471	0.17	698	0.05	1,554	81.1	98.5
1933	283	0.74	86	0.50	503	0.16	681	0.05	1,553	81.0	96.7
1934	288	0.75	91	0.50	601	0.17	784	0.04	1,765	92.0	103.3
1935	313	0.75	100	0.49	674	0.17	822	0.04	1,910	99.6	113.6
1936	343	0.73	112	0.48	804	0.17	902	0.04	2,160	112.7	127.9
1937	372	0.74	117	0.49	921	0.18	992	0.04	2,403	125.3	140.6
1938	368	0.74	114	0.49	828	0.17	984	0.03	2,294	119.6	134.9
1939	391	0.74	118	0.49	936	0.17	1,028	0.03	2,474	129.0	145.8
1940	444	0.71	135	0.48	996	0.17	1,081	0.03	2,655	138.4	162.1

Data, from successive issues of the Bureau of Mines' *Minerals Yearbook* and *Mineral Resources*, are for the total consumption of all natural gas produced. The weighted index of output (col. 11) is based on domestic-commercial and all industrial consumption combined, 1906–19; on domestic-commercial and industrial (other than field use and carbon black manufacture) consumption combined, 1919–30; and on domestic, commercial, and industrial (other than field use and carbon black manufacture) consumption combined, 1930–40. Before 1906 the weighted index was extrapolated by the unweighted, based on total consumption, including sales for field use and carbon black manufacture. The categories were combined by means of the Edgeworth formula, the method of computation following that described in Appendix Table A16.

In 1918–19 and 1923–27 the value of natural gas sold for carbon black manufacture was not reported separately to the Bureau of Mines, but was included with the value of gas sold for industrial use. The values, estimated by multiplying the quantities of gas sold for carbon black manufacture by estimated unit prices, are (in $ mil.): 1919, 1.6; 1920, 1.5; 1923, 3.9; 1924, 4.1; 1925, 3.9; 1926, 3.6. Unit prices were derived by extrapolating the movement of the prices reported in 1921, 1922, and 1927 by the average price of carbon black (*Mineral Resources*).

1929 and 1940; the weighted index based on total natural gas sales (excluding sales for field use and carbon black manufacture) of plants in both industries rises 62 percent. For the years before 1929 the latter index is the only measure of the output of the natural gas industry. The consequent duplication, however, is not great: the Census of Manufactures reported that in 1929 the plants constituting the manufactured gas industry purchased only 11.3 billion cubic feet of natural gas, or 2.8 percent of the 403.5 billion cubic feet sold by the industry. This small percentage serves to indicate the degree of the upward bias to which the index of output is subject, on this account, in the years before 1929. However, a slight further upward bias is probably imputed to the index because of the inclusion, prior to 1919, of natural gas sold for field use and carbon black manufacture.

5 Combined Output of the Manufactured and Natural Gas Industries

An index that combines the output of the natural and manufactured gas industries is desirable because their products satisfy similar needs (Table 30 and Chart 16). For about half of the period under review the output of the two industries, and therefore of the combined gas industry, moved similarly. The first large divergence occurs in the recession of the early '20's. Natural gas, with a greater proportion of sales for industrial use, is more sensitive to cyclical influences, and in 1920–21 the index declined 20.0 percent; the manufactured index, 3.4 percent. The subsequent more rapid rise in natural gas has been fairly consistent. In the '30's the index rose more than enough to offset the decline in the manufactured gas index, and the combined index after 1936 is well above its 1929 peak.

Whatever the judgment concerning the manufactured gas component, the manufactured and natural gas industry as a whole cannot be called 'declining', as is borne out by the logarithmic parabola fitted to the combined manufactured and natural gas index for 1899–1942 (Chart 16). However, retardation of growth is evident, averaging −0.19 percent per year, a lower rate than that for manufactured gas alone: −0.29 percent. The fitted trend for the combined gas index, unlike that for the manufactured, does not decline at the close of the '30's; it even registers an annual increase, albeit at an almost negligible rate. The trend of natural gas shows only slight retardation (Chart 15), at the annual rate of −0.08 percent,

TABLE 30
Manufactured and Natural Gas, 1899–1942
Indexes of Weighted Output (1929:100)

	MANUFACTURED GAS	NATURAL GAS	COMBINED INDEX		MANUFACTURED GAS	NATURAL GAS	COMBINED INDEX
1899	15.6	17.0	15.8	1921	69.2	52.3	62.9
1900	...	18.1	...	1922	73.2	59.4	67.9
1901	23.7	20.2	22.7	1923	79.5	64.7	73.7
1902	21.6	21.5	21.4	1924	82.0	68.2	76.5
1903	24.7	22.8	24.0	1925	83.6	69.2	77.8
1904	26.6	23.7	25.6	1926	92.2	76.4	85.8
1905	27.0	26.8	26.7	1927	97.3	80.2	90.4
1906	30.2	29.7	29.8	1928	98.2	87.3	93.8
1907	33.3	32.5	32.8	1929	100.0	100.0	100.0
1908	35.9	33.2	34.8	1930	100.6	102.3	101.4
1909	38.0	38.1	37.7	1931	98.0	99.9	98.9
1910	39.6	41.2	39.8	1932	90.6	94.9	92.5
1911	42.2	41.9	41.8	1933	85.4	92.1	88.4
1912	47.3	46.1	46.6	1934	85.9	100.0	92.0
1913	50.0	46.2	48.5	1935	85.9	107.9	95.5
1914	52.8	48.4	51.1	1936	81.0	124.8	100.0
1915	53.1	51.6	52.3	1937	81.9	132.1	103.7
1916	58.8	59.5	58.8	1938	81.9	126.0	101.1
1917	65.8	63.7	64.7	1939	83.6	135.8	106.3
1918	66.0	60.5	63.8	1940	88.5	150.0	115.3
1919	71.2	60.8	67.2	1941	90.9	159.9	120.9
1920	71.6	65.4	69.0	1942	96.8	178.4	132.3

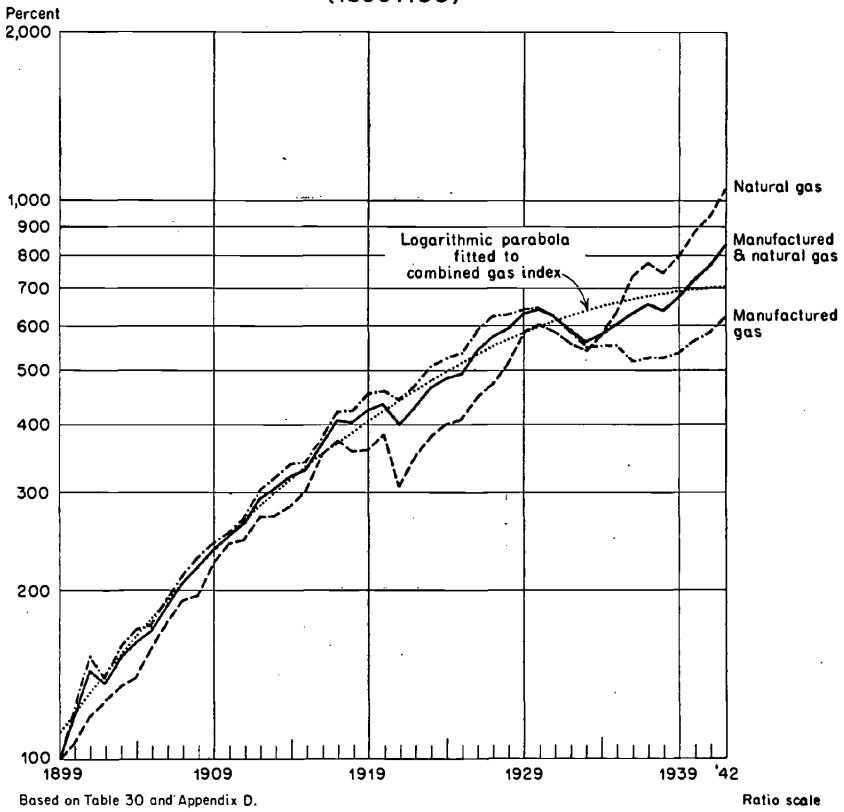
The weighted manufactured gas output index is from Table 26; the natural gas index, from Table 29 for 1899–1929, and from Table 28 for 1929–42. The two indexes were combined by using a modification of the Edgeworth formula, following the method described in Appendix Table A18.

and in 1940 was rising at an annual rate of more than 3 percent. However, let us repeat that though the secular trends traced by fitted growth curves are convenient summaries of an industry's growth for the period under review, they cannot, of course, constitute a basis for prophecy.

What are the prospects for the future? The growth of natural gas in the first four decades of the century, while showing some signs of retardation, seems likely to continue for a considerable time. Thus, the theoretical peak year for natural gas suggested by the logarithmic parabola fitted to the index of natural gas output is 1979. Such a hypothetical peak year may, as noted, serve merely as an extremely crude indicator of an industry's degree of maturity, but in the present instance it may justify regarding natural gas as a rela-

CHART 16

Manufactured and Natural Gas, 1899–1942
Weighted Indexes of Output
(1899:100)



tively young industry (see Ch. 1, Sec. 5, and Table 41). However, its future is not purely a function of demand. It depends also on such factors as the existence, extent, and availability of natural gas reserves. Whether they are sufficient for continued growth on the scale indicated by the fitted growth curve cannot be decided merely on the basis of present estimates of natural gas reserves, for these may have to be revised with new discoveries. For example, the American Gas Association estimate of 30 trillion cubic feet in 1931 was raised to 100 trillion cubic feet in 1938.[14] In 1944 natural gas

[14] Temporary National Economic Committee, Monograph 36, Reports of the Federal Trade Commission on Natural Gas, etc. (Washington, D. C. 1940), pp. 6, 7. Another estimate of gas reserves in 1938 cited by the TNEC was 66 trillion cu. ft.; the difference

reserves were estimated to be 110 trillion cubic feet, and in 1945, 141 trillion cubic feet.[15] Obviously, if new formations are discovered, calculations of available reserves would have to be increased frequently. The Federal Trade Commission has estimated that a reserve of 100 trillion cubic feet would permit withdrawals at the annual rate attained in 1938 for about 42 years. Such a reserve seems ample enough to permit withdrawals for at least another two decades, even at the increasing annual rate. Apparently, then, in the immediate future the threat of depletion will not halt the upward surge of natural gas consumption.

Yet the eventual exhaustion of natural gas deposits raises serious questions for the long term future, for natural gas is an irreplaceable resource whose exploitation, unlike that of most other minerals, does not entail rising costs when exhaustion is approached.[16] The fact that rising unit costs do not operate here as a restraining factor may suggest the need for a conscious husbanding of gas reserves. The ultimate disappearance of natural gas resources, however, implies that dependence on manufactured gas may continue. Whatever the immediate future of the manufactured gas industry, we may some day have to fall back on it as the sole source of gas, or else be prepared to abandon gas and shift completely to electricity or other (possibly atomic) sources of energy.

between the two estimates was attributed to many new discoveries in the California and Rocky Mountain area, which led the TNEC to observe that "natural gas, as well as crude oil, is being discovered more rapidly than it is being consumed".

[15] *American Gas Association Monthly*, June 1944, p. 249. The 1945 estimate is by E. De Golyer, submitted as Exhibit 23, Federal Power Commission Docket G. 580.

[16] Barger and Schurr, *op. cit.*, p. 261.

CHAPTER 4

Relation of Output to Input

IN CHAPTER 2 WE DISCUSSED the concept of productivity as a ratio of output and input aggregates designed to reveal trends in the efficiency of resource use in the production of electric light and power. In this Chapter we apply a similar analysis to the manufactured and natural gas industries.

1 Efficiency of Fuel Consumption in the Production of Manufactured Gas

Materials used in the production of manufactured gas are anthracite and bituminous coal, coke and breeze and oil. In addition, we may regard coke-oven and natural gas as components of input, to the extent that they are purchased by gas companies for distribution in mixtures (Table 31 and Chart 17).

Anthracite has declined greatly since 1909, as bituminous coal has become the increasingly dominant component of total fuel consumption in the manufactured gas industry, constituting more than half of the Btu. total in 1935. The relative shares of both coke and oil consumption have declined slightly since 1899; oil follows bituminous coal in order of importance, constituting about one-fifth. The reported consumption of natural gas is small because the Census of Manufactures excludes plants that have turned to natural gas distribution; however, the rapid rise in natural gas consumption after 1929 makes evident the increasing difficulty encountered by the Census in excluding such plants. The natural gas Btu. equivalent in 1935 was 13.7 percent of the total, much larger than in earlier years.

In comparing the movement of manufactured gas output with the materials and fuels required in the production process we can add the various components of output or input in either pecuniary

TABLE 31

Manufactured Gas, Census Data, 1899–1935
Materials and Fuels Purchased and Consumed

		1899	1904	1909 [a]	1914	1919	1921	1923	1925	1927	1929 [b]	1931 [c]	1933 [d]	1933 [d]	1935
Anthracite	th. l. t.			899 [e]	947 [f]	1388	1249	1246	822	265	178	116	112	110	104
	$ mil.			5.6	6.4	12.0	12.4	12.5	7.6	2.2	1.2	0.8	0.8	0.7	0.6
	$ per l. t. [f]			6.18	6.81	8.66	9.91	10.06	9.23	8.21	7.04	7.11	7.11	6.42	6.22
Bituminous	mil.sh. t.			4.67 [e]	6.08 [f]	7.38	6.96	7.28	7.93	9.04	10.04	9.66	9.59	7.88	7.96
	$ mil.			10.3	13.9	38.6	34.3	50.3	44.8	51.0	49.4	44.0	43.7	35.1	41.5
	$ per sh. t. [f]			2.21	2.28	5.23	4.92	6.91	5.65	5.64	4.92	4.56	4.56	4.46	5.21
All coal excl. fuel for boilers and retorts	mil. sh. t.	2.49	4.43	4.94											
	$ mil.	7.2	14.6	16.3											
	$ per sh. t.	2.88	3.30	3.30											
Coke and breeze, purchased	mil. sh. t.			.76	1.08	1.50	1.62	1.88	2.09	2.15	1.46	1.09	1.07	.84	.92
	$ mil.			3.4	5.0	13.2	16.2	20.7	19.1	18.6	10.9	6.7	6.6	4.9	5.7
	$ per sh. t. [f]			4.51	4.66	8.82	10.03	11.01	9.15	8.63	7.44	6.17	6.17	5.82	6.15
Coke and breeze, used for gas-making	mil. sh. t.	.22	.44	.59											
	$ mil.	0.7	1.6	2.7											
	$ per sh. t.	3.34	3.68	4.51											
Oil, purchased	mil. bbl. [f,g]			13.8	17.0	21.0	20.6	22.2	22.6	22.9	22.0	16.0	10.6	12.7	12.6
	$ mil.			17.1	24.7	50.8	37.6	49.2	55.0	48.6	38.8	16.0	10.6	15.5	20.4
	$ per bbl.			1.24	1.45	2.42	1.82	2.22	2.44	2.12	1.77	1.00	1.00	1.22	1.62
Oil incl. fuel oil made on premises	mil. gal. [h]	195	411	580											
	$ mil.	8.2	15.0	17.3											
	$ per gal.	.042	.037	.030											
Natural gas purchased outside industry	bil. cu. ft.					13.1	.32	13.6	1.2	1.9	11.3	10.2	10.2	28.7	50.0
	$ mil.					2.0	.06	2.6	.2	.4	1.8	1.7	1.7	5.0	8.7
	$ per th. cu. ft. [h]					0.15	0.18	0.19	0.18	0.18	0.16	0.17	0.17	0.18	0.17
Coke-oven gas	bil. cu. ft.					24.0	14.2	40.9	41.6	75.2	86.6	79.9	79.9	65.1	50.4
	$ mil.					3.8	3.4	12.0	11.8	20.8	23.6	20.8	20.8	17.0	13.0
	$ per th. cu. ft. [h]					0.16	0.24	0.29	0.28	0.28	0.27	0.26	0.26	0.26	0.26
Total gas purchased within and outside industry	bil. cu. ft.		2.7	16.8	28.4	67.1									
	$ mil.		.9	5.4	8.9	22.6									
	$ per th. cu. ft.		0.35	0.32	0.31	0.34									

NOTES TO TABLE 31

The data for purchased fuels exclude some very small quantities of fuel produced and consumed on the premises and are for the most part taken from or based on data in successive Census of Manufactures reports on the manufactured gas industry, the last of which is for 1935.

[a] Data for 1909 and prior years are published in the *1914 Census of Manufactures* (II, 544); they differ slightly from those reported after 1909 in that some fuel for boilers and retorts not used in gas making was excluded; a 1909 overlap is therefore provided.

[b] The 1929 data are from Census sources: For anthracite, bituminous, coke and breeze, and oil, quantity data were reported in the *1929 Census of Manufactures* (II, 760). For anthracite, bituminous coal, coke, oil and gas, other quantity and value data were reported in connection with the *1929 Census of Manufactures Fuel Report* (I, 158, 165). They may include small amounts of self-made (i.e., not purchased) fuel, but their unit values may be applied to the purchased fuels.

[c] Comparable with 1929.

[d] In the *1933 Census of Manufactures* a short schedule was used for small establishments; consequently, the 1933 data for such establishments are not complete. However, the Bureau of the Census has also reported 1931 data comparable with 1933 which allow us to compute indexes of output and input for 1933 on a 1931 base, to be spliced to the 1931 indexes computed on a 1929 base.

[e] Quantity data for 1914 are from the *1919 Census of Manufactures*, (General Report and Analytical Tables), VIII, 134; for 1909, from the *1914 Abstract of the Census of Manufactures*, p. 512.

[f] Since price data for anthracite were reported by the Census only for the years before 1921 and for 1929, the unit cost figures for other census years are interpolations and extrapolations of the Census unit cost figures by the BLS wholesale price index for anthracite. The corresponding price data for bituminous, coke and breeze, and oil were similarly obtained (see App. Table B4).

[g] 42 gallons: 1 barrel.

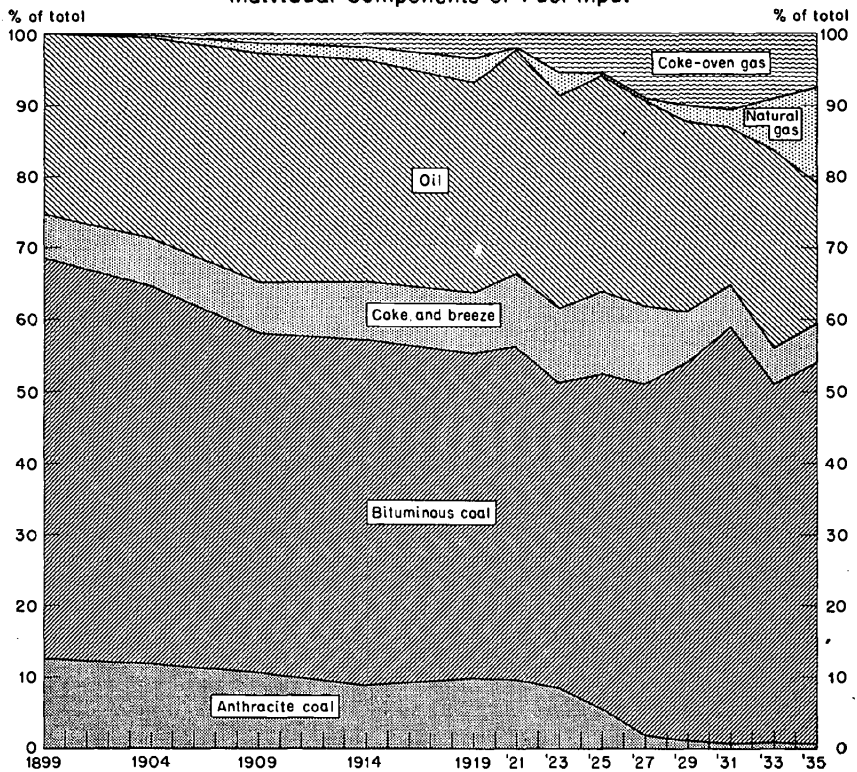
[h] The unit cost figures for natural gas, reported by the Census for 1919 and 1929, were interpolated for the intervening years by Bureau of Mines unit cost data (see App. Table B4).

or physical terms. For example, since we have price data for the various fuels consumed in the industry, we can construct a price-weighted index of fuel input to compare with the price-weighted index of manufactured gas output. Price-weighted indexes are of use when resort *must* be made to prices in order to add the heterogeneous physical quantities making up the output and input categories. In the present instance, however, the output and input categories can be aggregated in physical terms, and we can construct an index of Btu.-weighted output in which all manufacutred gas, whether sold at different rates to domestic, commercial, or industrial consumers, is given a constant weight of 575 Btu. per cu. ft. and the small amount of natural gas entering into manufactured gas mixtures is given a weight of 1,075 Btu. per cu. ft., in

accordance with their respective average heat values as determined by the Bureau of Mines. On the input side, the various fuels can be similarly aggregated if weighted by their respective Btu. values. Both the price-weighted and Btu.-weighted indexes of output per unit of fuel reflect the secular gain in the efficiency of fuel consumption in the manufactured gas industry (Table 32). Fuel input fol-

CHART 17

Manufactured Gas, 1899–1935
Percentages of Total Btu. Input Contributed by Individual Components of Fuel Input



Based on Table 86.

lowed output closely, and the efficiency of fuel consumption has gained moderately since 1899. However, an especially interesting aspect of the gain in efficiency is afforded when we focus attention on the Btu.-weighted indexes of output, fuel input, and output per unit of fuel.

The application of fuel conversion factors [1] to manufactured gas output and input yields output and input aggregates in terms of heat units which can be compared directly. In 1929, for instance, the manufactured gas industry consumed 497.5 trillion Btu. of materials and fuels, including purchased coke-oven and natural gas. In the process of converting these fuels into gas and distributing the latter to consumers together with the purchased gas, 237.6 trillion Btu. were realized. In other words, the industry may be said to have operated at a thermal efficiency of 47.8 percent, for 478 Btu. were delivered (i.e., sold) for every 1,000 Btu. consumed.[2] From 1899 to 1935 Btu. output per 1,000 Btu. input rose from 320.7 to 520.9, or 62.4 percent (Table 32). In the electric light and power industry kilowatt-hours generated per unit of fuel consumed rose much more rapidly — 411.2 percent from 1902 to 1935. And the price-weighted index of manufactured gas output per unit of fuel rose only 16.2 percent 1899–1935; the divergence from the Btu.-weighted index of output per unit of fuel is due in part to the increasing tendency for plants in the manufactured gas industry to purchase coke-oven gas, which can be distributed immediately without much further processing. Purchased gas is the most expensive (in dollars per Btu. equivalent) of all the materials and fuels consumed in the industry,[3] and the growing dependence on it will be more heavily reflected in a price-weighted than in a Btu.-weighted index of fuel input.

The plants canvassed by the American Gas Association in recent years have a somewhat lower average thermal efficiency than the sample canvassed by the Census (Table 33). In 1935, for instance, the AGA reported 506 Btu. of gas per 1,000 Btu. of input; the Census, 521. As the relation between the two samples is quite close — the fuel efficiency ratios for the two samples move similarly 1929–35 — the 1929 AGA ratio is spliced to that of the Census

[1] For anthracite, 27.2 mil. Btu. per sh. t; bituminous coal, 26.2 mil. Btu. per sh. t; natural gas, 1,075 Btu. per cu. ft; coke-oven gas, 575 Btu. per cu. ft; oil, 6 mil. Btu. per barrel; coke and breeze, 24.2 mil. Btu. per sh. t. (*Minerals Yearbook, Review of 1940;* Bureau of Mines, 1941; p. 777). The conversion factor for coke and breeze is from Alexander Meade, *Modern Gas Works Practice* (Benn Bros., London, 1921), p. 760.

[2] The thermal efficiency ratios would be somewhat higher if account could be taken of the heat value embodied in the coke and tar byproducts.

[3] The cost per mil. Btu. of the various fuels bought by the industry in 1935 was: anthracite, $.206; bituminous, $.199; coke, $.254; oil, $.270; natural gas, $.162, and coke-oven gas, $.447.

TABLE 32

Manufactured Gas, Census Data, 1899–1935

Indexes of Output, Fuel Input, and Output per Unit of Fuel, including Purchased Gas (1929:100)

	1899	*1904*	*1909*	*1914*	*1919*	*1921*	*1923*	*1925*	*1927*	*1929*	*1931*	*1933*	*1935*
Price-weighted Indexes													
Output	15.6	26.6	38.0	52.8	71.2	69.2	79.5	83.6	97.3	100.0	92.0	76.5	76.6
Fuel input	17.2	33.6	47.3	61.4	85.5	80.0	91.1	91.2	99.1	100.0	86.8	79.1	72.9
Output per unit of fuel	90.3	79.3	80.4	86.0	83.3	86.6	87.3	91.6	98.3	100.0	106.0	96.7	105.0
Output, tril. Btu.	35.4	59.4	80.8	109.6	168.1	160.0	192.5	195.7	227.5	237.6	216.8	191.0	204.5
Input, tril. Btu.	110.4	207.5	257.6	328.3	425.8	392.0	445.1	444.0	479.8	497.5	435.7	406.6	392.7
Btu. output per th. Btu. of input	320.7	286.3	313.5	333.7	394.8	408.2	432.4	440.8	474.2	477.7	497.6	469.7	520.9
Btu.-weighted Indexes													
Output	14.9	25.0	34.0	46.1	70.7	67.3	81.0	82.3	95.8	100.0	91.2	80.4	86.1
Input	22.2	41.7	51.8	66.0	85.6	78.8	89.5	89.3	96.5	100.0	87.6	81.7	78.9
Output per Btu. of input	67.1	59.9	65.6	69.9	82.6	85.5	90.5	92.3	99.3	100.0	104.2	98.3	109.0

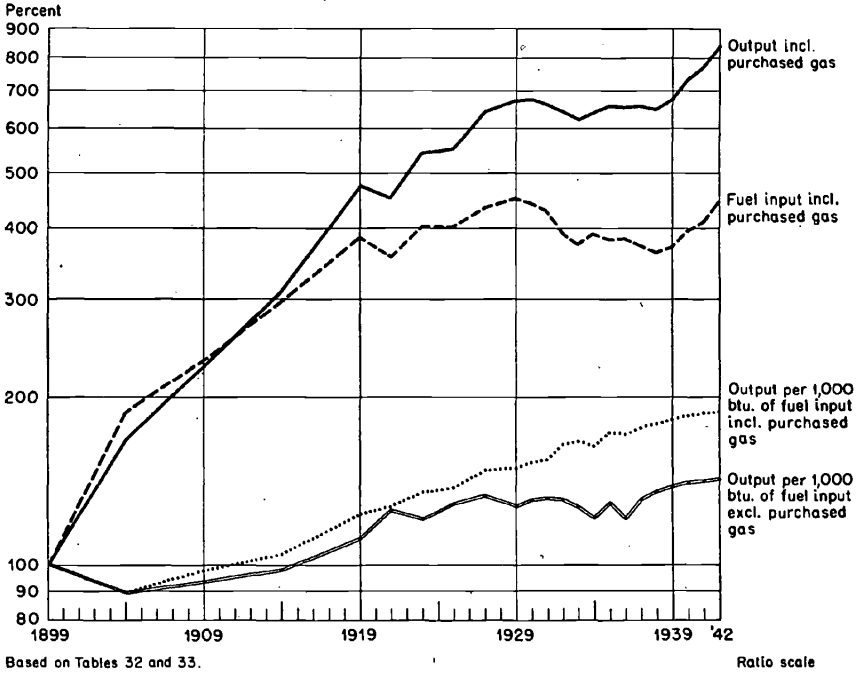
The price-weighted index of fuel input is constructed in such a manner as to parallel the construction of the weighted output index (see Appendix Tables A8, 11, 12, and 15), and is the result of applying the Edgeworth formula to the quantity and price data of Table 31. A sample worksheet is provided in Appendix Table B8, detailing the method of construction for 1919–29.

The construction of the Btu.-weighted indexes is described in Appendix Tables B5 and 6. For 1899–1919 and 1933 the published data were rendered comparable with 1929 by means of the overlaps shown in those tables.

plants and the movement of an index based on these ratios for the entire period 1899–1942 considered (Chart 18).

CHART 18

Manufactured Gas, 1899–1942
Indexes of Btu. Fuel Input and Btu. Output per Unit of Fuel
(1899:100)



In these 42 years the thermal efficiency of plants manufacturing gas seems to have doubled (Tables 32 and 33). While the rise, at least since 1904, has been well sustained, it is more moderate than in the electric light and power industry, whose fuel consumption efficiency rose nearly sixfold. Such comparisons, however, indicate little about the technical progress achieved in each industry beyond suggesting that the relatively more rapid rate of advance in the electric light and power industry may be associated with its relative youth. The efficiency of gas production gained greatly in the late 19th century, before our statistical record begins, and is not reflected in our indexes. The water-gas process, for instance, emerged after 1870 and soon proved far more efficient than the older coal gas process.[4]

[4] Coal gas is obtained from the dry distillation of coal in a retort or oven, heated ex-

TABLE 33

Manufactured Gas, Efficiency of Fuel Consumption, American Gas Association Data, 1929–1942

Indexes of Output per Unit of Fuel, including Purchased Gas (1929:100)

	1929	*1930*	*1931*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*
Gas sales, bil. cu. ft.	401.2	403.2	391.2	358.9	339.5	347.5	354.4	343.3	350.6	348.6	362.4	389.6	405.8	440.4
Mfd.	399.6	400.9	384.3	328.4	302.2	306.3	308.6	286.5	300.2	301.4	312.3	330.9	339.9	367.1
Natural	1.6	2.3	6.9	30.5	37.3	41.1	45.8	56.8	50.4	47.2	50.1	58.7	65.9	73.3
Gas sales, tril. Btu.	231.5	233.0	228.4	221.6	213.9	220.3	226.6	225.8	226.8	224.1	233.4	253.4	266.3	289.9
Btu. output index	100.0	100.7	98.7	95.7	92.4	95.2	97.9	97.5	98.0	96.8	100.9	109.5	115.1	125.2
Fuel consumed, total, tril. Btu.	529.4	519.2	503.9	459.0	438.3	460.0	447.8	447.8	438.1	425.3	435.9	465.2	483.3	524.4
Anthracite, th. sh. t.	267	206	141	115	132	186	126	144	178	181	199	214	258	284
Bituminous, mil. sh. t.	9.68	9.36	9.41	8.10	7.83	8.35	7.85	7.60	7.34	6.72	6.65	6.88	7.11	7.73
Coke and breeze, mil. sh. t.	3.94	3.80	3.52	2.92	2.58	2.60	2.59	2.51	2.41	2.35	2.43	2.60	2.61	2.82
Oil, mil. bbl.	17.3	17.5	16.2	14.4	12.6	12.4	12.2	12.3	12.6	13.9	15.0	16.1	16.5	17.9
Natural gas, bil. cu. ft.	1.58	2.30	6.93	30.47	37.31	41.12	45.76	56.78	50.38	47.20	50.08	58.71	65.94	73.28
All other gas, bil. cu. ft.	117.1	120.5	110.9	94.2	89.8	94.7	93.7	85.5	92.1	92.4	93.4	98.0	99.1	104.2
Btu. input index	100.0	98.1	95.2	86.7	82.8	86.9	84.6	84.6	82.7	80.3	82.3	87.9	91.3	99.0
Btu. output per th. Btu. input	437.2	448.7	453.2	482.7	488.0	479.0	506.1	504.1	517.6	526.8	535.5	544.7	551.0	552.7
Output per unit of fuel index	100.0	102.6	103.7	110.4	111.6	109.6	115.8	115.3	118.4	120.5	122.5	124.6	126.0	126.4

Data for 1932–42 from successive annual statistical bulletins published by the American Gas Association since 1931; data for 1929–31 from *Statistical Bulletin 10*, Oct. 1932, pp. 4, 6, 8. Since 1931 the data for each year are for plants manufacturing gas in that year regardless of their product before or after.

All natural gas purchased by the industry is assumed to have been sold without distribution loss. No information is available on this point, but the assumption is considered valid for the present purpose — to convert the industry's output into its Btu. equivalent. Details of the computations underlying the indexes are given in Appendix Table B7.

The thermal efficiency ratios considered above overstate the efficiency of fuel consumption in manufactured gas plants to the extent that the output and input aggregates include the Btu. value of purchased coke-oven and natural gas. If we exclude purchased gas from our totals, the level of thermal efficiency is lowered and the long time increase lessened.

BTU. OUTPUT PER 1000 BTU. OF INPUT, EXCLUDING PURCHASED GAS

	CENSUS RATIOS		AGA RATIOS
1904	282	1929	353
1909	295	1930	360
1914	309	1931	363
1919	352	1932	362
1921	395	1933	353
1923	379	1934	337
1925	407	1935	358
1927	419	1936	342
1929	403	1937	361
1931	422	1938	374
1933	400	1939	383
1935	393	1940	388
		1941	389
		1942	392

Thus, for gas produced in the industry from coal, coke and oil, 28.2 percent of the fuel heat value was realized in 1904, the first year for which we can separate the purchased gas component of total input. The thermal efficiency ratio rose fairly steadily to a peak in 1927 when gas plants realized about 42 percent of the Btu. value of the fuel consumed. Thereafter there was very little gain in fuel efficiency. Plants canvassed by the American Gas Association realized about 35 percent of the heat value of their fuel in 1929, and raised the ratio somewhat in the late thirties, but never went above the 42 percent peak level achieved by plants covered by the Census in 1927.

The increased emphasis on the use of coke-oven gas, particularly after 1920, when the production of beehive coke began a long secular decline, must also be regarded as a noteworthy fuel-saving innovation. A byproduct of the manufacture of coke, coke-oven gas is either purchased by a gas plant from plants connected with the steel industry on mutually advantageous terms or produced by the gas plant if the latter feels it can profitably dispose of the byproduct coke; the joint production process yields a high degree of fuel economy. Since 1899 the gradual improvement of gas-making practices

ternally; water gas is generated in a process that brings steam into contact with incandescent coke or anthracite.

— advances in the construction of boilers, retorts, the use of insulating materials, etc., all designed to extract the maximum heat value from the fuel consumed — has also made for savings in fuel.

2 Output and Capital Input in the Manufactured Gas Industry

We now consider other resources consumed in the manufacture of gas. In measuring capital input we are faced with the difficulties noted in Chapter 2, Section 2 — difficulties associated with the measurement of the movement over time of money values. In 1904 the Census of Manufactures reported the book value of land, buildings, and machinery owned by the industry as $594.7 million; in 1942 the American Gas Association reported it as $2,149.1 million.[5] An index of capital assets for 1942, based on the 1904 figure (assumed to be comparable) shows an increase of 261.4 percent (Table 34), but ignores accounting discontinuities due to capital revaluations, time lags, and the lack of a uniform treatment of depreciation reserves and other items in the corporate balance sheet. In the face of such difficulties, it may be foolhardy, though perhaps instructive, to deflate the index for capital price changes by means of an index of the cost of construction and equipment in the manufactured gas industry.[6] From 1904 to 1942 the latter index rose 194.0 percent; the net gain in the deflated index of capital values is about one-fifth, an extremely moderate rise when compared with the more than 1,000 percent gain indicated by a deflated index of capital value for the electric light and power industry 1902–37 (see Ch. 2, Sec. 2). This small rise in capital input, and the actual decline indicated in the years since 1929, is undoubtedly closely associated with the marked falling off in the growth of manufactured gas output.

The falling off in investment since 1929 in such capital equipment as gas mains is merely another indication of the decline characterizing the recent history of the manufactured gas industry, as we define it (Table 35).[7] In 1942 the index of gas main mileage in use

[5] AGA, *Statistical Bulletin 52*, p. 12.

[6] Such an index, while not synonymous with an index of book value prices, probably records a parallel secular movement. It is interesting to note the close correspondence between the index of capital construction costs in the gas utilities, 1904–37, which rises 163 percent, and our estimate that prices underlying electric utility book values rose 150 percent, 1902–37.

[7] Here again it must be recalled that the decline is a reflection of the shift to natural gas. A drop in manufactured gas main mileage does not mean that such mains were

TABLE 34
Manufactured Gas, Selected Years, 1904–1942
Indexes of Fixed Capital Assets

		1904	1911	1929	1937	1942
1	Book value, fixed capital assets, $ mil.[a]	594.7		1,965.3	1,991.1	2,149.1
	Indexes					
2	Capital assets (1904:100)	100.0		330.4	334.8	361.4
3	Construction and equipment cost, mfd. gas (1911:100) [b]		100.0	219.0	246.0	275.0
4	General construction costs (1913:100) [c]	87.4	93.4	207.0	234.7	276.3
5	Construction and equipment cost, mfd. gas (1904:100) [d]	100.0	106.9	234.1	263.0	294.0
6	Capital assets deflated (1904:100) (2 ÷ 5)	100.0		141.1	127.3	122.9

[a] The 1904 figure is the sum of the following reported capital values: land, $59.6 mil; buildings, $85.9 mil; machinery, $449.2 mil. (*Census of Manufactures, 1905*, I, 230.) The 1929, 1937, and 1942 figures (values of fixed capital as reported to the American Gas Association) are to be regarded as only roughly comparable, for probably no standard accounting practice was observed in the Census and AGA reports. The 1929 figure is for plants manufacturing gas in 1931; the 1937 and 1942 figures are for plants manufacturing gas then, regardless of their product in previous or subsequent years.
[b] Compiled by Whitman, Requardt, and Smith, Consulting Engineers, Baltimore, Md., and published in the *Engineering News-Record*, April 22, 1943, p. 100.
[c] *Ibid.*, p. 92.
[d] Index of construction and equipment cost in the manufactured gas industry (line 3) spliced to the index of general construction cost (line 4) at 1911. It is evident that the movements of these two indexes are not too dissimilar 1911–37.

was 111.8 percent higher than in 1909, but most of the rise (96.6 percent) had occurred by 1929. If we ignore quality changes, differences in the diameter and carrying capacity of the various mains, and if we assume a constant relation between the length of gas mains and other capital equipment required in the industry, we may perhaps say that an index of gas main expansion reflects one aspect of the growth of capital input, in somewhat the same manner as the growth of electric light and power kilowatt-rated-capacity measures one aspect of the movement of capital input in that industry. The gas main mileage series, in conjunction with total gas sales, reveals something about the efficiency of capital resource use in the manufactured gas industry. The industry distributed 3,343 th. cu. ft. of gas for every mile of gas main in use in 1909 (although this figure may include a small proportion of intra-industry sales which would not require gas main distribution). The gas main load rose to peak levels in 1923 and 1929 when sales to ultimate consumers per gas main mile were respectively 4,540 and 4,549 th. cu. ft. Thereafter sales per gas main mile declined steadily, and despite some slight cyclical upturns, did not advance much above the 1929 level during the succeeding 13 years, the ratio of sales to gas main mileage re-

scrapped or abandoned, but that the parent company was reclassified in the natural gas industry.

TABLE 35
Manufactured Gas, 1909–1942
Sales per Mile of Gas Main

	GAS SALES (bil. cu. ft.)	MILES OF GAS MAIN Mil.	MILES OF GAS MAIN Index (1929:100)	SALES PER MILE OF GAS MAIN Mil. cu. ft.	SALES PER MILE OF GAS MAIN Index (1929:100)
1909	151	45.1	50.9	3.34	66.9
1914	204	58.7	66.2	3.47	69.4
1919 [a]	308	69.7	78.6	4.42	88.5
1919 [a]	281	...	...	4.03	...
1921	278	68.1	76.8	4.08	89.8
1923	323	71.1	80.2	4.54	99.8
1025	339	81.0	91.3	4.19	92.1
1927	394	87.6	98.7	4.50	98.9
1929 [b]	404	88.7	100.0	4.55	100.0
1929 [b]	401	87.0	100.0	4.61	100.0
1930	403	90.5	104.1	4.45	96.6
1931	391	95.2	109.4	4.11	89.1
1932	359	95.3	109.6	3.76	81.6
1933	340	95.7	110.1	3.55	76.9
1934	347	94.1	108.2	3.69	80.1
1935	354	94.4	108.5	3.75	81.4
1936	343	91.4	105.1	3.75	81.4
1937	351	92.3	106.1	3.80	82.4
1938	349	90.9	104.5	3.84	83.2
1939	362	92.0	105.8	3.94	85.4
1940	390	92.0	105.8	4.24	91.8
1941	406	94.5	108.6	4.30	93.1
1942	440	93.7	107.8	4.70	101.9

Data prior to 1929 are for the plants canvassed by the Census of Manufactures; after 1929 for the American Gas Association sample.

[a] Before 1919 Census gas sales data may include a small but uncertain proportion of intra-industry sales. The data shown here for 1919–42 exclude such duplicatory sales. The overlap for 1919 allows us to splice indexes of gas sales per mile of gas main based on the sales data for the periods before and after 1919.

[b] The 1929 overlap indicates that the difference in the coverage of the AGA and Census samples, with respect to both sales and gas main mileage, was small enough to warrant splicing the indexes based on the data for the periods before and after 1929.

maining below 4,700 th. cu. ft. per mile. This fact is perhaps somewhat surprising, for with retardation in the growth of gas main mileage, we might expect increased intensity of use as a result merely of the greater concentration of population in urban areas. However, in recent years the decline in sales has evidently been large enough to keep the ratio of sales to gas main mileage from rising.

3 Labor Input in the Manufactured Gas Industry

Preceding the peak in output in 1929, employment reached a peak in 1927 with more than 75,000 wage earners and salaried personnel (Table 36), a 165.4 percent increase over the 28,400 workers em-

TABLE 36

Manufactured Gas, Census Data, 1899–1935

Indexes of Employment, Output per Man and per Manhour (1929:100)

		1899	1904	1909	1914	1919	1921	1923	1925	1927	1929	1931	1933	1935
1	Th. of wage earners	22.5	30.6	37.2	43.8	42.9	35.0	42.3	47.0	48.5	43.1	34.5	30.6	31.0
2	Wage and salaried employees (th.)	28.4	40.0	50.7	63.9	63.3	53.6	66.1	71.0	75.3	65.6	54.4	49.8	50.4
3	Average hours worked per week				51.6	50.8	52.5	49.5	46.8	47.9	51.4	49.7	44.3	41.1
						INDEXES								
4	Employment	43.2	60.9	77.3	97.4	96.5	81.7	100.8	108.2	114.7	100.0	82.9	76.0	76.9
5	Manhours				97.8	95.3	83.5	97.1	98.5	106.9	100.0	80.2	65.5	61.5
6	Weighted output	15.6	26.6	38.0	52.8	71.2	69.2	79.5	83.6	97.3	100.0	92.0	76.5	76.6
7	Output per													
	Man	36.0	43.7	49.1	54.2	73.9	84.7	78.9	77.2	84.8	100.0	110.9	100.8	99.6
	Manhour				54.0	74.7	82.9	81.9	84.8	91.0	100.0	114.7	116.9	124.6

All data except line 3 are from Census of Manufactures reports. The Census figures on total employment in 1931, 1933, and 1935 (line 2), however, required some adjustment. In 1935 the Census called for data on salaried personnel and wage earners engaged wholly in the manufacture of gas, and excluded employees engaged exclusively in distribution. The 1933 Census, on the other hand, included salaried personnel engaged in distribution but excluded such wage earners in 21 establishments. In the 1931 Census, all wage earners were included, whether engaged in manufacture or distribution, but no data on salaried personnel were reported. Consequently we made the following adjustments to restore some degree of continuity to the Census employment figures and render them comparable with the corresponding output data.

Wage earners engaged in distribution and excluded in 1935 were estimated to number 11,211 by the National Research Project, on the assumption that "the percentage change between 1933 and 1935 in the wage-earner requirement per thousand cu. ft. was the same for distribution as for production" (Magdoff, Siegel, and Davis, *Production, Employment and Productivity in 59 Manufacturing Industries, 1919–36*, Part III, p. 90). Wage earners engaged in distribution and excluded in 1933 numbered 4,336, according to the Census of Manufactures. After restoring these excluded wage earners to the respective wage earner totals for 1933 and 1935, we raised the wage earner totals for 1931 and 1935 to include salaried personnel by multiplying the 1931 figure by the average ratio of total employment to wage earners in 1929 and 1933 (1.5767), and applying to the 1935 wage earner total the 1933 ratio of total employment to wage earners (1.6296). The employment totals for most years exclude a few proprietors and salaried officers who were sometimes reported separately by the Census.

Average hours worked per week (line 3) are from the National Industrial Conference Board *Economic Almanac, 1943–44*, p. 334, which presents a series for "average actual hours per week per wage earner" in 1914, 1923, and 1927–42. For 1919–27 National Research Project (*op. cit.*, Part III, p. 90), interpolations of corresponding data for the odd-numbered years, adjusted to the level of the NICB series, were used.

ployed in 1899. Employment then declined rapidly to 50,000 in 1935 (Census of Manufactures), about the same number as in 1909. However, the Census employment totals after 1929 and the output per employee ratios based on them are somewhat doubtful. In 1933 and 1935 the Census, confronted with a growing tendency in the industry to turn from the manufacture to the distribution of gas, attempted to exclude from its employment figures employees engaged in distribution activities, even though the employing plant may have been predominantly engaged in manufacturing. Account has been taken of the resulting discontinuity of the data in Table 36, but the possibility remains that the comparability of the Census employment figures after 1929 has suffered seriously from the rapidly changing definition of the gas manufacturing industry.

These difficulties arising from discontinuities in Census data may be bypassed by considering the output and employment aggregates for plants reporting to the American Gas Association since 1929 (Table 37) with which the employment records are brought to date. The plants included in the AGA sample employed 76,400 in 1929, considerably more than the Census total. In the succeeding years of the post-1929 recession AGA employment in gas manufacturing declined to a low of 67,300 in 1932, and was 70,800 in 1935. These declines were not nearly as large as those recorded for plants canvassed by the Census authorities, who were experiencing the difficulties already noted in tabulating employment in gas manufacturing. The post-1929 decline in employment shown by the AGA data was not merely cyclical, for employment failed to rise even in the expansion of the late '30's. The drop to 58,800 in 1942 was due to wartime labor shortages, but even excluding this year, the trend is definitely downward (Chart 19). The decline in labor input, measured in manhours, is even more striking, for the average working week declined from about 52 hours in 1914 to 40 hours in the late '30's. The index of manhours consequently declined 37.1 percent from 1914 to 1942; the employment index, 21.1 percent (Table 37).

The behavior of the output per employee index for manufactured gas is of particular interest because we have to do here with a stage in industrial development not frequently encountered, i.e., a secular decline in output. When an industry passes its peak, do gains in output per worker cease? We do not have sufficient material for a satisfactory answer (chiefly because few industries can be clearly

TABLE 37
Manufactured Gas, 1899–1942
Indexes of Employment, Weighted Output per Man and per Manhour (1929:100)

	TOTAL EMPLOYMENT			EMPLOYMENT INDEX	AV. HOURS WORKED PER WEEK	INDEXES		
	Interpolated Census	AGA					Weighted output per	
	(1)	(2)	(3)	(4)	(5)	Manhours (6)	man (7)	manhour (8)
1899	28.4			43.2			36.0	
1904	40.0			60.9			43.7	
1909	50.7			77.3			49.1	
1914	63.9			97.4	51.6	97.8	54.2	54.0
1919	63.3	71.0		96.5	50.8	95.3	73.9	74.7
1920	57.7	71.0		88.0	51.6	88.3	81.4	81.1
1921	53.6	73.0		81.7	52.5	83.5	84.7	82.9
1922	59.2	75.4		90.2	51.0	89.5	81.2	81.8
1923	66.1	79.2		100.8	49.5	97.1	78.9	81.9
1924	69.0	83.0		105.2	48.2	98.6	78.0	83.1
1925	71.0	85.8		108.2	46.8	98.5	77.2	84.8
1926	73.2	88.4		111.5	47.4	102.8	82.7	89.7
1927	75.3	91.0		114.7	47.9	106.9	84.8	91.0
1928	71.0	91.6		108.1	50.3	105.8	90.8	92.8
1929	65.6	90.9	76.4	100.0	51.4	100.0	100.0	100.0
1930			75.8	99.2	50.6	97.6	101.5	103.1
1931			73.5	96.2	49.7	93.0	101.9	105.3
1932			67.3	88.1	43.5	74.5	102.9	121.6
1933			71.0	92.9	44.3	80.1	92.0	106.7
1934			71.9	94.1	41.8	76.5	91.3	112.3
1935			70.8	92.6	41.1	74.1	92.8	116.0
1936			70.2	91.8	42.2	75.4	88.3	107.5
1937			69.9	91.4	41.6	74.0	89.6	110.6
1938			67.6	88.5	41.2	70.9	92.6	115.5
1939			67.4	88.2	40.6	69.7	94.8	120.0
1940			68.7	89.9	40.9	71.5	98.5	123.8
1941			68.2	89.2	40.8	70.8	101.9	128.4
1942			58.7	76.9	41.1	61.5	125.9	157.5

In column 1 the Census employment totals (Table 36) were interpolated annually, 1919–29, by means of column 2. Thus, the ratios of column 1 to column 2 for successive pairs of odd-numbered years were averaged and applied to the intervening employment total in column 2. The employment series in column 2, from American Gas Association *Statistical Bulletin 8*, p. 28, represents all plants manufacturing gas for all or any part of 1919–29. As such, its level is considerably higher than that of column 3, which for the most part covers plants manufacturing gas in the year in question, regardless of their product in preceding or subsequent years. The data in column 3, except for 1929, 1930 and 1931, which are from *Bulletin 10* (October 1932, p. 9), are from successive issues of the AGA statistical bulletins, and cover plants manufacturing gas in 1931. However, the output data on which the output-employment ratios are based are for the same plants.

For the period before 1929 the indexes in columns 4, 6, 7, and 8 are based on the interpolated Census data, and for the period after 1929 on the AGA data. The resulting indexes for 1899–1942 are regarded as retaining a fair degree of continuity, although different sets of data were used in their computation. The series on average hours worked per week is the NICB series in Table 36.

characterized as declining), but the evidence of the manufactured gas industry is highly suggestive, though necessarily qualified by the rather special character of its 'decline', which, as we saw, was a

consequence of a shift to natural gas. The index of manufactured gas output per employee rose rapidly, from 36.0 in 1899 to 73.9 in 1919, or at an average annual rate of 3.6 percent. The annual rate of gain during the next decade was about 3.1 percent; while in the final period after 1929 there was no increase at all if we exclude the years after 1940, when, under the combined pressure of labor shortage and unprecedented demand, the industry operated at a level of output-employment efficiency 25 percent greater than in 1929. The failure of the manufactured gas output-employment ratio in the '30's to exceed the level attained in the preceding decade is noteworthy and may be contrasted to the output-employment ratio of the railroad industry, another public utility: despite a sustained decline in traffic after 1929, the ratio continued to rise considerably. The average annual rate of retardation indicated by a logarithmic parabola fitted to the manufactured gas index of output per man (Chart 19) is quite pronounced — −.102 percent; the annual rate of gain, averaged for the entire period 1899–1942, is 2.35 percent.

4 Relation of Input to the Output of Manufactured and Natural Gas

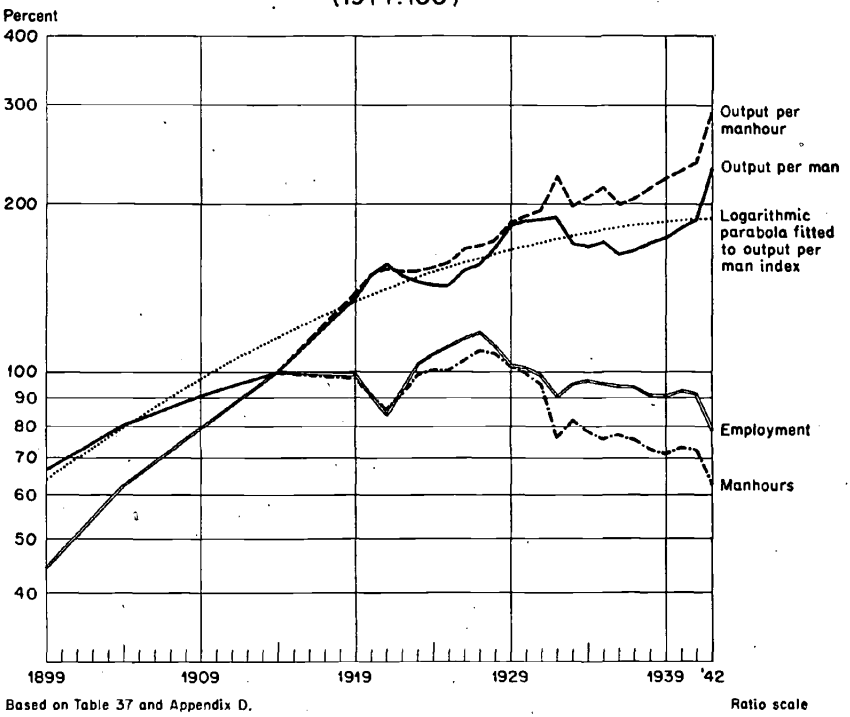
Data on the resources consumed in the production of natural gas are fewer than for manufactured gas. With respect to fixed capital assets, the former industry has in recent years overtaken the latter. It reported over $2.00 billion in 1942 to the American Gas Association; in the manufactured gas industry the value of such assets has remained fairly stationary, fluctuating about the $2 billion level since 1929.[8] We do not know the size of natural gas capital assets in 1929 or before, but as the mileage of gas mains in the industry has increased some 30 percent since 1931, capital assets probably mounted rapidly (Table 38).

Data on employment in the natural gas industry go back only to 1929, for not until then did the American Gas Association recognize the natural gas industry as a statistical entity separate from the manufactured gas industry. The contrast to the manufactured gas industry since 1929 is striking. In the late '30's natural gas employment rose slightly above the 1929 level; the peak was reached in 1941 with 70,700. By the close of the '30's weighted output per employee had advanced more than 25 percent over 1929, even if the

[8] The assets are for the utility plants of all companies included by the AGA in the natural gas industry. Pipe lines and producers of natural gas are included if they are engaged in the sale of natural gas to domestic, commercial, or industrial consumers.

CHART 19

Manufactured Gas, 1899–1942
Indexes of Employment, Manhours, and Output per Unit of Labor
(1914:100)



remarkable upward surge in 1942 is ignored. These are certainly characteristics of a growing industry. As noted, the gain in gas main mileage in this period was substantial, but it still lagged far behind the gain in natural gas output. Sales per mile of gas main rose 55.5 percent: from 5,608 th. cu. ft. in 1931 to 8,718 in 1942.

Thus when we consider the manufactured and natural gas industries as components of a single gas industry we get a picture far more favorable than the traditional view of manufactured gas as a 'declining' industry, for natural gas is the dynamic factor in modern gas distribution. A picture of the probable over-all change in the output-employment ratios for the combined manufactured and natural gas industry since 1899 is shown in Table 39, based, however, on some admittedly arbitrary assumptions concerning employment in natural gas distribution in 1899. If we accept as valid the 1899 data in Table 39, though they do not rest on as sound a

TABLE 38

Natural Gas, 1929–1942

Indexes of Output, Employment, and Gas Main Mileage

	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
Total sales, bil. cu. ft.	954	954	875	804	818	960	1,039	1,231	1,314	1,213	1,328	1,442	1,606	1,768
Employment, th.	62.8	55.3	51.0	47.0	48.2	54.0	56.3	65.2	65.7	64.0	65.3	69.5	70.7	63.2
Miles of gas main, th.			156.0	160.0	165.9	169.1	172.0	179.7	182.3	186.8	190.3	195.1	198.8	202.8
Sales per mile of gas main, th. cu. ft.			5,608	5,023	4,933	5,679	6,038	6,850	7,210	6,494	6,981	7,388	8,079	8,718
						INDEXES								
Weighted output, 1929:100	100.0	102.3	99.9	94.9	92.1	100.0	107.9	124.8	132.1	126.0	135.8	150.0	159.9	178.4
Unweighted output (sales), 1929:100	100.0	100.0	91.7	84.3	85.8	100.7	108.9	129.0	137.8	127.2	139.3	151.2	168.4	185.4
Employment, 1929:100	100.0	88.1	81.2	74.9	76.8	86.0	89.6	103.8	104.7	101.9	104.0	110.7	112.6	100.6
Miles of gas main, 1937:100			85.6	87.8	91.0	92.7	94.3	98.5	100.0	102.5	104.4	107.0	109.0	111.2
Weighted output per employee, 1929:100	100.0	116.1	123.0	126.7	119.9	116.2	120.4	120.2	126.1	123.6	130.6	135.6	142.0	177.3
Sales per mile of gas main, 1937:100			77.8	69.7	68.4	78.8	83.8	95.0	100.0	90.1	96.8	102.5	112.1	120.9

Successive issues of the American Gas Association's *Annual Statistics of the Natural Gas Industry*. Data for each year are for the activities of plants distributing natural gas in that year, though in former years they may have been classified in the manufactured gas industry. The employment data for 1931–33, however, are for plants distributing natural gas in 1933 (AGA *Statistical Bulletin 13*), while the employment figures for 1929 and 1930 were derived by subtraction of the corresponding gas manufacturing employment from employment totals for the two industries combined, which the AGA made available to us. These combined totals were: 1929, 139.2 th; 1930, 131.1 th. The gas main mileage figures for 1931–33, similarly, are for the natural gas industry as defined in 1933.

factual basis as the data for later years, then total employment in the combined industry in 1942 was 173.3 percent higher than in 1899; total weighted output, 737.9 percent. The consequent increase in total weighted output per man was more than 200 percent. The equivalent annual rate of increase, 2.6 percent, is far less than the over-all annual rate of increase in output per man for electric light and power (5.2 percent), but is considerably higher than that for the manufacturing, agricultural, mining, and railroad groups (Ch. 5, Sec. 2).

In terms of aggregate sales per employee, the combined industry distributed about 4 million cubic feet per man in 1899 and 18.1 million in 1942, an increase of more than 350 percent; the ratios for the manufactured gas industry alone were 2.4 million cubic feet per man in 1899 and 7.5 million in 1942, an increase of about 200 percent. The rapid rise of natural gas adds greatly to the efficiency of gas distribution, in terms of total gas sales per man. We cannot ascertain precisely how much over-all economy of labor is contributed by the natural gas industry, because our estimate of natural gas employment in 1899 (Table 39) was based on the assumption that sales per man 1899–1929 increased at the same rate in the two industries. However, the 350 percent estimated increase in total manufactured and natural gas sales per man since 1899 reflects the greater labor economy achieved by the natural gas industry than in the manufactured gas industry since 1929,[9] and in addition, reflects the effect on aggregate sales per man of the higher level of 'labor efficiency' at which the natural gas industry operates and

TABLE 39

Manufactured and Natural Gas, 1899, 1929, 1937, and 1942
Indexes of Total Output, Employment, and Output per Man (1899:100)

	1899	*1929*	*1937*	*1942*
Weighted output index	100.0	633.4	656.7	837.9
Employment, th.	44.6	139.2	135.6	121.9
Employment index	100.0	312.0	304.0	273.3
Weighted output per man	100.0	203.0	216.0	306.6
Total sales, bil. cu. ft.	178.6	1,354.9	1,665.1	2,208.2
Sales per man, mil. cu. ft.	4.00	9.73	12.28	18.11
Sales per man index	100.0	243.2	307.0	452.8

The figures for 1929, 1937, and 1942 are for total employment in both industries as reported to the American Gas Association. The employment figure for 1899 was

[9] E.g., the annual rate of increase in the weighted output per man index for the combined gas industry 1929–37 is about 0.8 percent; for manufactured gas alone, it declined 1.4 percent per year.

estimated as the sum of the Census figure, 28.36 th., and a rough estimate for natural gas employment, 16.25 th. The latter was based on the assumption that the ratio of total sales to employment in 1899 was 2.9 times as great in the natural as in the manufactured gas industry — the relation prevailing in 1929, when sales per employee in the natural and manufactured gas industries were 15,194 th. cu. ft. and 5,249 th. cu. ft. respectively (AGA data).

Sales per employee for the manufactured gas industry in 1899 amounted to 2,366 th. cu. ft. Intra-industry gas sales may have been included in the 1899 Census sales totals, but were probably of slight importance, since in 1904 industry purchases of gas from all sources totaled 2.7 bil. cu. ft. (Table 31).

In 1899 223.0 bil. cu. ft. of natural gas were sold, including, however, sales for field use and carbon black manufacture which did not require utility service. We must make some estimate of the proportion of total natural gas sales that could be regarded as a utility service. In 1919, the first year in which sales for industrial consumption were distinguished from sales for field use and carbon black manufacture, the industrial component made up 36.3 percent of the total, as against 34.3 percent for domestic and commercial sales, and 29.4 percent for non-utility sales (see Table 29). The latter probably declined in relative importance as pipeline distribution facilities became available. However, we cannot more than guess how much higher the non-utility percentage of total natural gas sales was in 1899. We arbitrarily allocated one-half of total sales to the utility industry and regarded the other half as a nonutility component. Making this assumption, we may estimate natural gas employment in 1899 from the equation $\frac{111.5 \text{ bil.}}{x} = 2.9\ (2366 \text{ th.});\ X = 16.25 \text{ th.}$

This method of estimation credits the natural gas industry with the same rise in output per man achieved by the manufactured gas industry 1899–1929, and the resulting 1899 employment figure must therefore be regarded as very crude. Reflecting the more rapid rise in natural gas productivity since 1929, the ratio of total sales to employment in 1942 was 3.7 times as great in the natural gas industry as in manufactured gas.

which of course is a consequence of the fact that our natural gas employment data include no production employment. The manufactured gas industry distributed 7.5 million cu. ft. per man in 1942, the natural gas industry, 28.0 million — a notable difference.[10]

[10] A precise estimate of the net *social* gain in total gas output per man due to the growth of natural gas consumption would necessitate estimating the labor required in the production (i.e., the 'mining') of natural gas. Such employment is included with the employment associated with the output of petroleum, and cannot be segregated except for very recent years, though we can infer that it must have been very small in all years. In 1938 the *Minerals Yearbook* reported 8,100 persons engaged in the production (as a mining operation) of natural gas. Inclusion of such employment (if possible) could not have much effect on measures of total gas output per man (see Barger and Schurr, *op. cit.*, pp. 325–6).