Preliminary Evaluation of the Use of Powdered Coal as a
Natural Gas Substitute for Sewage Sludge Incineration

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Abstract

Data was collected from each EPA region, each state environmental protection agency, and certain U. S. cities relative to oil, gas, and electricity usage for purposes of wastewater sludge incineration. At present, in the U. S. 7.2×10^{12} BTU of premium fuels are utilized for sludge incineration, 68% of which is from gas and 31.5% from oil. Major urban areas at present utilize 3.5×10^{12} BTU/yr of these fuels of which 99.5% is from natural gas.

By considering sludge incinerators planned and under construction, it may be expected that by 1980, about 9.1×10^{12} BTU of premium fuels will be used for this purpose. If ocean dumping and landfilling of sludge were prohibited, and all major urban areas were to utilize sludge incineration, it may be expected that about 32×10^{12} BTU (or 159,000 heating equivalents) of premium fuels would be used for this purpose.

Coal may be utilized to replace the premium fuels used for sludge incineration. Powdered coal may be utilized in biological reactors as nucleation sites for bio-floc development resulting in enhanced biological processing efficiency, while the resulting coal-biological sludge mixture may be sent to the sludge incinerator. Powdered coal usage at levels dictated by bio-reactor requirements indicate that the possibility exists to recover surplus coal-sludge generated energy from incineration, it may be expected that 60×10^{12} BTU of premium fuel freed up for public use. The total social impact of this incinerator is about 450,000 home heating equivalents of energy, about 77.5% of which located in major urban areas.

Key words

powdered coal

natural gas

oil

sludge incineration

coal

wastewater treatment

wastewater sludge

water pollution

sludge disposal

coal based wastewater treatment

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Introduction

The problems of sludge disposal are particularly acute for large urban area wastewater disposal facilities. On a national scale, approximately 35% of all municipal sludge is incinerated, 25% landfilled, 25% applied directly to the soil (land application) and 15% disposed of in the ocean. Direct land application for large urban areas wastewater sludges is often non-cost effective due to the large quantities produced, lack of nearby land suitable for such application, and transportation costs involved. Large eastern and pacific coast cities using ocean disposal face environmental pressures to cease using this disposal alternative.

Coupled with strict sludge disposal environmental restrictions and an increasing awareness of the secondary impact of land and ocean sludge disposal, are requirements for improved wastewater treatment as outlined by public law 92-500. Based on the requirements of the act, it may be estimated that the yearly quantities of municipal sludge to be disposed of will double within the next 10 years. It may further be assumed that the quantity of sludge to be disposed of from the industrial sector is many times larger than that from municipal wastewater treatment.

The review provided in this project indicates that the incineration of sludge is on the increase particularly in urban areas.

The rationale for this increase, as pointed out, is due to rapid increases in land costs and decreases in availability for land suitable for sludge disposal, an increase in political pressure to dispose of sludge in the close proximity to its generation and an increase in awareness of the health and aesthetic effects of sludge handling and disposal.

The rationale for sludge disposal is simple, it provides for a higher degree of volume reduction, and produces sterilized and odor free end products. These end products are an inert residual ash, CO_2 , H_2O with some SO_2 and NO_x .

The calorific value of sludge varies and is a function of its moisture content, volatile content, grease content, and ash content. Vesilind (1) reports a rough value of about 10,000 BTU/lb VSS as the fuel value of sludge, which is in fair agreement with data presented by Balakrishnan (2). While a rough rule of thumb is that 30% dry sludge solids can sustain combustion, EPA data (3) point out that sludges dewatered to 18 1/2% to 42% solids have in fact sustained combustion without external fuels. An analysis of this data may be misleading while evaporation of moisture and carbonaceous solids combustion are the principal goals of sludge incineration, often excess fuel is utilized in practice to assure proper odor control. As summarized by Neufeld (4) deodorization of sludge in incineration stack gases occur when the fire box temperature is in the neighborhood of 1350° to 1400°F. Lower temperatures may lead to partially oxidized organics with lower odor thresholds than that of the parent compound. Accordingly it is common practice for operating sludge incineration to utilize excess fuel over and above that minimum for self combustion.

At present, about 4.9×10^9 ft³/yr of natural gas, 16.6×10^6 gal/year oil and 9.24×10^5 KWH/yr of energy are used as fuel supplements for sludge incineration. This is the energy equivalent of heating about 37,500 homes per year. Due to the potential public health hazards associated with malfunctioning wastewater treatment plant and their sludges, there often exists a higher priority for the use of natural gas by wastewater facilities than for the industrial sector. There exists a sensitive situation today regarding natural gas and oil supplies. The main thrust of this study is to document the quantity of these premium fuels used for sludge incineration as categorized by states, EPA regions, and major urban areas.

Alternatives Proposed

Alternatives to the use of premium fuels for sludge incineration include development of non-energy intensive sludge dewatering devices, development of sludge-municipal waste pyrolysis schemes, or development of techniques to utilize non-premium fuels such as powdered coal.

Previous research has demonstrated that the addition of powdered coals to biological reactors typical of those found in wastewater treatment plants yield improvements in overall plant efficiency and enhanced environmental quality (5). Calculations performed in conjunction with the data collected in this project indicate that use of all of the above premium fuels now in use for sludge incineration may more than be replaced with powdered coal by adding the coal to the biological reactor in an amount of about 2,000 mg/l. The rationale for enhanced wastewater treatment efficiency is that the powdered coal when added to the biological reactor also serves as nucleation sites for the growth of fixed film biota (6). Thus, as shown on Figure 2, the biological reactor would have both suspended biomass (as in the case of a conventional system) and fixed biomass. The closest analogy now in practice is the new

Philadelphia (7) "Surfact" system which employs large rotating plastic disks in an aeration tank (biological reactor) to support fixed biota in a solution of suspended biota. The advantage of the coal based "hybrid" system over the Philadelphia system is that more surface area exists for fixed film biota, and the wasted sludge which ultimately is incinerated, contains coal. In this fashion, existing usage of premium fuel may be replaced by the energy value of powdered coal. A detailed analysis of the kinetics and improved efficiencies that may be expected from the "Hybrid" system are presented by Yodnane (6).

The data collected in conjunction with this project indicate that at present in the U.S., about 7.2×10^{12} BTU/yr of premium fuels are used in sludge incineration which as indicated above, represents about 37,500 home equivalents. Most of this usage occurs in EPA regions V, VI, and III. This energy may be replaced with about 280,000 tons of powdered coal, a level determined by wastewater optimal design considerations (5,6).

A 2,000 mg/l level of coal addition, to the biological remotor, indicates the possibility of energy reclamation from coal-sludge mixtures incineration for a total amount of about 70,000 home equivalent based on current sludge incineration rates. This implies a total coal usage of about 800,000 tons/yr.

Significance

While the total energy now utilized for sludge incineration and potential for powdered coal usage is small on a national scale, the application is localized in major urban areas: thus the impact is great where the need is the most acute.

Future: Data analysis of 1980 actual plans for sludge incineration indicates that a total of 9.1×10^{12} BTU/yr of premium fuels will be

used in the U.S. for sludge incineration. About 1/3 of this usage shall occur mainly in the 9 largest urban areas. The use of the coal based wastewater treatment system (Hybrid reactor) will free up these premium fuels and provide additional surplus energy translatable to a total of home equivalents as being generated by the sludge incinerator. Thus elimination of premium fuels for sludge incineration and a net total of about 120,000 home equivalents of energy may possibly be realized if existing and planned incinerators along with large urban area waste treatment systems utilize a coal based wastewater treatment system.

If all of the 17 large urban areas such as New York City and Chicago (see Table 3) utilize sludge incineration by 1980, it may be conservatively expected that an additional 21.5×10^{12} BTU/yr of premium fuels will be utilized. Replacement of this fuel usage by powdered coal indicates a total savings of at least 147,716 home heating equivalents per year. Assuming coal will also be used in the biological monitor for efficiency enhancement purposes, an additional 23×10^{12} BTU/yr will be generated by such sludge incineration facilities. By combining the energy from premium fuels saved from coal replacement and the energy generated from environmental enhancement uses of coal, a total energy credit of 265,747 home heating equivalent may be conserved each year (Table 4).

Figure 1 is an energy summary diagram showing (a) energy usage by major urban areas for sludge incineration, (b) total energy usage in the U.S. for sludge incineration, and (c) total energy to be made available to society if a coal based wastewater treatment facilities were employed and excess energy produced were recovered. These levels of energy usage are illustrated for (1) 1970 actual data, (2) for 1980 utilizing data for new sludge incinerators now under construction or in planning stages and (3) for 1980 assuming all major urban areas (such as New York City)

will utilize sludge incineration. As can be seen, if sludge disposal alternatives such as ocean dumping and land fill force major urban areas to utilize sludge incineration, about 31×10^{12} BTU/yr of premium fuel may be expected to be used for this purpose. This value is in fact conservative in that for calculation purposes it was assumed that the sludge was dewatered to 20% prior to incineration.

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Chapter II

Details of Project

PROCEDURES FOR DATA ACCUMULATION

I. Fuel used for sludge incineration in the U. S.

A. Approach

Letters were sent to 10 EPA Regional Offices and 50 state water pollution control agencies. The letter explained the purpose of the study and requested a list of treatment plants that practice sludge incineration. The specific information requested was (a) type and amount of fuel used, (b) sludge production rate, (c) quantity of sludge incinerated and the number of operating days per year.

A list of existing sludge incinerators in Pennsylvania was obtained from the solid waste division of the Pennsylvania Department of Environmental Resources. Some treatment plants were contacted by telephone in order to obtain the necessary data.

The response from EPA region V indicated that Mr. Alan Hais, of the Municipal Technology Branch, EPA Headquarters, Washington, D. C. was assigned the task of collecting data of fuel used for sludge incineration from other EPA regions. This activity was initiated by E. P. A. due to the request of Congressman John D. Dingell of the House Committee on Interstate and Foreign Commerce. The Congressman requested information regarding the use of physical means to help dry sludge indicating that the use of natural gas for other critical uses might have a more positive impact on

environmental quality than its use as a fuel for drying and incinerating sewage sludge.

Mr. Alan Hais was contacted by project personnel for copies of the data concerned.

B. Analysis of Data

The data received from the states, EPA Regions, and Mr. Hais was categorized by city, state, and EPA region, and presented in tables 1 through 4. Fuel usage for sludge incineration in each appropriate treatment plant is presented similarly; the data for total use of gas, oil, and electricity for sludge incineration is presented respectively by state, and EPA Region.

The following energy equivalents were used for calculations:

1 cubic foot of gas	= 1,000 BTU
1 gallon of oil	= 137,000 BTU
1 KWH of electricity	= 3,413 BTU
193×10^6 BTU	Fuel used to heat 1 Pittsburgh home for 1 year *

The home equivalence to fuel used in each treatment plant is calculated and tabulated by states and EPA regions.

The estimate of extra gas, oil and electricity saved by coal addition to a biological reactor is calculated as follows:

Previous literature (5) indicated that the suitable amount of powdered coal addition to enhance waste treatment is 2000 mg/l. This amount of coal addition is often equal to the MLVSS in the most activated sludge systems. To maintain 2000 mg/l of coal in a biological reactor as sketched in Figure 2, coal addition is approximately equal to the sludge drymass wasting rate. The extra energy saved is equivalent to that recoverable by the sludge incineration facility.

*Data provided by Peoples Gas Co., Pittsburgh.

When necessary and in the absence of specific data, estimates of premium fuel usage in sludge incineration and of coal substitution was based on the following:

- A) If the data of the amount of sludge wasted is available, the estimate of coal addition was equal to the amount of sludge wasted on a dry weight basis.
- B) Where there is a lack of sludge wasting rate data, but known size of treatment plant (MGD), the sludge wasting rate is prorated from existing data for other plants. For example, the Alcosan waste treatment plant in Allegheny County, Pennsylvania is 173 MGD and reports sludge wasting at 42,133 tons/yr. If a treatment plant is 10 MGD, the sludge wasted per yr. is about $\frac{10 \times 42,133}{173} = 2435$ dry tons/yr, and coal addition is also estimated to be 2435 tons/yr.
- C) The majority of the provided EPA data did not list treatment plant size, but did indicate fuel usage. Sludge wasting rate was estimated by estimating flow rate of the treatment plant on a population basis using published population data. The assumption of 200 gpcd is used to estimate flow rate. The sludge wasting rate and the level of coal addition is then estimated by approach B.

The energy input due to coal addition is estimated by using 13,000 BTU per pound of coal as a conversion factor. The net BTU surplus from coal addition is obtained by subtracting the energy needed for sludge incineration from that provided by coal. The net BTU surplus may then be re-interpreted as home-heating equivalences based on Pittsburgh annual averaged home usage.

II. Fuel net used for sludge incineration in 17 largest U. S. urban areas

Seventeen major urban areas were selected for a closer study of present premium fuel consumption and the potential of fuel consumption for sludge incineration in the future. Nine out of the seventeen largest U. S. cities are presently incinerating sludge and the remaining 8 have a high probability of incinerating in the near future.

Each city was contacted by personal communication to obtain necessary data. The specific data requested was: the size of the plant, sludge production rate, percent sludge solids, method of sludge disposal, and fuel used if incineration is employed.

The estimated amount of premium fuel saved by coal substitution is also presented by using the approach as presented above.

Chapter 3

Results

Table 1 is a summary table indicating levels of premium fuels used in each state grouped by EPA region. As shown at the end of this table, as of 1976 a total of 4.9×10^3 ft³/yr of natural gas, 16.6×10^6 gallons of oil, and 925×10^3 kilowatt hours of electricity representing a total of 7.2×10^{12} BTU are used each year for sludge incineration. This represents the equivalent of about 37,500 homes which may be provided with energy throughout the year. These data are pictorially represented on Figure #3.

As shown by column 6 of Table 1, if coal is added to a biological reactor for purposes of enhancing process efficiencies in accord with the hypothesis of Yodnane (6) and Neufeld, incineration of the residual coal rich sludge will provide recoverable energy in the total amount of 70,000 home heating equivalents utilizing about 800,000 tons of coal per year. The recoverable energy, plus the premium fuels not used for sludge incineration represent a total of 107,535 home heating equivalents. This information is also shown in Table 1.

Table 2, based primarily on federal data, lists sludge incineration facilities either in planning or construction stages with expected date of operation by EPA region. The table summary shows this incremental planned usage to be 18.5×10^{12} BTU/yr or 9,572 home equivalents. Figure 4 illustrates 1976 and future projected requirements of each of the three premium fuels used for sludge incineration. Much of incinerator facility planning was done prior to the advent of the "energy crisis", and prior to the current era of rapidly inflating oil price. It is therefore interesting to see that Figure 7 indicates such a relatively sharp increase in the specific use of oil. This increase may now be tempered via the substitution of coal for premium fuels as outlined in this report.

Change In Existing Sludge Disposal Scenerio for Large Urban Areas

Recently, major urban areas have faced serious difficulties with sludge disposal via land fill and ocean dumping. Table 3, developed land or direct contact with municipalities in question, shows present sludge disposal techniques used, quantities of natural gas actually used for applicable incinerators, and a calculated potential quantity of natural gas to be used if all ocean dumping and land fill operations were converted to sludge incineration operations.

For purposes of gas usage calculations, it is assumed that the sludge to be incinerated is 20% solids, representing a relatively high degree of dewatering. As shown on Tables 3 and 4, New York, Chicago and Los Angeles represent the majority of potential natural gas users for sludge incineration totalling 19.5×10^9 out of a possible 21.6×10^9 ft^3/yr of gas. Present gas consumption for sludge incineration in these urban areas is about 3.5×10^9 ft^3/yr with Houston, Detroit and Pittsburgh as the largest existing users. On a national scale, large urban areas use about 80% of all natural gas used for sludge incineration purposes.

Figure 5 is a pictorial representation of premium fuel conservation which may be realized if each of the 17 major urban areas listed on Table 4 utilize coal based wastewater treatment with sludge incineration. As shown on this figure, if a policy were made to substitute coal for natural gas in sludge incineration, a savings of about 25×10^{12} BTU/yr of premium fuels would result. Additional coal usage for environmental purposes would result in an additional 22.8×10^{12} BTU/yr to be recovered by such incineration facilities with a total impact of about 265,747 home equivalents. It is important to note that about 80% of these homes will be located in New York, Chicago, and Los Angeles and not dispersed across the country.

Costs

Appendix B is a marginal cost estimate associated with the use of coal based biological wastewater process with coal-sludge incineration.

Costs are taken for increased capital and debt service, coal and operation-maintenance costs. Credits are taken for premium fuels conserved and for energy generated at a nominal $\$2/10^6$ BTU. While these calculations are admittedly rough, it highlights the viability of this approach. Under conditions assumed, a net cost of $\$2.28/\text{Million}$ gallons of wastewater will result from coal-sludge incineration with coal addition to the biological reaction. If the cost of premium fuels and recovered energy is estimated to be $\$2.13/10^6$ BTU, break even will occur. Additional values represented by lack of need for ocean disposal or land filling for sludge have not been considered, nor has the social value of premium fuels now available to the public.

Thus, for larger urban areas, the concept of coal-sludge incineration with excess coal-energy recovery becomes increasingly attractive both from a financial point of view, and as an approach to increase the locally available supply of premium fuels.

Table 1

Fuel used and potential of fuel saving by coal substitution in the U.S. - 1976 Data

EPA Region	1 State	2 Fuel Used	3 BTU Used ($\times 10^9$ - BTU/yr)	4 Home Equiv. Based on Col. 3	5 Estimated Coal Substituted (tons/yr) *	6 Home Equiv. of Net Surplus BTU from Coal (Col. 5)	7 Net Impact Col. 4 & Col. 6
I	Conn.	O = 1,396 G = 44	270.	1,404	21,783	1,544	2,948
	Mass.	O = 7.88 G = 58.3	165.	688	17,103	1,445	2,133
	New Hamp.	O = 58	7.95	41	530	30	71
	Rhode Island	O = 275	37.6	195	2,500	142	337
	Vermont	No **					
	Maine	No					
	Sub-Total	O = 2,517 G = 102.3	480.45	2,328	41,916	3,161	5,489
II	New York	O = 3,092 G = 9.13 E = 179,720	432.52	2,235	33,500	2,272	4,507
	New Jersey	O = 828 G = 3920 E = 9.13	112.8	670	12,000	1,032	1,702
	Sub-Total	E = 179,720	545.32	2,905	45,500	3,304	6,209

O = Oil in 10^3 gal/yr
 E = Electricity in KWH/yr
 G = Gas in 10^6 ft³/yr
 ** = No sludge incinerator

*Assuming Coal based biological
 Reactor is employed

Table I
(Con't.)

1	2	3	4	5	6	7	
EPA Region	State	Fuel Used	BTU Used ($\times 10^9$ - BTU/yr)	Home Equiv. Based on Col. 3	Estimated Coal Substituted (tons/yr) *	Home Equiv. of Net Surplus BTU from Coal (Col. 5)	Net Impact Col. 4 & Col. 6
III	Penna.	O = 914 G = 692.6	816.74	4,232	66,508	4,728	8,960
	Maryland	O = 650 G = 8.18	97.18	464	3,750	2	466
	Virginia	O = 1,662 G = 51.6	279.16	1,445	17,500	910	2,355
	W. Va.	No					
	Delaware	No					
	Sub- Total	O = 3,226 G = 752.38	1,193.08	6,141	87,758	5,640	11,781

Table 1
(Con't.)

	1	2	3	4	5	6	7
CPA Region	State	Fuel Used	BTU Used (x 10 ⁹ - BTU/yr)	Home Equiv. Based on Col. 3	Estimated Coal Substituted (tons/yr) *	Home Equiv. of Net Surplus BTU from Coal (Col. 5)	Net Impact Col. 4 & Col. 6
IV	Alabama	No					
	Miss.	No					
	Tennessee	O = 335 G= 165.6	211.5	1,096	25,000	2,270	3,366
	North Carolina	O = 443 G= 36	96.6	497	11,250	1,013	1,510
	South Carolina	O = 9.6 G= 100	101.3	528	8,500	620	1,148
	Kentucky	O = 114	15.6	80	1,250	87	167
	Georgia	G= 119	119	616	39,900	4,758	5,374
	Florida	O = 1,276 G= 11	185.81	963	29,250	2,977	3,940
	Sub- Total	O = 2,064 G= 432	729.81	3,780	115,150	11,725	15,505

Table 1

(Con't.)

1	2	3	4	5	6	7	
EPA Region	State	Fuel Used	BTU Used (x 10 ⁹ - BTU/yr)	Home Equiv. Based on Col. 3	Estimated Coal Substituted (tons/yr) *	Home Equiv. of Net Surplus BTU (from Coal (Col. 5)	Net Impact Col. 4 & Col. 6
V	Illinois	No					
	Indiana	No					
	Michigan	G= 1033.2	1033.2	5,352	103,750	8,527	13,879
	Minnesota	G= 500	500	2,590	54,000	4,751	7,341
	Ohio	O = 4,262 G= 6	589.7	3,057	113,250	12,201	15,258
	Wisconsin	G=15.8	15.8	82	1,053	60	142
	Sub- Total	O = 4,262 G= 1,555	2138.7	11,081	272,053	25,539	36,620

Table 1

(Cun't.)

	1	2	3	4	5	6	7
EPA Region	State	Fuel Used	BTU Used (x 10 ⁹ - BTU/yr)	Home Equiv. Based on Col. 3	Estimated Coal Substituted (tons/yr) *	Home Equiv. of Net Surplus BTU from Coal (Col. 5)	Net Impact Col. 4 & Col. 6
VI	New Mexico	No					
	Oklahoma	G= 6.67	6.67	34	1,000	100	134
	Arkansas	G= 81.12	81.12	420	6,250	422	842
	Texas	G= 1,230 E=750,000	1,232.6	6,385	82,172	4,683	11,068
	Louisiana	G= 89.62	89.62	464	11,500	1,083	1,547
	Sub- Total	G=1,407.4 E=750,000	1,410	7,303	100,922	10,088	
VII	Nebraska	O = 79.5 G= 124.2	135	700	17,500	1,658	2,358
	Iowa	G= 36.5	36.5	189	175,000	484	
	Kansas	G= 41.36	41.36	214	15,750	1,907	2,121
	Missouri	O = 130 G= 320	377.9	1,747	59,250	6,232	7,979
	Sub- Total	O = 209.5 G= 522	550.6	2,850	97,500	10,281	13,131

Table 1
(Con't.)

	1	2	3	4	5	6	7
EPA Region	State	Fuel Used	BTU Used (x 10 ⁹ - BTU/yr)	Home Equiv. Based on Col. 3	Estimated Coal Substituted (tons/yr) *	Home Equiv. of Net Surplus BTU from Coal (Col. 5)	Net Impact Col. 4 & Col. 6
VIII	Montana	No					
	Wyoming	No					
	Utah	No					
	Colorado	No					
	N. Dakota	No					
	S. Dakota	No					
IX	California	O = 54.75 G = 71.74	79.24	412	12,125	1,223	1,636
	Nevada	G = 26.8	26.8	139	3,750	366	505
	Arizona	No					
	Hawaii	No					
	Sub- Total	O = 54.75 G = 98.54	106.04	551	15,875	1,589	2,140

Table I

(Con't.)

1	2	3	4	5	6	7	
PA Region	State	Fuel Used	BTU Used (x 10 ⁹ - BTU/yr)	Home Equiv. Based on Col. 3	Estimated Coal Substituted (tons/yr) *	Home Equiv. of Net Surplus BTU from Coal (Col. 5)	Net Impact Col. 4 & Col. 6
X	Washington	O = 40 G = 22.8	28.3	147	8,000	931	1,078
	Oregon	O = 340	46.5	240	5,000	433	673
	Idaho	No					
	Alaska	G = 7.8	7.8	40	8,500	1,105	1,145
	Sub- Total	O = 380 G = 30.6	82.6	427	21,500	2,469	
	TOTAL	O=16,633.25 G=4909.35 E=929,720	7,236.6	37,495	798,174	70,030	107,525

1976 Summary: Total gas used = 4.909×10^9 ft³/yroil used = 16.633×10^6 gal/yr

Electricity used = 929,720 KWH/yr

Home Equivalence = 37,495

Potential (Estimated) for powdered coal substitution = 798,174 tons/yr

Home equivalence of net surplus

BTU from coal substitution = 70,030 (excess energy due to coal alone)

Total home heating equivalents due to premium fuels not used and energy recoverable = 107,525 homes.

TABLE 2

CURRENTLY PLANNED FACILITIES FOR SLUDGE INCINERATION
Incremental Premium Fuel Usage Until 1980

1	2	3	4	5	6	7	8
EPA Region	State	City	Expected Date of Expansion	Estimated Fuel Requirement	BTU Requirements $\times 10^9$ BTU/yr	Home Equivalence (Based on Col. 3)	Estimated Home Equivalence due to Premium fuel Source + Energy Production
I	Rhode Island	Woonsocket	1977	O = 127.5 G = 17.8	35.2	182	2,346
	Sub-Total		1977	O = 127.5 G = 17.8	35.2	182	2,346
II	New York	Buffalo	1978	O = 6,822	934	4840	62,266
		Niagra S. D.	1978	O = 6	8.2	5	547
		Amherst	1979	O = 3,056	418	2170	27,866
		Oswego (West)	1978	O = 74.8	10.2	55	680
		Oswego (East)	1978	O = 116.5	16	80	1,066
		New Rochelle	1979	G = .285	.285	1.5	19
	New Jersey	Pequanock	1978	O = 145	19.8	100	1,320
	Sub-Total		1978	O = 7164.3	988.2	5120	65,680
			1979	O = 3,056 G = .285	418.2	2190	27,885

TABLE 2 (cont.)

CURRENTLY PLANNED FACILITIES FOR SLUDGE INCINERATION
Incremental Premium Fuel Usage Until 1980

1	2	3	4	5	6	7	8	
EPA Region	State	City	Expected Date of Expansion	Estimated Fuel Requirement	BTU - Requirements $\times 10^9$ BTU/yr	Home Equivalence (Based on Col. 3)	Estimated Coal Substitution	Estimated Home Equivalence Due To Premium Fuel Source - Energy Production
III	Virginia	Hopewell	1977	O = 250	34	180	2,267	485
	Sub-Total		1977	O = 250	34	180	2,267	485
IV	Florida	Boyton- Delray	1979	O = 50 G = 6	13	67	867	184
	South Carolina	Aiken County	Not Indicated	O = 1,095	150	780	10,000	2,127
	Georgia	Gainesville	1977	E = 50,000	.17	1	11	3
	Sub-Total		1977	E = 50,000	.17	1	11	3
			1979	O = 50 G = 6	13	67	867	184
			Not Indicated	O = 1,095	150	780	10,000	2,127

TABLE 2 (cont.)

CURRENTLY PLANNED FACILITIES FOR SLUDGE INCINERATION
Incremental Premium Fuel Usage Until 1980

	1	2	3	4	5	6	7	8
EPA Region	State	City	Expected Date of Expansion	Estimated Fuel Requirement	BTU Requirements $\times 10^9$ BTU/yr	Home Equivalence (Based on Col. 3)	Estimated Coal Substitution	Estimated Home Equivalence Due To Premium Fuel Source + Energy Production
V	--	--	--	--	--	--	--	--
VI	Texas	Houston (Almeda Sims)	Not Indicated	G= 189	189	979	12,600	2,676
		Trinity River	Not Indicated	G= 3	3	15	200	42
		Plano	Not Indicated	E= 1,380,000	4.7	24	313	66
	Sub-Total		Not Indicated	G= 192 G= 3 E= 1,380,000	196.7	1018	13,113	22,784
VII	---	---	---	---	---	---	---	---
VIII	---	---	---	---	---	---	---	---
IX	California	Monterey	1979	G= 14.2	14.2	74	947	202
	Sub-Total		1979	G= 14.2	14.2	74	947	202

TABLE 2 (cont.)

CURRENTLY PLANNED FACILITIES FOR SLUDGE INCINERATION
Incremental Premium Fuel Usage Until 1980

1	2	3	4	5	6	7	8	
EPA Region	State	City	Expected Date of Expansion	Estimated Fuel Requirement	BTU Requirements $\times 10^6$ BTU/yr	Home Equivalence (Based on Col. 3)	Estimated Coal Substitution	Estimated Home Equivalence Due To Premium Fuel Source - Energy Production
X	Alaska	Wrangell	Not Indicated	E= 30,000	0.1	.5	7	2
		Petersburg	Not Indicated	E= 40,000	0.13	.5	7	2
	Washington	Aberdeen	Not Indicated	E= 120,000	0.4	2	26	5
Sub-Total			Not Indicated	E= 190,000	0.63	3	40	9
TOTAL			1977	O = 377.5 G = 17.8 E = 50,000	69.68	361	4,645	988
* O = oil $\times 10^3$ gal/yr G = gas $\times 10^6$ cu. ft./yr E = KWH/yr			1978	O = 7164.3	446	2311	29,733	6,316
			Not Indicated	O = 1095 G = 192 E = 1,575,000	347.33	1780	23,155	4,900
			TOTAL To 1980	O = 11,742 G = 230.3 E = 1,620,000	1,851.21	9,572	123,413	26,200

(Does not include 1976)

Table 3

City	Average Flow (MGD)	Sludge Prod. Rate Dry ton/yr	Sludge Disposal Method	Nat. Gas Used Actual	cu. ft/yr Potential
New York	6000	10^6	Ocean dumping Land Fill		15×10^9
Chicago	1300	2.45×10^5	Land Fill		3.675×10^9
Los Angeles	360	51,369	Ocean dumping		$.77 \times 10^9$
Boston	460	49,450	Ocean dumping		0.738×10^9
Houston (e)	300	--	Incineration	12.3×10^8	
Detroit	300 ^e		Incineration	6.44×10^8	
Minneapolis	218	33,000 ^e	Incineration	$^e 5 \times 10^8$	
Philadelphia	190	30,441	Ocean dumping		0.45×10^9
Dallas	135	25,333	Land Fill		0.38×10^9
Pittsburgh	173	42,135	Incineration	6.32×10^8	
St. Louis (MO)	125	-	Incineration	2.8×10^8	
Atlanta	120	-	Incineration	$.57 \times 10^8$	
Denver	106	18,250	Land Fill		0.273×10^9
Kansas City (MO.)	100	-	Incineration	0.4×10^8	
San Francisco	81	19,710	Land Fill		$.29 \times 10^9$
Jacksonville (e)	105	-	Incineration	$.11 \times 10^8$	
Omaha (NB) (e)	70	-	Incineration	1.24×10^8	
				Oil = 75,639 gal/yr	
e = estimated based on population		Total Natural Gas Usage		3.5×10^9 ft ³ /yr	21.6×10^9 ft ³ /yr **
		Home Equivalence		18,186	111,792
		Total Home Equivalence		129,178	

**The potential gas used will be double if the average concentration of common sludge solid of 10% is used.

TABLE 4
SLUDGE INCINERATION BY 17 MAJOR URBAN AREAS

City	1 Gas Used $\times 10^8 \text{ ft}^3/\text{yr}$ (1980) Actual Potential		2 Estimated Coal Substitution ($\times 10^3$ tons) (1980)	3 BTU Provided By Coal ($\times 10^{11}$)	4 BTU Used/Yr ($\times 10^{11}$)	5 Net Recoverable Surplus BTU From Coal Substitution	6 Home Equiv. Due To Premium Fuel (Col. 4)	7 Home Equiv. Due To Energy Surplus (Col. 5)	8 Home Equivalence
New York		150	1010	262	150	112	77,720	58,031	195,751
Chicago		36.75	245	63.2	36.75	26.4	19,041	13,678	32,791
Los Angeles		7.7	51	13.2	7.7	5.5	3,990	2,850	6,840
Boston		7.38	49	12.7	7.38	5.3	3,824	2,746	6,570
Houston	12.3		82	21.32	12.3	9	6,373	4,663	11,036
Detroit	6.44		75	19.5	6.44	13.06	3,337	6,767	10,103
Minneapolis	5.0		54	14.1	5	9.1	2,591	4,715	7,306
Philadelphia		4.5	30	7.8	4.5	3.3	2,332	1,710	4,042
Pittsburgh	6.32		42	10.9	6.32	4.63	3,275	2,399	5,674
Dallas		3.8	25	6.5	3.8	2.7	1,969	1,399	3,368
St. Louis	2.8		31.2	8.1	2.8	5.3	1,451	2,746	4,197
Atlanta	.57		37.5	9.75	.57	9.18	295	2,756	5,051
Denver		2.7	18	4.68	2.7	1.95	1,399	1,010	2,409
Kansas City (MO)	.4		25	6.5	.4	6.1	207	3,161	3,368
San Francisco		2.9	19.3	5	2.9	2.1	1,502	1,088	2,590
Jacksonville	.1 0 = 76,000 gal.		26.2	6.8	2.14	6.61	1,109	3,425	4,539
Omaha	1.2 0 = 75,539 gal.		17.5	4.5	1.35	3.2	699	1,658	2,357
TOTAL	35.00	215.73	1,837.7	477.8	250	227.8	129,530	118,031	247,561
Home Equiv.	18,186	111,777			129,530	118,031	+ 18,186 (Col. 1) 147,716		+ 18,186 (Col. 1) 265,747

FIG. 1

FIG. 2

FIG.(2) COMPLETELY MIXED COAL BASED WASTE WATER TREATMENT SYSTEM

FIGURE 3

PREMIUM FUELS USED FOR SLUDGE INCINERATION IN THE U.S.
1976 DATA

FIG. 4

PROJECTED PREMIUM FUEL REQUIREMENTS FOR
SLUDGE INCINERATION IN THE UNITED STATES

FIG 5

NATURAL GAS SAVINGS BY COAL SUBSTITUTION
FOR 17 MAJOR URBAN AREA SLUDGE INCINERATORS
FEED SLUDGE = 20% SOLIDS

APPENDIX A

Raw Data Listed By States and Cities:

- a) Premium fuels used for sludge incineration
- b) Potential for recoverable energy via use of coal based biological reactor with sludge incineration (calculated)

ALASKA

35

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Anchorage	34	G=7.8	7.8	40	8,500	221	213.2
TOTAL		G=7.8	7.8	40	8,500	221	213.2

e = Flow estimated from population data

0 = oil gal./yr
G = gas mil. ft. /yr
E = Electricity KWH

¹ coal added equal to sludge produced per day

Connecticut

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. -7 Col. 4 (Btu $\times 10^9$)
Hartford	^e 31	O=10 ⁶	137	710	7500	195	58
Water- bury	^e 21	O=220,000	30	156	5000	132	102
West Haven	10	O=30,000	40	207	2400	62.4	22.4
Torrington	^e 6.5	O=26,000	3.5	18	1550	40	5
Mottabassett	^e 10	G=44	44	228	2933	76	32
New Haven	^e 10	O=120,000	16	85	2400	62.4	46
TOTAL		O=1,396,000 G=44	270	1404	21,783	568	298

^e= Flow estimated from population data

ARKANSAS

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Little Rock	*25	G=81.12	81.12	420	6,250	162.5	81.38
TOTAL		81.12	81.12	420	6,250	162.5	81.38

CALIFORNIA

38

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home. Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
South Tahoe	e ₂₀	G=30.3	30.3	157	5,000	130	99.7
San Clemente	18	G=27.3	27.3	142	4,500	117	89.7
Monterey	e ₅	G=7.1	7.1	37	1,250	32.5	25.4
Ora Loma	e ₃	G=6.2	6.2	32	750	19.5	13.3
Palo Alto	e _{1.5}	G=0.84	0.84	4	125	3.25	2.41
San Bernardino	e ₂	G=54,750	7.5	40	500	13	5.5
TOTAL		G=54,750 G=71.74	79.24	412	12,125	315.25	236

FLORIDA

39

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Jackson- ville	105	O=76,000 G=11	21.41	111	26,250	682.5	661
Pens- acola	12	O=1,200,000	164.4	852	3,000	78	-86.4
TOTAL		O=1,276,000 G=11	185.81	963	29,250	760.5	574.6

GEORGIA

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Atlanta	120	G=57	57	295	37,500	975	918
Utoy Creek	30						
Dekalb County	9.6	G=62	62	321	2400	62.4	.4
TOTAL		G=119	119	616	39,900	1037.4	918.4

IOWA

	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Cedar Rapids	^a 20	G=36.5	36.5	189	5,000	130	93.5
TOTAL		G=36.5	36.5	189	5,000	130	93.5

KANSAS

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col.-7 Col. 4 (Btu $\times 10^9$)
Kansas City	e 33	G=15.8	15.8	82	8,250	214.5	198.7
Shawnee Mission	30	G=25.56	25.56	132	7,500	195	169.4
TOTAL		41.36	41.36	214	15,750	409.5	368.1

KENTUCKY

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col.-7 Col. 4 (Btu $\times 10^9$)
Camp- bell Kentoo City	e5	0=114,000	15.6	80	1250	32.5	16.9
TOTAL		0=114,000	15.6	80	1250	32.5	16.9

LOUISIANA

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per Yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided By Coal ($\times 10^9$)	Energy Generated Col. 7 & Col. 4 (Btu $\times 10^9$)
New Orleans (East Bank)	e ₁₅	G= 41.873	41.873	217	3750	97.5	55.67
New Orleans (West Bank)	e ₁₀	G= 15.429	15.429	80	2500	65	49.5
Lake Charles	e ₁₀	G= 14.940	14.940	77	2500	65	50
Jefferson Parish	e ₈	G= 11.376	11.376	59	2000	52	40
Wachi- toches	3	G= 6.0	6	31	750	19.5	13.5
TOTAL		G= 89.62	89.62	464	11,500	299	209

MARYLAND

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Annapolis	10	G=8.18	8.18	42	2500	65	56.8
Hyattsville	5	O=650,221	89	460	1250	32.5	56.5
TOTAL		O=650,221 G=8.18	97.18	464	3750	97.5	113

MASSACHUSETTS

46

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col.-7 Col. 4 (Btu x 10 ⁹)
New Bedford	30	G = 16	16	83	7,200	187	171
U. B. W. P. A. D.	e ₂₀	G=44.8 O=180,000	69.5	193	4633	120.5	51
S. E. S. D.	e ₃	G= 8.7	8.7	45	580	15.08	6.38
May- nard	e ₁₃	O=356,000	48.7	252	3200	83.2	34.5
Fitch- burg	e ₅	O=142,000	19.4	101	1250	32.5	13.1
	e ₁	O=20,000	2.74	14	240	6.24	3.5
TOTAL		O=788,000 G=58.3	165	688	17,103	444	279

MICHIGAN

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Detroit	^e 300	G=644	644	3336	75,000	1,950	1,306
Lans- ing	^e 26	G=41	41	212	6,500	169	128
Ann Arbor	18	G=53.2	53.2	275	4,500	117	63.8
Kala- mazoo	^e 17	G=69	69	357	4,250	110.5	41.5
Sagin- aw	^e 18	G=20	20	104	4,500	117	97
Wyon- Bay City	^e 11 ₉	G=48	48	244	2,750	71.5	23.5
	^e 9	G=12	12	62	2,250	58.5	46.5
Wyan- dotte	^e 8	G=125	125	648	2,000	52	-73
Tren- ton	^e 8	G=21	21	109	2,000	52	31
TOTAL		G=1033.2	1033.2	5352	103,750	2697.5	1663

MINNESOTA

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col.-7 Col. 4 (Btu $\times 10^9$)
Minneapolis	218	G=500	500	2540	54,000	1,417	917
TOTAL		G=500	500	2590	54,000	1,417	917

MISSOURI

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
St. Louis	^e 125	G=280	280	1450	31,250	812.5	532.5
Kansas City	^e 100	G=40	40	207	25,000	650	610
St. Charles	^e 6	G=98,000	13.4	70	1500	39	25.6
Cape Girardeau	^e 6	G=32,000	4.3	20	1,500	39	34.7
TOTAL		G=130,000 G=320	337.7	1,747	59,250	1540.5	1202.8

NEBRASKA

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col.-7 Col. 4 (Btu x 10 ⁹)
Omaha	e ₇₀	O=79,539 G=124.2	135	700	17,500	455	320
TOTAL		O=79,539 G=124.2	135	700	17,500	455	320

NEVADA

51

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col.-7 Col. 4 (Btu x 10 ⁹)
Clark County	15	G=26.8	26.8	139	3,750	97.5	70.7
TOTAL		G=26.8	26.8	139	3,750	97.5	70.7

NEW HAMPSHIRE

52

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Lebanon	1.65	0=58,000	7.95	41	530	13.8	5.83
TOTAL		0=58,000	7.95	41	530	13.8	5.83

NEW JERSEY

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Gloucester County	e ₈	0=260,000	35	180	2,000	52	17
Bay- shore	e ₈	0=217,700	29.8	150	2,000	52	22.2
Somerset	e ₆	0=150,000	20.5	100	1500	39	18.5
North- west	e ₆	0=161,000	22	110	1500	39	17
Jersey City	e ₂₀	0=40,000	5.5	30	5,000	130	124.5
TOTAL		0=828,700	112.8	670	12,000	312	199.2

NEW YORK

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per Yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy Generated Col. 7 & Col. 4 (Btu $\times 10^9$)
Albany (North)	35	O = 272,800	37.3	193	8750	227.5	190.2
Albany (South)	19	O = 232,900	31.9	160	4700	123.5	91.6
Utica	15	O = 342,274	46.8	240	3750	97.5	50.7
Tona- wanda	^e 5	G = 9	9	47	1250	32.5	23.5
Van Lore	^e 45	O = 2,100,000	287	1,490	11,250	292.5	5.5
Albano	9.35	G = .13 E = 174,720	.72	5	2300	59.8	59
Schen- ectady	^e 5	O = 120,000	16.5	80	1250	32.5	3.2
	^e 1	O = 24,000	3.3	20	250	6.5	3.2
TOTAL		O = 3,091,974 G = 9.13 E = 174,720	432.52	2235	33,500	871	438.5

NORTH CAROLINA

65

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Greene- boro	e ₃₀	G=36	36	187	7500	195	159
Rocky Mt.	e ₇	O=133,000	18	90	1750	45.5	27.5
Concord	e ₄	O=226,000	31	160	1000	26	-5
Shelby	e ₃	O=60,813	8.3	40	750	19.5	11.2
N	e ₁	O=24,000	3.3	20	250	6.5	3.2
TOTAL		O=443,813 G=36	96.6	497	11,250	292.5	195.9

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Cleveland (South)	e75	0=500,050	68.5	350	18,750	487.5	419
Cleveland (West)	e40	0=250,025	34.2	180	10,000	260	225
Akron	e75	0=550,000	75.3	390	18,750	487.5	412.2
Cincinnati	e100	0=1,095,000	150	780	25,000	650	500
Columbus (North)	e100	0=1,095,000	150	780	25,000	650	500
Columbus Jackson Pike	e20	0=175,930	24	120	5,000	130	106
Warren	e10	G=6	6	31	2,500	65	59
Euclyde	e15	0=85,775	11.7	60	3,750	97.5	85.8
Loraine	e15	0=474,500	65	340	3,750	97.5	32.5
Franklin	e3	0=36,500	5	26	750	19.5	14.5
TOTAL		0=4,262,780 G=6	589.7	3,057	113,250	2944.5	2354

OKLAHOMA

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Lawton	e ₃	G=5.47	5.47	28	750	19.5	14.03
Muskogee	e ₁	G=1.2	1.2	6	250	6.5	5.3
TOTAL		G=6.67	6.67	34	1000	26	19.3

OREGON

58

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Hills- boro	20	0=340,000	46.5	240	5,000	130	83.5
TOTAL		0=340,000	46.5	240	5,000	130	83.5

PENNSYLVANIA

59

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Pgh.	173	G=632	632	3,275	42,133	1095	463
Erie	65	G=39 O=612,780	122	632	16,000	416	294
Colmar	e ₅	G=14	14	75	1,250	32.5	18.5
Lans- dale	e ₄	G=6.24	6.24	32	1,000	26	19.7
Morris- vale	e ₄	O=156,000	21.3	110	1,000	26	4.7
Johns- town	e ₈	G= .204	204	1	2,000	52	51.8
Hummels- town	e _{1.5}	O=57,372	7.8	40	375	9.75	1.95
Prus- sia	e ₂	O=88,000	12	60	500	13	1
Norris- town	e ₇	G=.886	.886	5	1,750	45.5	43.7
Scranton	e ₂	G=.305	.305	2	500	13	12.7
TOTAL		O=914,161 G=692.63	816.74	4232	66,508	1729.2	912.46

RHODE ISLAND

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Providence	^c 10	0=275,000	37.6	195	2,500	65	27.4
TOTAL		0=275,000	37.6	195	2500	65	24.4

SOUTH CAROLINA

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Charleston	c ₁₄	G=100	100	518	3500	91	-9
Columbus	c ₂₀	G=9,600	1.3	10	5000	130	128.7
TOTAL		G=9,600 G=100	101.3	528	8500	221	119.7

TENNESSEE

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu $\times 10^9$)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal ($\times 10^9$)	Energy generated Col. 7 Col. 4 (Btu $\times 10^9$)
Nash- ville	e ₉₀	G=150 O=335,000	195.5	1015	22,500	585	389
Mary- ville Alcoa	e ₁₀	G=15.6	15.6	81	2,500	65	49.4
TOTAL		O=335,000 G=165.6	211.5	1096	25,000	650	438

TEXAS

	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Houston	e ₂₀₀	G=757	757	3922	50,466	1,312	555
Houston	e ₁₀₀	G=473	473	2450	31,533	819.8	347
Richardson	e ₁₀	E=750,000	2.6	13	173	4.5	1.9
TOTAL		G=1230 E=750,000	1232.6	6385	82,172	2136.3	903.9

VIRGINIA

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
	e ₃₀	0=264,000 G=51.6	87.76	455	7,500	195	107
Williams- burg	e ₃₀	0=1,300,000	178	920	7,500	195	17
Arling- ton	e ₁₀	0=98,000	13.4	70	2,500	65	51.6
TOTAL		0=1,662,000 G=51.6	279.16	1445	17,500	455	175.6

WASHINGTON

65

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Billings ham	10	G=11.5	11.5	59	2,500	65	53.5
Cowlitz County	10	G=4.1	4.1	21	2,500	65	60.9
Vancouver	8	G=7.2	7.2	37	2,000	52	44.8
Edmonds	4	G=40,000	5.5	30	1,000	26	20.5
TOTAL		G=40,000 G=22.8	28.3	147	8,000	208	179.7

WISCONSIN

66

1	2	3	4	5	6	7	8
City	Flow MGD	Fuel Used Per yr. (Real Data)	Btu. Used (Btu x 10 ⁹)	Home Equiv.	Coal Added ¹ Tons/Yr.	Btu. Provided by Coal (x10 ⁹)	Energy generated Col. 7 Col. 4 (Btu x 10 ⁹)
Fort Atkinson 20		G=15.8	15.8	82	1,053	27.3	11.6
TOTAL		G=15.8	15.8	82	1,053	27.3	11.6

Appendix B

**Marginal Cost and Savings for a 100 MGD Plant
Using a Coal Based Biological Wastewater Treatment
Process With Sludge Incineration**

I. Capital Cost, Installed

1. 170-ton capacity incinerator, water cooled with heat recovery; building, feeder, air pollution controls, water treatment, etc. at \$30,000 per ton per day. Total cost = \$5,100,000.

2. Coal added per day = Dry sludge produced per day.
Estimation of dry sludge produced per day = 70 ton/day.
Addition incinerator capacity = $170 + 70 = 240$ ton/day.

Capital cost of 240 ton incinerator based on the cost of 170 ton unit is assumed to be $(240/170)^{.6} \times \$5,100,000$.

Cost of 240 tons capacity incinerator = \$6,272,310

First sub-total = 6,272,310

3. Miscellaneous expenses:
15 percent of First sub-total = 940,846

4. Engineering Cost
15 percent of First sub-total = 940,846
Total cost to be capitalized = 8,154,003

II. Operation and Maintenance (Including coal cost)

1. Man Power
No extra man power needed for existing incinerator.

2. Maintenance, supplies, etc. Weekly Cost
Assume extra requirements equal to one man, 40 hours
per week at \$6 per hour \$ 240

3. Power and utilities
Estimated on the basis of \$2 per million gallon pumped. 1,400

4. Coal cost; assume \$25/ton @ 70 ton/day 12,250
a) per week 13,890
b) per million gallon 19.84

Debt Service

\$ 8,154,003 at 6% interest for 25 years

- 1) per week 12,113
- 2) per million gallon 17.30

Total cost of debt service and coal cost per million
gallon = \$17.30 + \$19.84 = \$37.14

*Reference "Development of a Coal-Based Sewage Treatment Process" Final Report, Office of Coal Research, Research and Development Report No. 55, pp. 471-473.

II. Credit for Excess Energy Recovery

- a) Assume 70 tons/day of dry sludge, coal used = 70 tons/day

$$\text{BTU provided by coal} \\ (70 \text{ tons}) \left(2000 \frac{\text{lb}}{\text{ton}} \right) \left(13,000 \frac{\text{BTU}}{\text{lb}} \right) = 1.82 \times 10^9 \text{ BTU/day}$$

$$\text{BTU needed to burn 1 ton of dry sludge @ 20\% solids} = 1.5 \times 10^7 \text{ BTU} *$$

$$\text{BTU required} = (70) (1.5 \times 10^7) = 1.05 \times 10^9$$

$$\text{Recoverable BTU @ 90\% efficiency} = .90 (1.82 \times 10^9 - 1.05 \times 10^9)$$

- b) Assume energy is worth \$2/10⁶ BTU

$$\text{Value of recovered energy} = \$1,386/\text{day} \\ \text{or } \$13.86/\text{million gallons of wastewater}$$

IV. Savings for Premium Fuels Not Used

$$\text{Assume gas @ } \$2/10^3 \text{ cu. ft.}$$

Assume 15,000 cu. ft. gas needed to incinerate 1 ton dry sludge solids in a 20% solids concentration.

[Data from ALCOSAN, Pittsburgh, PA]

$$\text{Total Gas (NOT) Consumed/Day} = (70 \text{ ton/day}) (15 \times 10^3 \text{ ft}^3/\text{ton}) \\ = 1.05 \times 10^6 \text{ cu. ft./gas}$$

$$\begin{aligned} \$\$ \text{ Saved at } \$2/10^3 \text{ cu. ft./gas} &= \$2,100/\text{day} \\ \text{or} &= \$21/\text{million gallons} \end{aligned}$$

Based on actual data from the ALCOSAN Sewage Treatment Plant, Pittsburgh, PA.

Marginal Cost and Savings Associated with Coal Sludge Incineration

	<u>\$ /Million Gallons</u>
I. Capital and Debt Service	\$ 17.30
II. Coal, Operation and Maintenance	<u>19.84</u>
Total	\$ 37.14
less	
III. Credit for Energy Recovery and Sales at \$2/10 ⁶ BTU	13.86
IV. Savings for Premium Fuels Not Used @ \$2/10 ⁶ BTU	<u>21.00</u>
net cost	\$ 2.28 /Million Gallons

- Note: 1. This balance does not take into account savings due to land fill or ocean disposal of sludge which will not be done.
2. Break even price for energy = \$2.13/10⁶ BTU.