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Laboratory
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Research and Development

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Project Summary

Waste Heat Recovery Potential in Selected Industries

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The goal of the research project summarized herein is to establish the location, thermal quality, and quantity of waste heat discharged to the environment by energy-intensive industries and emerging energy-conversion technologies.

Among the industries studied are the eight which discharge the largest quantities of waste heat. Potential thermal pollution streams from the new energy conversion technologies are also discussed.

Data from this study will permit evaluation of various energy management techniques and identification of possible beneficial uses of waste heat.

The principal goals of the EPA in this project are: decreased quantities of discharged pollutants as a result of decreasing fuel consumption; increased efficiency of energy utilization as a pollution control technique; and assuring that new pollutants are not generated by new waste heat recovery systems.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This study assesses the potential for energy recovery from selective industries (Table 1) and emerging energy-conversion technologies (Table 2). Data from this study can be used to evaluate various heat-management techniques (Table 3).

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Table 1. Standard Industrial Classifications of Energy Intensive Industries

SIC#	Classification	SIC#	Classification
2611	Pulp Mills	3211	Flat Glass
2621	Paper Mills (ex. Bldg. Paper)	3221	Glass Containers
2631	Paperboard Mills	3229	Pressed and Blown Glass
2812	Alkalies and Chlorines	3241	Cement Hydraulic
2813	Industrial Gases	3274	Lime
2819	Industrial Inorganic Chemicals	3312	Blast Furnace and Steel Mills
2865	Cyclic Crudes & Intermediates	3321	Grey Iron Foundries
2869	Industrial Organic Chemicals	3331	Primary Copper
2873	Nitrogenous Fertilizers	3334	Primary Aluminum
2911	Petroleum Refineries		

Table 2. Emerging Technologies for Energy Development

Coal Conversion
Gasificator
Lurgi Gasifier
Koppers-Totzek Gasifier
Wellman-Galusha Gasifier
Winkler Process
Hygas
CO_2 Acceptor Process
Sythane Process
Low Btu Synthesis
Liquefaction
Bergius Process
Fisher-Tropsch Process
Coed Process
H-Coal Process
Oil Shale Retorting
Indirect heat transfer retorts
Combustion zone retorts
Externally heated gas/liquid retorts
Externally heated solid retorts
Uranium Enrichment
Paducah, Kentucky
Oak Ridge, Tennessee
Portsmouth, Ohio

Table 3. Optimum Operating Temperature of Waste-Heat Recovery Processes

Temperature Range		
High 1200°F-2000°F (649°C-1093°C)	Medium 250°F-1200°F (121°C-649°C)	Low 0°F-250°F (0°C-121°C)
• Radiation recuperator	• Metallic heat wheel	• Heat pumps
• Convection recuperator	• Passive gas to gas regenerator (air preheater)	
• Ceramic heat wheels	• Heat pipe exchanger	
• Refractory regenerators	• Finned tube heat exchanger (economizers)	
	• Shell and tube heat exchangers	
	• Waste heat boilers	
	• Gas and vapor expanders	
	• Organic Rankine cycle heat engine	

This study identified industries and emerging technologies which offer the greatest potential for discharging substantial quantities of waste heat to the environment. For each of the industries, a study was conducted to document all waste-heat discharges to the environment. The major source of data collected on flue gases was the National Emissions Data System (NEDS) Point Source Listings. These data on point sources of discharge were then verified for each industrial classification by discussion with various industry officials and by correlation with other related studies conducted both by the Environmental Protection Agency and the Department of Energy. Data on wastewater and non-contact cooling waters containing significant quantities of waste heat were also identified, when possible, utilizing EPA development documents for effluent limitations, correspondence with industrial pollution control officers, literature surveys, and various United States government-sponsored research and development reports.

The energy intensive industries included in this study are presented in Table 1.

The emerging technologies for energy development and the specific processes reviewed in this report are presented in Table 2.

Several waste heat recovery technologies were also reviewed to identify their potential for recovering waste heat energy from a fluid (i.e., liquid or gaseous) waste stream product, or byproduct, and returning it to a process stream in such a manner that a net heat energy transfer resulted in a credit to the overall energy balance of the process. These processes and devices are shown in Table 3.

In the final project report each of these processes is described, applications in industry are provided, and limitations and/or specific advantages for each technique are given.

Environmental Impacts of Waste Heat

The environmental impacts which may result from the discharge of waste heat to the environment may be separated into two general categories: 1) those impacts resulting from the release to the environment of the various chemical and particulate pollutants contained in the waste heat stream, and 2) those impacts resulting from the release to the environment of the heat energy contained in the waste heat stream.

The environmental impacts resulting from the release of pollutants are specific to the composition and volume of each discharge. However, any action which results in an increase in the efficiency of energy utilization (whether it is accomplished by waste heat recovery or general conservation practices) may be considered as a pollution control alternative in that these actions will result in a reduction in fuel consumption, and, generally, in a corresponding decrease in the quantity of pollutants discharged.

The greatest potential impact of waste heat discharges is to natural bodies of water and their aquatic ecosystem. Although a large number of studies have been and are being conducted in attempts to further define these cause and effect relationships, considerable data are still lacking. Some of the known and reported effects associated with temperature increases of natural waterways are: decreasing gas (oxygen) solubilities; changes in species diversity, metabolic rates, reproductive cycles, digestive and respiration rates, and behavior of the aquatic organism; and increasing the parasitic bacterial population. All of these have the potential for creating an unbalanced aquatic ecosystem.

Major Project Results

Energy Intensive Industries

The United States consumed approximately 73 quadrillion Btu (quads) (77 exajoules) of fuels in 1977. Slightly over 21.4 quads (25.4 exajoules) was used either directly or indirectly (e.g. through electricity consumption) by the industrial sector alone. Approximately 6.5% of the Nation's purchased energy in 1977 was discharged as waste heat to the environment by the eight most energy intensive industries. Approximately four percent was discharged as flue gases, and two percent was discharged as identified wastewater and cooling water discharges.

Of the industrial sector's fuel consumption, approximately 37% was discharged to the environment as waste heat by major energy-intensive industries included in this study. Flue gases accounted for about 23%, and identified wastewaters and cooling waters accounted for about 14%.

This wasted heat is not only costly for industry and hence the consumer, but it is becoming increasingly apparent that thermal pollution affects climatic and biotic conditions. In light of the present energy shortage and environmental problems faced today, it is apparent that waste heat should be minimized through process design and/or recovery techniques.

Figure 1 presents the annual waste heat discharged by flue gases for the major energy intensive industries in 1977. Petroleum Refining, SIC 2911, discharged the largest quantity of flue gas waste heat to the environment. Steel Mills, SIC 3312, was the second largest annual discharger of flue gas waste heat. These two together represent approximately 50% of the total annual flue gas waste heat discharged by the nineteen SIC groups included in this study.

Figure 2 presents the percentage of the annual waste heat discharged by flue gases at temperatures above 350°F (177°C). The heat content of the waste heat discharges above 350 F (177°C), were considered "Btu Available" due to their greater potential for energy recovery via conventional heat exchanger devices.

Figure 3 presents the percent of energy consumed (purchased fuels and electricity) discharged as flue gas waste heat by each SIC. As the figure shows, Flat Glass, SIC 3211, discharged more then 75% of the energy content of its purchased fuels and electricity as flue gas waste heat. Six industries: Flat Glass, Petroleum Refineries, Hydraulic Cement, Blast Furnaces and Steel Mills, Primary Copper, and Lime, all discharged more than 50% of their purchased fuels and electricity as flue gas waste heat. Only three industries, Paperboard Mills, Cyclic Crudes and Intermediates, and Nitrogenous Fertilizers, discharged less than 10% of their purchased fuels and electrical energy as flue gas waste heat.

The figure also indicates that the Flat Glass Industry, SIC 3211, has the greatest percent of its flue gas waste heat discharged at temperatures greater than 350°F (177°C). Only three industries, Flat Glass SIC 3211, Petroleum Refining SIC 2911, and Glass Containers SIC 3221, discharge more than one half of their flue gas waste heat at temperatures greater than 350°F (177°C). The Paper and Allied Products (i.e., SIC 2611, 2621, 2631) discharged greater than 80% of their waste heat as low grade waste heat at temperatures less than 350°F (177°C).

The percentages presented in Figure 3 may be somewhat conservative since the data used in this analysis do not include wastewater and cooling water discharges, nor do they account for the relative feedstock energy content.

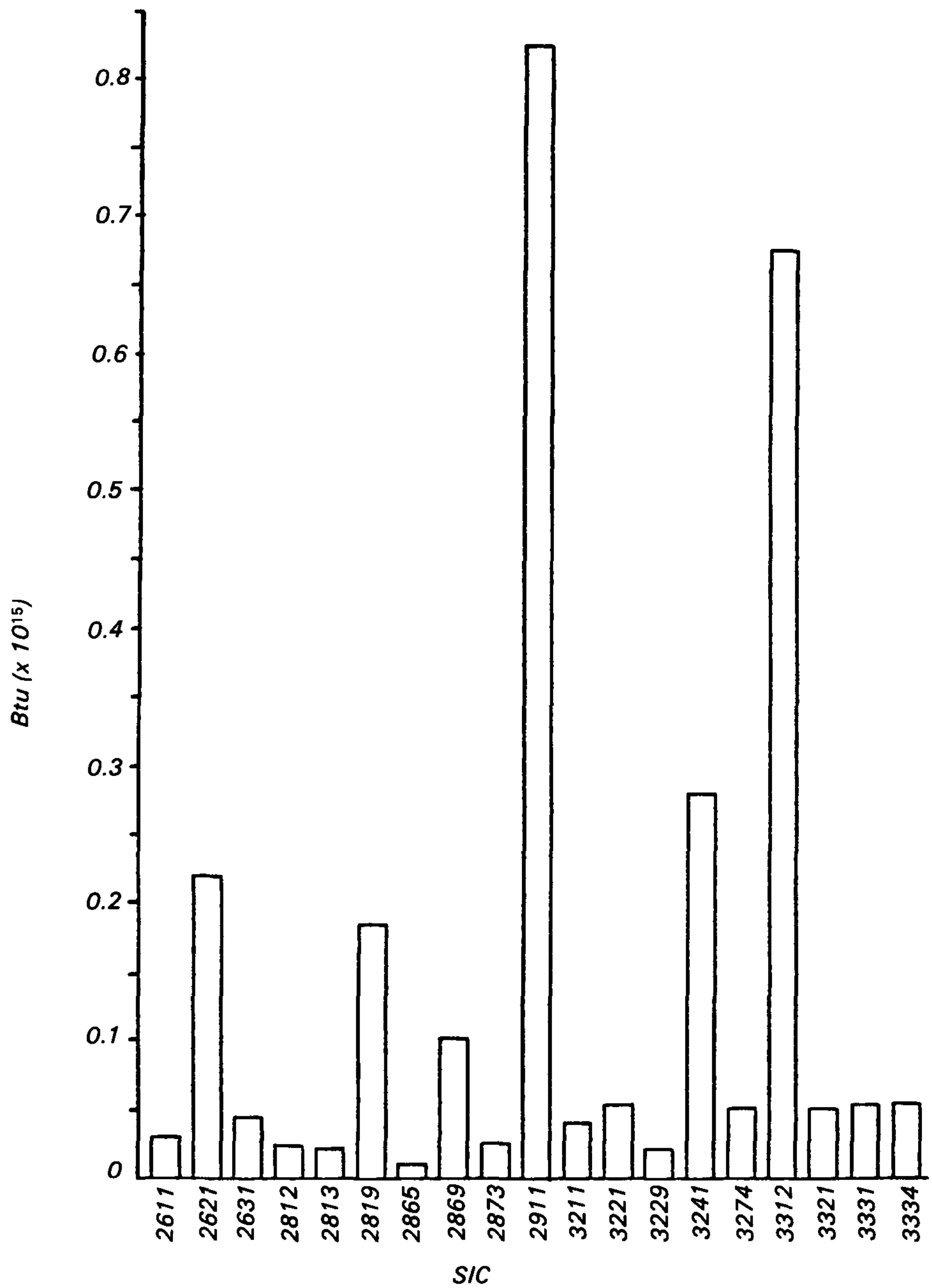

Figure 1. *Annual waste heat discharged (flue gases only) by SIC numbers. (1977).*

These figures are discussed in the individual industry evaluations contained in the complete report.

Figure 4 presents the annual flue gas waste heat discharged in the 10 EPA Regions. These data reflect the regional potentials for commercial use of low-grade waste heat in the fields of space heating, soil warming, agriculture, and other applications, as well as for industrial recycling of high-grade waste heat.

EPA Regions 3, 5, and 6 have the largest quantities of flue gas waste heat discharged to the environment. Region 5 has the greatest quantity of flue gas waste heat discharged. This waste heat is discharged primarily by the Steel, Petroleum, and the Organic Chemicals Industries. Waste heat discharges in Region 5 were due primarily to waste heat discharged by Petroleum, Organic Chemicals, Cement, Inorganic Chemicals and Papermills. The waste heat in

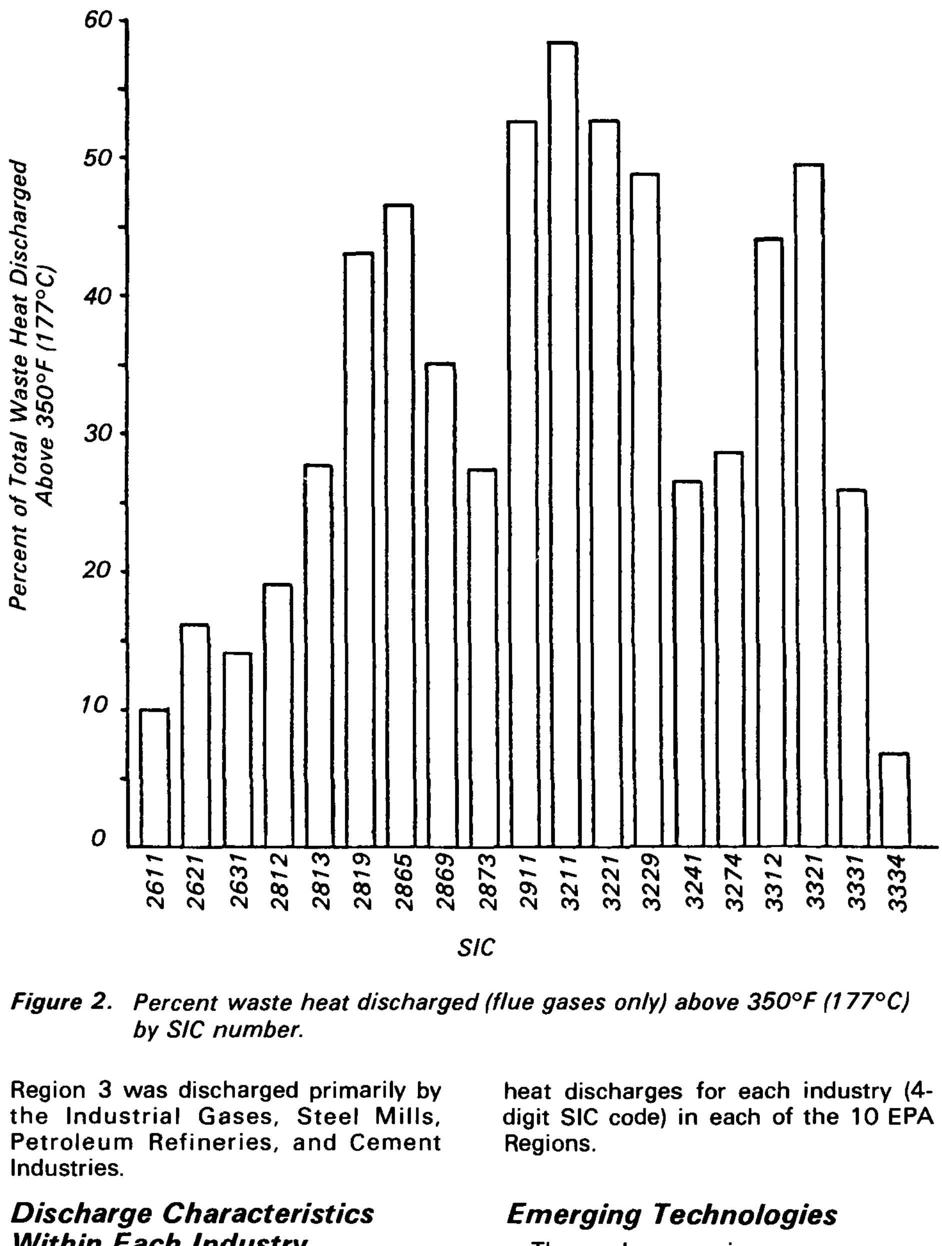

Figure 2. *Percent waste heat discharged (flue gases only) above 350°F (177°C) by SIC number.*

Region 3 was discharged primarily by the Industrial Gases, Steel Mills, Petroleum Refineries, and Cement Industries.

Discharge Characteristics Within Each Industry

The final report describes the sources, quantities and thermal qualities of waste heat discharged from each of the 19 SIC industries listed in Table 1. This includes a brief description of the industry, its geographic distribution in the United States and its energy consumption patterns. For each industry, waste heat discharges are provided by source (e.g. process), with a description of the temperature range of the discharge, its total annual energy content, and the total annual energy discharged at a sufficiently high temperature to be available for reuse. The report also provides temperature profiles of waste heat discharges for each industry (4-digit SIC code) in each of the 10 EPA Regions.

Emerging Technologies

The coal conversion processes currently under development range in overall energy conversion efficiencies from a low of 38% for the Fisher-Tropsch coal liquefaction process to a high of 80% for the low Btu gas synthesis process. This overall efficiency is defined as the heating value of the refined fuel products divided by the heating value of the coal feedstock. The result indicates that a large percentage of the heating value of the feedstock is rejected into the environment. If energy self-sufficiency is to be realized, it could be assumed that imported fuels would be replaced by domestic fuels converted from coal. During 1976, the United States imported 1900 million barrels (bbl) of crude oil, a figure that represents over 40% of the domestic consumption. Assuming a crude oil of 5.8 x 10^6 Btu/bbl and a nominal fuel conversion efficiency of 67% for coal conversion processes, the heat rejected from fuel conversion plants producing the same quantity of fuel as was imported, would equal 1.00 x 10^{13} Btu/day (10.5 petajoules/day) or 3.63 quads/year (3.83 exajoules/year).

At the time of completion of this study, the TOSCO II Report was the oil shale retorting process considered one of the most promising on the basis of ease of environmental effluent control, shale oil extraction efficiency, and technical advancement. Although data were not available to evaluate accurately the thermal efficiency of this and other viable processes, two major sources of waste heat discharges were identified. The first is the evaporation of cooling water. A 50,000-bbl/day TOSCO plant operating on 35 gallon per ton oil shale, resulted in the evaporative losses from the cooling towers of 1000 gallons per minute. This corresponds to a thermal discharge of approximately 240 million Btu (253 gigajoules) per 1000 bbl of upgraded shale oil.

The other major source of waste heat from oil shale processing stems from the heat content of the spent shale. The TOSCO process produces approximately 2.14 x 10^6 lb (971 megagrams) of spent shale per 1000 bbl of upgraded shale oil produced, corresponding to 64.35 x 10^6 Btu (67.9 gigajoules) of waste heat per 1000 bbl produced.

Recommendations

In order to minimize the adverse impacts of waste heat discharges, support should be continued for programs which foster energy conservation, either through the development of new, more efficient processes or through the use of efficient, low cost waste heat recovery devices. A variety of conventional waste recovery devices are currently available. However, there are two areas where the development and demonstration of new devices could significantly enhance the technology of waste heat recovery.

The first application is for the utilization of low-grade waste heat for the direct conversion to electric energy through the use of various heat engine devices. The development of low-cost efficient heat pumps and Organic Rankine Cycle Heat engines are two devices which

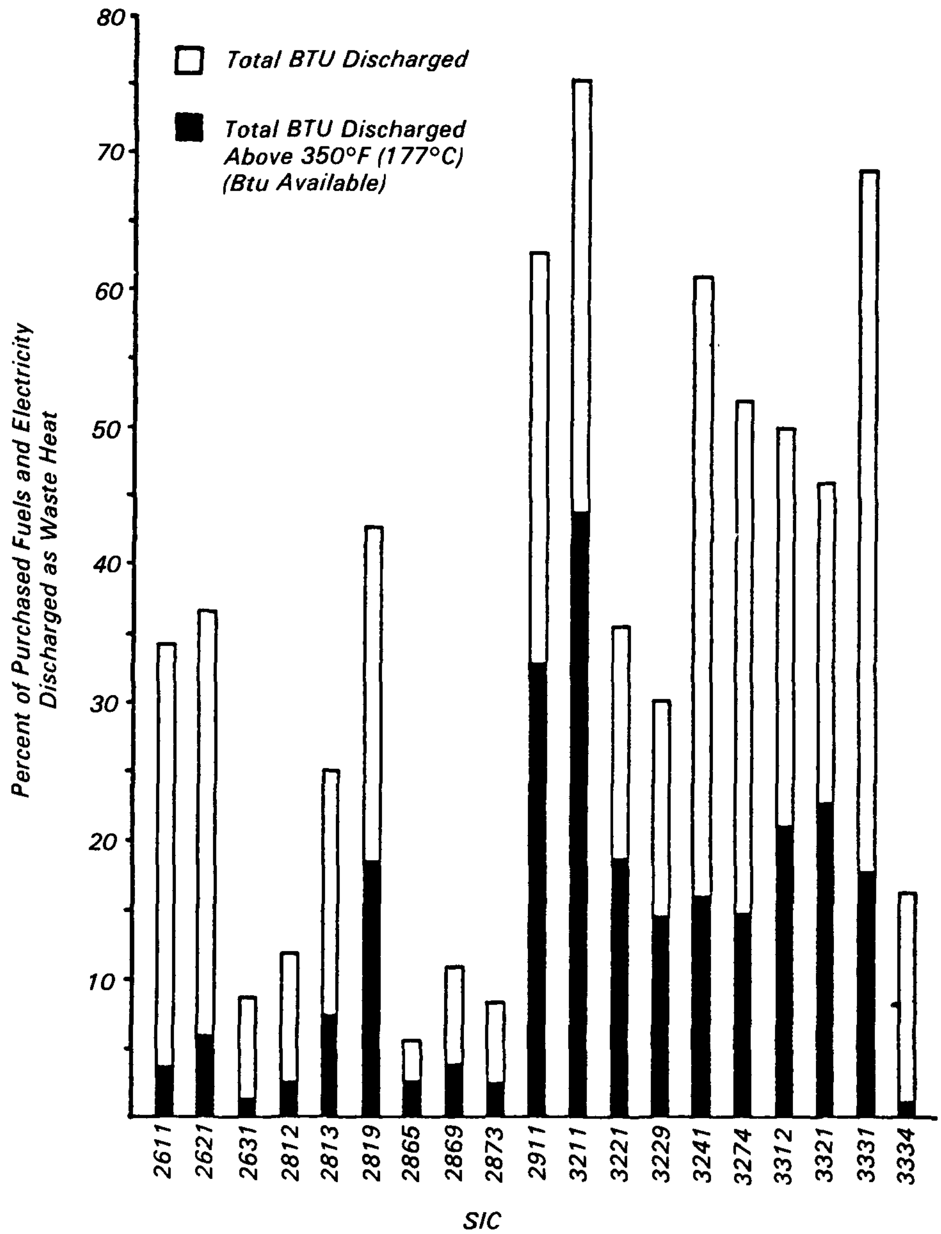

Figure 3. *Percent of purchased fuels and electricity discharged as waste heat by SIC number (1977).*

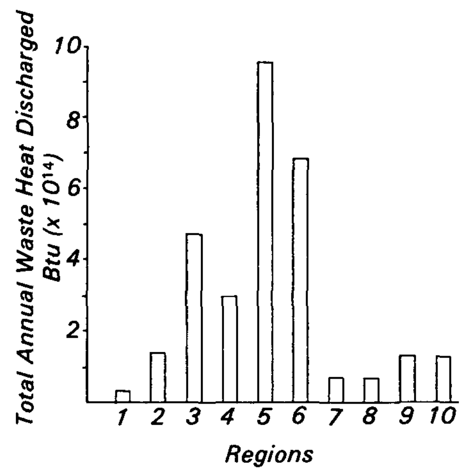

Figure 4. *Annual waste heat discharged (flue gases only) by EPA Region (1977).*

could foster increased waste heat recovery of low grade waste heat sources, i.e., less than 350°F (177°C).

The second application is in the recovery of waste heat from high temperature flue gases. Current industrial waste heat recovery operators generally do not reduce flue gas temperatures much below 350°F (177°C) due to the potential condensation of corrosive liquids. Therefore, the development and demonstration of a waste heat recovery device which could reduce the flue gas temperature beyond the condensation temperature, while avoiding the high cost of corrosion resistant materials, would significantly enhance the incentives for more complete waste recovery.

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The complete report, entitled "Waste Heat Recovery Potential in Selected Industries," (Order No. PB 82-259 276; Cost: $22.50, subject to change) will be available only from:

National Technical Information Service
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