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ENERGY CONSUMPTION:

FUEL UTILIZATION

AND CONSERVATION IN INDUSTRY

U.S. Environmental Protection Agency
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ENERGY CONSUMPTION:

FUEL UTILIZATION

AND CONSERVATION IN INDUSTRY

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SECTION I

CONCLUSIONS

Annual fuel utilization in the six largest fuel consuming industrial sectors in the early 1970's is characterized as follows:[1]

• Chemical industry usage[2]	$1160 \pm 120 \times 10^{12}$ kcal
• Primary metals industry usage	$1310 \pm 130 \times 10^{12}$ kcal
• Petroleum industry usage	$766 \pm 80 \times 10^{12}$ kcal
• Paper industry usage	$645 \pm 65 \times 10^{12}$ kcal
• Stone-clay-glass-concrete industry usage	$365 \pm 40 \times 10^{12}$ kcal
• Food industry usage	$323 \pm 30 \times 10^{12}$ kcal
• Total for the six sectors	$4569 \pm 500 \times 10^{12}$ kcal*

Annual fuel utilization by unit operation in the six industrial sectors is characterized as follows:

• Direct heating of process streams	$1780 \pm 400 \times 10^{12}$ kcal
• Compression	$340 \pm 100 \times 10^{12}$ kcal
• Distillation	$300 \pm 100 \times 10^{12}$ kcal
• Electrolysis	$340 \pm 50 \times 10^{12}$ kcal
• Evaporation	$165 \pm 30 \times 10^{12}$ kcal
• Drying	$270 \pm 50 \times 10^{12}$ kcal

*This amounts to 25 to 30 percent of the total energy consumption in the United States.

- Cooking, sterilizing, and digestion — 185 ± 30 x 10^{12} kcal
- Feedstock — 490 ± 50 x 10^{12} kcal
- Other or unaccounted for — 699 x 10^{12} kcal
- Total — 4569 ± 500 x 10^{12} kcal

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[1] Purchased electricity is valued at 2500 kcal/kWh throughout this report.

[2] Process fuel utilization - 670 x 10^{12} kcal
Feedstock fuel utilization - 490 x 10^{12} kcal

Annual fuel utilization by type of fuel is characterized as follows:

- Purchased electricity — 813 ± 80 x 10^{12} kcal
- Coal — 853 ± 85 x 10^{12} kcal
- Petroleum — 701 ± 70 x 10^{12} kcal
- Natural gas — 1602 ± 160 x 10^{12} kcal
- Other — 600 ± 60 x 10^{12} kcal
- Total — 4569 ± 500 x 10^{12} kcal

Level of annual heat rejection from process is characterized as follows:

- Radiation, convection conduction, other — 410 ± 150 x 10^{12} kcal
- Below 100°C — 1420 ± 300 x 10^{12} kcal
- From 100°C to 250°C — 728 ± 200 x 10^{12} kcal
- From 250°C to 800°C — 557 ± 150 x 10^{12} kcal
- From 800°C to 1800°C — 254 ± 100 x 10^{12} kcal

Energy conservation efforts should be capable of decreasing annual energy usage in the short run (less than 5 years) as follows:

• Chemical industry	187×10^{12} kcal
• Primary metals industry	208×10^{12} kcal
• Petroleum industry	130×10^{12} kcal
• Paper industry	170×10^{12} kcal
• Stone-clay-glass-concrete industry	37×10^{12} kcal
• Food industry	36×10^{12} kcal
• Total	774×10^{12} kcal

Energy conservation approaches should be capable of decreasing annual energy usage in the short run (less than 5 years) as follows:

• Waste utilization	86×10^{12} kcal
• Maintenance and insulation	190×10^{12} kcal
• Operation modification	68×10^{12} kcal
• Design modification	215×10^{12} kcal
• Process integration	139×10^{12} kcal
• Process modification	72×10^{12} kcal
• Market modification	4×10^{12} kcal
• Total	774×10^{12} kcal

SECTION II

RECOMMENDATIONS

The use of recommended energy conservation approaches is grossly estimated to reduce short term annual fuel consumption in the six biggest energy consuming industries by 774 x 10^{12} kcal. It would appear worthwhile to look in more detail at these conservation approaches with the goal of answering the following questions:

- What are the shortcomings in the present energy conservation techniques?
- How can the conservation techniques be improved?
- What are the costs, success odds, and possible impact of research on conservation techniques?

SECTION III

INTRODUCTION

Purpose

The purpose of this task is to prepare a tabular summary of fuel utilization by industry, process, and unit operation for the six biggest energy consuming industrial categories. These industries include chemicals, primary metals, petroleum, paper, stone-clay-glass-concrete, and food.

Scope

This report presents tables containing estimates of the following:

- Fuel utilization in the six biggest fuel consuming industries by industry, process, and unit operation.
- Level of heat rejection in the six biggest fuel consuming industries.
- Short term effects of applying recommended conservation approaches.

General Background

The National Academy of Engineering (NAE) has been commissioned by the Environmental Protection Agency (EPA) to conduct a comprehensive assessment of the current status and future prospects of sulfur oxides control methods and strategies. The agreement between the EPA and the NAE states explicitly that special data collection projects may be required to provide the NAE panel with the background necessary for viewing all aspects of the problem in perspective. Three reports (EPA-650/2-75-032-a, EPA-650/2-75-032-b, and EPA-650/2-75-032-c) were written by the authors of this report as one segment of the data collection project associated with the NAE assessment. The three reports presented information on energy utilization by operation in a number of processes in the six biggest energy using industrial groups. They also gave information on level of rejected heat and the possible effects of energy conservation approaches for the process covered. The present report presents more information on fuel utilization, level of rejected heat, and probable short term effects of using recommended conservation approaches in the six biggest energy using industrial groups.

SECTION IV

FUEL UTILIZATION AND CONSERVATION IN INDUSTRY

The annual fuel utilization in the six biggest fuel consuming industries by industry and operation is shown in Table I. The largest fuel user is primary metals (1310 ± 130 x 10^{12} kcal). Next is the chemical industry (1160 ± 120 x 10^{12} kcal). However, 42 percent of this energy is for feedstock material. Third is the petroleum industry (766 ± 80 x 10^{12} kcal). Fourth is the paper industry (645 ± 65 x 10^{12} kcal) while fifth is the stone-clay-glass-concrete industry (365 ± 40 x 10^{12} kcal) and sixth the food industry (323 ± 30 x 10^{12} kcal). The above quantities value purchased electricity at the fuel value required to generate the electricity (2500 kcal per kWh). The estimates apply for the years 1971, 1972, or 1973 depending on the industry.

Table 1 indicates that purchased electricity accounts for 17-18 percent of the energy usage, coal for 18-19 percent, petroleum for 15-16 percent, natural gas for 35 percent, and other fuels for 13 percent.

Table 2 shows the fuel utilization in the six biggest fuel consuming industries by unit operation. Direct heating of process streams by fuel combustion or electricity is the largest energy user with an estimated annual usage of 1780 ± 400 x 10^{12} kcal. Other listed operations are compression with 340 ± 100 x 10^{12} kcal, distillation with 300 ± 100 x 10^{12} kcal, electrolysis with 340 ± 50 x 10^{12} kcal, evaporation with 165 ± 30 x 10^{12} kcal, drying with 270 ± 50 x 10^{12} kcal, cooking or digestion with 185 ± 30 x 10^{12} kcal, feedstock with 490 ± 50 x 10^{12} kcal, and other with 699 x 10^{12} kcal.

Table 3 shows the level of heat rejection in the six biggest fuel consuming industries. Radiation, convection, conduction, and other losses account for 410 ± 150 x 10^{12} kcal per year. The estimated heat rejected at a temperature below 100°C is 1420 ± 300 x 10^{12} kcal per year. The estimate at a temperature between 100°C and 250°C is 728 ± 200 x 10^{12} kcal per year. At 250°C to 800°C the estimate is 557 ± 150 x 10^{12}

Table 1. FUEL UTILIZATION IN THE SIX BIGGEST FUEL CONSUMING INDUSTRIES BY INDUSTRY AND OPERATION

Industry (or process) and operation	Fuel Used (10^{12} kcal/year)					
	Purch. Elect. at fuel value (2500 kcal per kWh)	Coal	Petroleum	Nat. Gas	Other	Total
Chemical[1]						
Direct heating[2]						140 ± 40
Compression	100					190 ± 50
Distillation						100 ± 50
Electrolysis	55					90 ± 20
Evaporation						65 ± 20
Drying						10 ± 5
Other	15					75
Feedstock			365	125		490 ± 50
Total	200	65	395	480	20	1160 ±120

[1] for the year 1973

[2] Direct heating of process streams only. Energy used to generate utility steam is alloted to the unit operation where the steam is used. If the steam directly enters into the process stream then heat required for its generation is included under direct heating.

	Purch. Elect.	Coal	Petroleum	Nat. Gas	Other	Total
Primary metals[3]						
Steel						
Coking	4	70[4]		4		78 ± 8
Agglomeration		20	2	10		32 ± 5
Blast furnace	4	350	10	9		373 ± 35
Steel making	40	6	10	12		68 ± 7
Casting, soaking		22	4	24		50 ± 15
Primary rolling	8					8 ± $^{8}_{2}$
Reheating		16	7	51		74 ± 20
Rolling mills	26					26 ± $^{1}_{2}$[5]
Heat treatment	11	6	3	13		33 ± 10
Other	7	65	10	43		125
Sub-total	100	555	46	166		867 ± 90

Table 1. (continued)

	Purch. Elect.	Coal	Petroleum	Nat. Gas	Other	Total
Aluminum						
Digestion & Evap.	4			15		19 ± 5
Calcining				8		8 ± 2
Electrolysis	150[5]		15[6]			165 ± 20
Melting, heat treating	1			6		7 ± 2
Sub-total	155		15[6]	29		199 ± 20
Other metal processes	65	70	4	105		244
Total	320	625	65	300		1310 ±130

[3] For the year 1972

[4] 30 x 10^{12} kcal of the coal is used to produce oils, tar, and coke breeze not returned to the steel process.

[5] Fuel value of purchased and self-generated electricity using a conversion factor of 2500 kcal/kWh. Approximately 50% of the electricity generated for aluminum reduction is from hydroelectric plants. However, because the extensive interconnection of U.S. electric utilities permits the ready exchange of power between regions, aluminum production must be regarded as a load on the entire electricity grid. Therefore, the typical utility fuel value of 2500 kcal per kWh is used to calculate fuel consumption.

[6] Fuel value of carbon electrodes consumed in electrolysis reaction.

	Purch. Elect.	Coal	Petroleum	Nat. Gas	Other[8]	Total
Petroleum[7]						
Petroleum refining						
Crude distillation						170 ± 30
Cracking & fractionation						230 ± 50
Reforming & fractionation						80 ± 20
Alkylation & fractionation						50 ± 10
Asphalt plant						25 ± 10
Coking & fractionation						20 ± 5
Other operations						166
Sub-total	53	3	60	275	350[8]	741 ± 70
Other processes						25 ± 10
Total						766 ± 80

Table 1. (continued)

[7] For the year 1971.

[8] Other - refinery gas = 253 x 10^{12} kcal; petroleum coke = 80 x 10^{12} kcal; acid sludge = 7 x 10^{12} kcal; purchased steam = 10 x 10^{12} kcal.

	Purch. Elect.	Coal	Petroleum	Nat. Gas	Other	Total
Paper[9]						
Kraft process						
Digester & washer						75 ± 15
Liquor evaporation						40 ± 10
Pulp & paper drying						100 ± 20
Lime regeneration						20 ± 5
Other operations						140 ± 30
Other paper making processes						220 ± 40
Other sectors of paper industry						50 ± 10
Total	90	60	110	155	230[10]	645 ± 65

[9] For the year 1972.

[10] Other - bark and wood = 40 x 10^{12} kcal; black liquor = 190 x 10^{12} kcal.

	Purch. Elect.	Coal	Petroleum	Nat. Gas	Other	Total
Stone-clay-glass-concrete[11]						
Cement						
Kiln	5	42	16	54		117 ± 10
Other	22	2	1	2		27 ± 3
Sub-total	27	44	17	56		144 ± 15
Glass						
Melting	12					63 ± 10
Annealing	1					7 ± 1
Other	2					9 ± 1
Sub-total	15	1	3	60		79 ± 10

[11] For the year 1972.

Table 1. (continued)

	Purch. Elect.	Coal	Petroleum	Nat. Gas	Other	Total
Brick & clay tile	2	3	2	20		27 ± 4
Ready-mixed concrete	2	x	11	x		13 ± 2
Lime	2	10	1	9		22 ± 3
Other	12	7	1	60		80
Total	60	65	35	205		365 ± 40
Food[12]						
Meat packing	8	4	3	11		26 ± 5
Fluid milk	8	1	4	7		20 ± 4
Canned fruits & veg.	3					15 ± 3
Frozen fruits & veg.	5					13 ± 3
Animal feeds	4	1	2	12		19 ± 4
Bread, cake, related products	5					18 ± 4
Beet sugar	1					21 ± 4
Malt beverage	6					17 ± 4
Wet corn milling	2					18 ± 4
Soy bean oil	4					14 ± 3
Other	44					142
Total	90	35	36	162	x	323 ± 30
Totals	813	853	701	1602	600	4,569 ±500

[12] For the year 1971.

Table 2. FUEL UTILIZATION IN THE SIX BIGGEST FUEL CONSUMING INDUSTRIES BY UNIT OPERATION

Operation & Industry	Type and Amount of Energy (10^{12} kcal/year) Purch. Elect.	Coal	Petroleum	Gas	Other	Total
Direct heating						
Chemical						140 ± 40
Primary metals	75	550	50	225		900 ± 150
Petroleum refining						450 ± 100
Paper						20
Stone-clay-glass-conc.						250 ± 50
Food						20
						1780 ± 400
Compression						
Chemical	120					190 ± 50
Primary metals						10
Petroleum						70 ± 30
Paper						---
Stone-clay-glass-conc.						---
Food	60					70 ± 30
						340 ± 100
Distillation						
Chemical						100 ± 50
Primary metals						---
Petroleum						200 ± 75
Paper						---
Stone-clay-glass-conc.						---
Food						---
						300 ± 100

Table 2. (continued)

Operation & Industry	Type and Amount of Energy (10^{12} kcal/year) Purch. Elect.	Coal	Petroleum	Gas	Other	Total
Electrolysis						
Chemical	55					90 ± 20
Primary metals	200					250 ± 50
Petroleum						---
Stone-clay-glass-conc.						---
Food						---
						340 ± 50
Evaporation						
Chemical						65 ± 20
Primary metals						20
Petroleum						---
Paper						50 ± 10
Stone-clay-glass-conc.						---
Food						30
						165 ± 30
Drying						
Chemical						10
Primary metals						10
Petroleum						---
Paper						200 ± 40
Stone-clay-glass-conc.						20
Food						30
						270 ± 50
Cooking (digesting)						
Chemical						---
Primary metals						10
Petroleum						---

Table 2. (continued)

Operation & Industry	Type and Amount of Energy (10^{12} kcal/year) Purch. Elect.	Coal	Petroleum	Gas	Other	Total
Paper						125
Stone-clay-glass-conc.						---
Food						50 ± 10
						185 ± 30
Feedstock						
Chemical	---	---	365	125	---	490 ± 50
Other or unaccounted for						
Chemical						75
Primary metals						110
Petroleum						46
Paper						250
Stone-clay-glass-conc.						95
Food						123
						699
GRAND TOTAL	813	853	701	1602	600	4569 ± 500

Table 3. HEAT REJECTION IN THE SIX BIGGEST FUEL CONSUMING INDUSTRIES

Industry (or Process) and Operation	Rejected Heat (10^{12} kcal/yr)[1]					Heat Used for Reactions (10^{12} kcal/yr)
	Radiation, Convection, Conduction, Other	Below 100°C	100°-250°C	250°-800°C	800°-1800°C	
Chemical						
Chlorine/caustic soda	10	64	13	x		14
Ethylene/propylene	5	38	20	10		20
Ammonia	8	29	35	10		70
Ethylbenzene/styrene	0.3	6	7	x		0.3
Carbon black	0.5	x	8	x		
Sodium carbonate (syn.)	0.5	9	4	x		(1)[2]
Oxygen/nitrogen	0.3	43	37	x		x
Cumene	x	1	1	x		(0.3)[2]
Phenol/acetone	x	2	2	x		(1)[2]
Other	25	158	73	20		
Total	50	350	200	40		
Primary Metals						
Steel	75	20	100	150	200	180
Aluminum	30	95	20	5	20	30
Other	30	100	30	10	20	
Total	135	215	150	165	240	
Petroleum	80	250	125	175		65
Paper	50	350	190	30		25
Stone-clay-glass-conc.						
Cement	30	20	10	55		
Glass	25	15	3	22	9	
Other	25	20	10	40	5	
Total	80	55	23	117	14	

Table 3. (continued)

Industry (or Process) and Operation	Radiation, Convection, Conduction, Other	Below 100°C	100°-250°C	250°-800°C	800°-1800°C	Heat Used for Reactions (10^{12} kcal/yr)
Food	15	200	40	30	____	
GRAND TOTAL	410 ± 150	1420 ± 300	728 ± 200	557 ± 150	254 ± 100	

[1] The rejected heat includes heat rejected in generating purchased and self-generated electricity for the process.

[2] Exothermic reactions.

kcal per year, and the estimate at 800°C to 1800°C is 254 ± 100 x 10^{12} kcal per year.

Table 4 shows the estimated short term (less than 5 years) effect of applying recommended conservation approaches to the six big fuel consuming industries. Research and development on new processes, on increasing product yields, or on other areas might yield even more beneficial effects on fuel utilization. This conservation approach was not included in this analysis because the effects of research and development efforts are very difficult to estimate. The estimated effect of applying conservation approaches other than research and development is to decrease annual fuel usage by 774 x 10^{12} kcal. The order of effectiveness of conservation approaches is design modification, maintenance and insulation, process integration, waste utilization, process modification, operation modification, and market modification.

Tables 5 and 6 show more detailed information on fuel utilization by unit operation and process in the chemical industry. Processes accounting for approximately 48 percent of the total chemical process (non-feedstock) energy usage are analyzed in Table 6. The total chemical industry energy consumption by operation (Table 5) was estimated using the analyzed process information plus published information on total energy usage in the chemical industry. Feedstock coverage in analyzed processes was much more complete. Approximately 77 percent of published total feedstock consumption was accounted for in the chemical processes which were analyzed in Table 6.

Tables 7, 8, 9, 10, 11, and 12 show more detailed information on energy conservation in the six big energy consuming industries. Table 13 gives information on production volume, fuel usage and the economic importance of energy in the six big fuel using industries.

Table 4. ENERGY CONSERVATION IN THE SIX BIGGEST FUEL CONSUMING INDUSTRIES

Industry	Conservation Approach	Estimated Fuel Savings (10^{12} kcal/yr)	Industry Energy Usage (10^{12} kcal/yr)
Chemical	Waste utilization	14	
	Maintenance and insulation	50	
	Market modification	1	
	Operation modification	24	
	Design modification	78	
	Process integration	20	
	Total	187	670[1]
Primary Metals	Waste utilization	35	
	Process integration	13	
	Process modification	36	
	Design modification	66	
	Maintenance and insulation	30	
	Operation modification	28	
	Total	208	1310
Petroleum	Process integration	32	
	Design modification	40	
	Maintenance and insulation	40	
	Waste utilization	8	
	Operation modification	16	
	Total	136	766
Paper	Process integration	68	
	Marketing modification	3	
	Process modification	15	
	Design modification	5	
	Waste utilization	29	
	Maintenance and insulation	50	
	Total	170	645

Table 4. (continued)

Industry	Conservation Approach	Estimated Fuel Savings (10^{12} kcal/yr)	Industry Energy Usage (10^{12} kcal/yr)
Stone-clay-glass-conc.	Process modification	21	
	Maintenance and insulation	10	
	Design modification	6	
	Total	37	365
Food	Maintenance and insulation	10	
	Process integration	6	
	Design modification	20	
	Total	36	323
GRAND TOTAL		774	4569

[1] Process energy only. This does not include feedstock energy usage.

Table 5. FUEL UTILIZATION BY OPERATION IN THE CHEMICAL INDUSTRY

Operation	Energy Consumption Processes Analyzed (10^{12} kcal/year)[1]	All Chemical Processes (10^{12} kcal/year)[1]
Direct heating	106 ± 15	140 ± 40
Compression	99 ± 25	190 ± 50
Distillation	20 ± 5	100 ± 50
Electrolysis	63 ± 10	90 ± 20
Evaporation	27 ± 4	65 ± 20
Drying	4 ± 1	10 ± 5
Feedstock	413 ± 50	490 ± 50
Other	---	75
Total	732 ± 75	1160 ± 120

[1] For the year 1973

Table 6. FUEL UTILIZATION BY PROCESS AND OPERATION IN THE CHEMICAL INDUSTRY

Process and Operation	Fuel Usage (10^{12} kcal/Year)[1] Purchased Electricity[2]	Coal	Petroleum Products	Natural Gas	Feedstock	Total
Chlorine/ Caustic Soda						
Electrolysis	33	[sum of three]=		29	x	63 ± 10
Compression	4	["]=		3	x	7 ± 2
Evaporation		["]=		26	x	26 ± 5
Other		["]=		4	x	4
	37	10	3	50		100 ± 10
Ethylene/ Propylene[3]						
Direct heating[5]		[sum of three]=		49	x	49 ± 10
Compression	3	["]=		38	x	41 ± 8
Distillation		["]=		6	x	6 ± 2
Feedstock	x	x	x	x	272[4]	272 ± 30
	3	4[6]	1[6]	88[6]	272[4]	368 ± 40
Ammonia						
Compression	7	[sum of three]=		20	x	27 ± 5
Direct heating[5]		["]=		41	x	41 ± 8
Feedstock	x	x	x	x	87[7]	87 ± 10
	7	--	5	56	87[7]	155 ± 16
Ethylbenzene/ Styrene						
Direct heating		[sum of three]=		5	x	5.5 ± 1
Distillation	[1]	["]=		7	x	7.5 ± 2
Feedstock	x	x	x	x	22[8]	22 ± 4
	1	1	0.3	11	22	35 ± 4

Table 6. (continued)

Process and Operation	Fuel Usage (10^{12} kcal/Year)[1] Purchased Electricity[2]	Coal	Petroleum Products	Natural Gas	Feedstock	Total
Carbon Black						
Direct heating				9		9 ± 2
Drying				1		1
Feedstock	x	x	x	x	25[9]	25 ± 5
				10	25[9]	35 ± 5
Sodium Carbonate[10]						
Compression	--	[sum of three]=		3	x	3 ± 1
Drying	--	[	"]=	3	x	3 ± 1
Distillation	--	[	"]=	3	x	3 ± 1
Direct heating	--	[	"]=	2.5	x	2.5 ± 1
		3	1	7.5	x	11.5 ± 2
Oxygen/ Nitrogen						
Compression	19.5	0.3	0.3	0.4	x	20.5 ± 2
Cumene						
Process		0.3	0.3	1.5	x	2.1 ± 0.5
Feedstock	x	x	x	x	8.5[8]	8.5 ± 2
	x	0.3	0.3	1.5	8.5	10.6 ± 1
Phenol/ Acetone[11]						
Distillation		[sum of three]=		3.7	x	3.7 ± 1
Other	0.4	[	"]=	1	x	1.4 ± 0.5
	0.4	1	0.3	3.4	x	5.1 ± 0.5
Total	68	18	11	223	378	

NOTE: Footnotes on following page.

Table 6. (continued)

[1] For the year 1973.

[2] Fuel value of purchased electricity using a conversion factor of 2500 kcal/kWh.

[3] Approximately 55% of the propylene produced in 1973 was a by-product of ethylene production.

[4] 89×10^{12} kcal as ethane, 95×10^{12} kcal as propane, 87×10^{12} kcal as naphtha.

[5] Direct heating includes heating of steam which enters into the process stream.

[6] Considerable gaseous by-products are produced in the ethylene process which can be used as fuel. They are not credited to the ethylene process in this analysis. Their 1973 fuel value was 55×10^{12} kcal.

[7] Natural gas feedstock.

[8] Benzene feedstock.

[9] 22.5×10^{12} kcal as oil, 2.5×10^{12} kcal as natural gas.

[10] Synthetic sodium carbonate only. Approximately 50% of the U.S. production in 1973 was synthetic.

[11] The cumene oxidation process only. This process accounted for approximately 87% of the U.S. production of cumene in 1973.

Table 7. ENERGY CONSERVATION IN THE CHEMICAL INDUSTRY

Conservation Technique	Estimated Fuel Savings (10^{12} kcal/Yr)
1. Waste Utilization	
a. Recover the fuel value of wasted by-product in chlorine process. Assume that 50% is now being wasted.	4
b. Increase burning of other wasted by-products.	10
2. Insulation and Maintenance	
Improve maintenance and insulation of steam systems. This should reduce steam usage by 15 to 20%.	50
3. Operation Modification	
a. Operate electroysis cells at lower current densities.	9
b. Closely control excess air to furnaces.	10
c. Closely control the reflux on distillation colums.	5
4. Design Modification	
a. Increase waste heat recovery from hot streams such as furnace stack gases or hot process streams.	50
b. Design distillation columns to operate at a lower reflux.	10
c. Convert the chlorine cells using graphite anodes (approximately 50%) to metal anodes.	8

Table 7. (continued)

Conservation Technique	Estimated Fuel Savings (10^{12} kcal/Yr)
d. Replace inefficient compressors and motors with more efficient equipment.	10
5. Process Integration	
Increase efforts to co-produce steam and electricity.	20
6. Market Modification	
Substitute 50% NaOH in half of the applications now using 100% NaOH.	1
Total	187

Total chemical industry process fuel usage ~ 670 x 10^{12} kcal/year.

Table 8. ENERGY CONSERVATION IN THE PRIMARY METALS INDUSTRY

Conservation Approach	Estimated Fuel Savings (10^{12} kcal/Yr)
1. Waste Utilization	
a. Use 25% of the presently unaccounted for blast furnace gas as fuel.	15
b. Increase domestic recycle of scrap steel. Decrease exports by 3×10^6 tons per year (~40% of exports in 1972).	10
c. Increase old scrap recycle of aluminum from approximately 5% of aluminum production to 10%.	10
2. Process Integration	
Co-produce electricity and steam. If 50% of the process steam generated in manufacturing steel were co-produced with electricity, approximately 7×10^{12} kcal of electricity could be generated using an extra 8×10^{12} kcal of fuel. This amount of electricity typically requires 21×10^{12} kcal of fuel for its generation.	13
3. Process Modification	
a. Replace the open hearth process for producing steel with the basic oxygen process. Assume that one-half of the open hearth portion of steel production (26% in 1972) is replaced with the basic oxygen process.	9

Table 8. (continued)

Conservation Approach	Estimated Fuel Savings (10^{12} kcal/Yr)
b. Increase the use of continuous casting in the steel industry from 6% of raw steel cast in 1972 to 50% of raw steel cast.	15
c. Increase the ratio of iron-ore pellets to sinter in the blast furnace charge. Reduce sinter charge to 20% of the total charge.	7
d. Use Alcoa's newly developed aluminum process to produce 10% of the U.S. aluminum production.	5
4. Design Modification	
a. Increase waste heat recovery by charging hot sinter, pellets, and coke into the blast furnace. Assume that 30% of the heat from these materials can be salvaged.	9
b. Preheat combustion air supplied to sinter and pellet furnaces. Assume that 25% of the heat from hot stack gases can be recovered.	5
c. Increase the air blast temperature to 1100°C and the top gas absolute pressure to 210 kN per m^2 in the blast furnace on 50% of the furnaces. Coke savings of 20% on the charged furnace can be achieved.	35
d. Assume that the off-gases from 50% of the basic oxygen furnaces are used for their fuel and sensible heat.	5

Table 8. (continued)

Conservation Approach	Estimated Fuel Savings (10^{12} kcal/Yr)
e. Improve heat recuperators in open hearth furnaces, soaking pits, reheat furnaces, and heat treating furnaces.	8
f. Reduce electrolyte resistance in aluminum electrolysis cells by closer electrode spacing or modifying bath composition.	4
5. Operation Modification	
a. Operate aluminum electrolysis cells at 20% lower current density.	20
b. Closely control depth of aluminum pad, the distance between anode and cathode, and bath composition.	8
6. Maintenance and Insulation	
Improve maintenance and insulation of steam systems in all primary metals processes. This should result in savings of 10 to 20% in steam usage.	30
Total	208

Total primary metals energy usage ~ 1310 ± 130 x 10^{12} kcal/yr.

Table 9. ENERGY CONSERVATION IN THE PETROLEUM INDUSTRY

Conservation Approach	Estimated Fuel Savings (10^{12} kcal/Yr)
1. Process Integration	
Co-produce electricity and process steam. At present only 10 to 15% of process steam production is combined with electric generation. Assume that this can be increased to 50%. Then an additional 17 x 10^{12} kcal of electricity could be generated using 19 x 10^{12} kcal of fuel. Utilities typically require 51 x 10^{12} kcal of fuel to generate this quantity of electricity.	32
2. Design Modification	
a. Increase heat recuperation from furnaces. Assume that air preheaters which will decrease fuel consumption 15% are installed on an additional 25% of industry furnaces.	16
b. Increase heat interchange between process streams.	8
c. Increase use of turbines to recover mechanical energy from high pressure process streams.	8
d. Design distillation columns to require lower reflux.	8
3. Maintenance and Insulation	
Improve maintenance and insulation on steam systems. This should reduce steam consumption by 15 to 20%.	40

Table 9. (continued)

Conservation Approach	Estimated Fuel Savings (10^{12} kcal/Yr)
4. Waste Utilization	
Increase the use of flue gas from catalytic crackers as fuel.	8
5. Operation Modification	
Closely control steam stripping operations, use of H_2 in desulfurization operations, use of excess air in furnaces, and reflux in fractionation operations.	16
Total	136

Total petroleum industry fuel usage ~ 766 ± 80 x 10^{12} kcal.

Table 10. ENERGY CONSERVATION IN THE PAPER INDUSTRY

Conservation Approach	Estimated Fuel Savings (10^{12} kcal/Yr)
1. Process Integration	
a. Co-produce electricity and process steam. At present approximately 20 to 25% of the possible steam-electricity co-production possibilities are being exercised. If this were increased to 50%, an additional 30 x 10^{12} kcal of electricity could be generated using an additional 33 x 10^{12} kcal of fuel. A typical utility would require 90 x 10^{12} kcal of fuel to generate this quantity of electricity.	60
b. The movement toward integrated pulp and paper mills should be continued because of the expenditure of 0.85 x 10^6 kcal/ton of pulp dried in non-integrated mills. Assume that production from integrated mills increases from the present 60% of the total to 75% of the total.	8
2. Process Modification	
Use paper-forming processes which require less fuel for drying in 25% of the mills (Thermo Electron's Lodding K-Former process).	15
3. Waste Utilization	
a. Increase waste paper recycle from the present level of 19% of produced paper to 21% of produced paper.	9

Table 10. (continued)

Conservation Approach	Estimated Fuel Savings (10^{12} kcal/Yr)
b. Increase use of process wastes as fuel from the present level of 230 x 10^{12} kcal to 250 x 10^{12} kcal.	20
4. Design Modification	
Continue replacement of batch digesters with continuous digesters. Assume that the continuous digester production increases from its present 50% of the total to 75%.	5
5. Maintenance and Insulation	
Improved maintenance and insulation of steam systems should result in a 10% decrease in steam usage.	50
6. Market Modification	
Substitute unbleached paper for bleached paper in 15% of the present bleached paper market.	3
Total	170

Total paper industry energy usage ~ 645 ± 65 x 10^{12} kcal/yr.

Table 11. ENERGY CONSERVATION IN THE STONE-CLAY-GLASS-CONCRETE INDUSTRY

Conservation Approach	Estimated fuel savings (10^{12} kcal/year)
1. Process modification	
a. Convert 25 percent of the present wet process cement production to the dry process using a suspension preheater system.	12
b. Convert 25 percent of the present dry process cement production using a long kiln to the dry process using a suspension preheater.	6
c. Enrich combustion air with oxygen on 50 percent of the glass furnaces. Use agglomerated feed in 50 percent of the glass furnaces.	3
2. Design modification	
Continue trend to larger glass furnaces in which radiation losses are less and heat recuperation is more feasible.	6
3. Maintenance and insulation	
Improve maintenance of insulation and increase insulation in cement kilns and and glass melting furnaces.	10
Total	37
stone-clay-glass-concrete energy usage $\sim 365 \pm 40 \times 10^{12}$ kcal/year	

Table 12. ENERGY CONSERVATION IN THE FOOD INDUSTRY

Conservation Approach	Estimated fuel savings (10^{12} kcal/year)
1. Maintenance and insulation	
Improved maintenance and insulation of steam systems should decrease steam consumption by 20 percent.	10
2. Process integration	
Co-produce electricity along with process steam. Assume that 25 percent of the steam production is combined with electricity production. Then approximately 3 x 10^{12} kcal of electricity could be produced using 3.3 x 10^{12} kcal of fuel. A typical utility would use 9 x 10^{12} kcal to produce the 3 x 10^{12} kcal of electricity.	6
3. Design modifications	
a. Increase the use of high temperature, short time pasteurization equipment in the milk process.	20
b. Replace batch canning operations with continuous operations.	
c. Use baking ovens with air agitation.	
d. Use a more efficient evaporation system in the beet sugar process.	
e. Increase use of heat recuperation in many processes.	
f. Use more efficient cooling equipment.	
Total food industry fuel use ~323 ± 30 x 10^{12} kcal/year	36

Table 13. PRODUCTION VOLUME, FUEL USAGE, AND ECONOMIC IMPORTANCE OF ENERGY IN THE SIX BIGGEST FUEL CONSUMING INDUSTRIES

		Fuel Usage (%) [1]			
Industry (or process)	Production (10^9 kg/year)	Purchased and self generated electricity	Steam (for heating or mechanical drive)	Direct firing	Economic importance of energy kcal used / $ of value added
Chemical					
Chlorine & caustic soda	19	70	30	x	200,000
Ethylene + propylene[2]	12 [2]	3	46	51	x x x
Ammonia	14	10	29	60	200,000[4]
Ethylbenzene + styrene	6	8	55	37	x x x
Carbon black	1.6	x	x	100	130,000[4]
Sodium carbonate[3]	3.5[3]	x	78	22	140,000
Oxygen	14.5	95	5	x	40,000
Total industry	x	37	43	20	35,000
Primary metals					
Steel	83.5	15	20	65	
Aluminum	3.7	77	10	13	
Total industry	x	24	15	61	40,000
Petroleum	610	6	34	60	140,000
Paper	56	23	74	3	50,000
Stone-clay-glass-concrete					
Cement	73	19	x	81	90,000
Glass	16	19	x	81	25,000
Total industry	x	20	5	75	40,000
Food	x	30	65	5	10,000

[1] Process fuel only. Does not include feedstock.

[2] Includes only propylene manufactured as a dry product of the ethylene process. This is approximately 55 percent of the U.S. production.

[3] Synthetic sodium carbonate only.

[4] Includes feestock energy

SECTION V

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SECTION VI

GLOSSARY OF ABBREVIATIONS

conc.	-	concrete
elect.	-	electricity
kcal	-	kilo calories
kg	-	kilogram
kN	-	kilonewton
kWh	-	kilowatt hour
m	-	meter
purch.	-	purchased
syn.	-	synthetic
yr.	-	year

SECTION VII

APPENDIX

ENERGY CONSERVATION APPROACHES

Design modification - This term includes design changes in equipment or process.

Insulation - This term implies that a review of the economics of additional insulation is needed.

Maintenance - This term implies that the economics of additional maintenance effort needs review.

Process integration - This term relates to the best use of steam by using the same steam in more than one process or to the optimization of the steam-electricity production ratio. It also covers the combination of two or more processes within one plant.

Research and development - This term relates to the improvement of processes by future discoveries.

Operation modification - This term includes changes in operating procedures or practices that do not require a design change.

Market modification - This term relates to the substitution of a low energy consumption product for a high energy consumption product.

Process modification - This term relates to a change in a process due to a change in process feedstock, raw materials, or process route.

Waste utilization - This term relates to the use of fuel value of waste process streams or to the recycling of used materials.

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16. ABSTRACT The report gives results of a study of fuel utilization and energy conservation for the six biggest energy consuming industrial groups: chemicals, primary metals, petroleum, paper, stone/clay/glass/concrete, and food. Total annual fuel usage in these industries in the early 1970s was 4569 + or - 500 x 10 to the 12th power kcal. Purchased electricity (valued at 2500 kcal per kWh) accounts for 17-18% of the energy use, coal for 18-19%, petroleum for 15-16%, natural gas for 35%, and other fuels for 13%. Unit operations accounting for energy use include direct heating (39%), compression (7-8%), distillation (6-7%), electrolysis (7-8%), evaporation (3-4%), drying (6%), cooking or digestion (4%), feedstock (10-11%), and other (15-16%). Approximately 800 x 10 to the 12th power kcal per year of energy is rejected in these industries at a temperature above 250 C. Intense efforts at waste heat recovery should eventually allow use of most of this rather high level heat. In the short term, use of a variety of conservation approaches should reduce annual fuel use in the big six industrial groups by 774 x 10 to the 12th power kcal below the level without conservation.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Air Pollution	Chemical Industry	Air Pollution Control	13B	07A
Fuels	Metal Industry	Stationary Sources	21D	11F
Fuel Consumption	Petroleum Industry	Primary Metals Industry		
Energy	Paper Industry	Stone Industry		11L
Conservation	Glass Industry	Clay Industry		11B
Industries	Concretes		05C	13C
Heat Recovery	Food Industry		20M, 13A	06H

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