HEAT RECOVERY RECOMMENDATIONS AT SMALL AND MEDIUM SIZED MANUFACTURING PLANTS

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ABSTRACT

Results are presented of industrial energy assessments performed by Energy Analysis and Diagnostic Center (EADC) programs funded by the U.S. Department of Energy at thirty universities in the United States. The results and data from the assessments have been compiled in an EADC database that resides at Rutgers, The State University of New Jersey. Energy use and cost information as well as other non-proprietary data pertaining to operations are also recorded in this database. In addition, energy savings and cost data are compiled for over 34,000 recommendations made to 5,226 manufacturers since 1980. Although the implementation rate of recommendations vary for each university, the mean implementation rate was about 53%. The first year recommended energy savings were 11.4%, with a cost savings of 10% . A breakdown of these assessments is given by SIC code, and additional details are given for food processing, pulp and paper, chemical and fabricated metal products industries.

A more specific analysis was made by searching for recommendations of heat recovery as one broad measure of savings. Comparison of energy and cost reduction opportunities with general measures and heat recovery show that recovery is a measure with a relatively large potential for savings, averaging four times the recommended energy savings and twice the cost savings of general measures. Heat recovery represents 6.35% of recommended measures and is responsible for 12.3 % of the potential energy savings and 10.6 % of the potential cost savings. The implementation rates of the general energy conservation opportunities and their savings indicate strong acceptance by industry. Heat recovery measures have approximately twice the implementation cost of general measures, which may result in the lower acceptance than the average recommendation. A discussion of the possible causes for these differences is presented.

INTRODUCTION

The world consumption of fossil fuel resources currently increases by three per cent annually [1]. In the U.S. total energy consumption is estimated to be approximately 84 Quadrillion Btu annually, of which 35% or 30 Quad was for the industrial sector in 1993 [2]. After peaking in the mid-seventies, industrial energy consumption dropped off, but now it has again begun to rise and is nearing its historical peak. The United States Department of Energy (DOE) has established several programs to assist manufacturers to reduce their industrial energy use. One of these programs, funded by the Office of Industrial Technology, is the Energy Analysis and Diagnostic Center (EADC) program. The DOE objective for this program is to provide on-site industrial energy conservation assistance to small to medium sized (Gross Sales less the $75 million) manufacturing plants with fewer than 500 employees and having energy costs less than $1.75 million annually. There are currently thirty universities in this country participating in the EADC program. Recently, funding at some of the schools has been expanded in order to address waste reduction and pollution prevention assistance in manufacturing operations. These schools, identified as Industrial Assessment Centers (IAC), perform combined energy/waste assessments in addition to conventional energy audits. Each EADC/IAC performs thirty Energy Audits or Industrial Assessments a year at small and medium sized manufacturing plants. Assessment teams from each university visit these plants to identify ways to reduce energy use, reduce waste and pollution and lower manufacturing costs. A report is prepared after each site visit in which the analysis and recommendations for energy savings, waste prevention and productivity enhancements are described. Since 1980 site visits have been performed at more than 5,200 companies and more than 34,000 energy conservation opportunity (ECO) recommendations have been made. Data from each of these plant visits are maintained in an EADC Database at

Rutgers, The State University of New Jersey [3]. Included in the database are non-proprietary data pertaining to each plant along with data on the specific recommendations made to each manufacturer by the EADC/IAC. As part of the assessment process, each EADC/IAC follows up on the report recommendations by contacting the manufacturer, from six to twelve months after the report has been received, to determine what, if any, recommendations have been implemented. This data is also compiled in the EADC Database at Rutgers, The State University of New Jersey. With the introduction of the Industrial Assessments, waste, pollution prevention and productivity enhancement recommendations are also included in the EADC Database. Because of the time interval between plant visit and plant contact for implementation, the EADC Database is not completely up to date. Typically, Plant Assessments with all data available are about twelve to sixteen months behind the current date.

In order to characterize the recommendations and to organize the data in a meaningful way, an Assessment Recommendation Code (ARC) has been devised [4]. The ARC is a list of recommendations that have been grouped together in a manner that would be most useful to experienced professionals. The ARC allows for energy saving, waste reduction and productivity enhancement recommendations. In this presentation we will only consider the energy saving recommendations of the ARC. Individual energy savings recommendations in the ARC consist of a four digit code, but two and three digit ARC groupings are also used to assist in categorizing assessment recommendations. By grouping similar recommendations, the listings can be used to describe three, two or one digit ARCs that represent either significant systems or strategies. For example, ARC 2432 "Recover Heat from Oven Exhausts" is within ARC 243 "Heat Recovery from Specific Equipment," which in tern is within ARC 24 "Heat Recovery," followed by ARC 2, which is "Thermal Systems." The ARC is a practical and convenient means to characterize EADC plant recommendations, and we will use the ARC system to compare implementation rates in our discussion.

Heat recovery, ARC Number 24, is an important area for saving energy in plants reviewed by EADCs. They are also one of the recommendations that is most likely not to be implemented by companies. This paper will present data on implementation rate of common EADC plant assessment recommendations and compare them with heat recovery recommendations. The data set that was analyzed for this paper includes the 4,376 assessments and the associated 28,850 recommendations performed between 1980 and 1993 and for which implementation data has been received in the database.

Energy Use by Source

Manufacturing energy use is tabulated in the EADC Database by source. For the manufacturers considered in this paper, the energy use and energy cost data is shown in Table 1. The average annual consumption was 81 billion Btu. The most used energy source was natural gas with 155 trillion Btu, with approximately 44% of the total energy consumption, as shown in Figure 1. The second most common energy source was electricity with 26% of the total energy consumption (based on 3,412 Btu/kWhr). Average plant consumption of natural gas and electricity for the plants studied were 35.6 and 21 billion Btu, respectively, with nearly 70% of the energy use in these two categories. Figure 2 shows the cost to manufacturers of their major energy sources, with fuel oils combined in one category. It can be seen that electricity and natural gas account for nearly 90% of the energy expenditures.

TABLE 1. 1980-94 TOTAL ENERGY USE AND COST BY SOURCE

	MMBTU	COST
Electricity	91,346,277	$1,420,588,540
Natural Gas	155,906,309	$527,308,176
L.P.G.	4,034,066	$10,243,848
#1 Fuel Oil	19,094	$128,865
#2 Fuel Oil	7,538,891	$14,465,427
#4 Fuel Oil	1,514,645	$6,115,049
#6 Fuel Oil	16,597,405	$20,297,954
Coal	24,184,994	$37,435,200
Wood	42,492,607	$23,484,838
Paper	6,000	$171,000
Other uses	12,305,666	$15,020,567
TOTAL	355,945,954	$2,075,259,464

Figure 1 Energy Use by Source

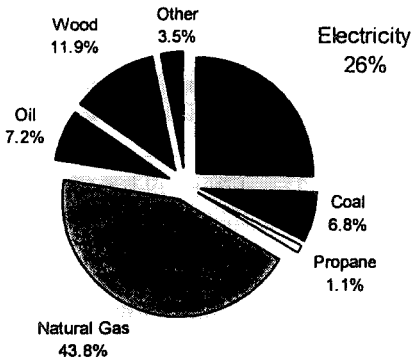
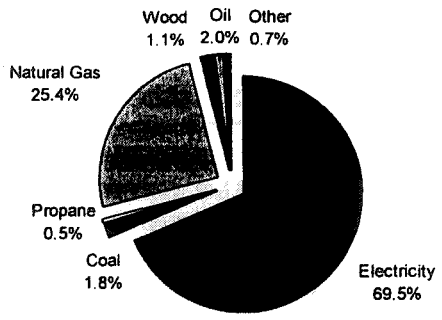


Figure 2 Energy Cost by Source



Plant Assessment Data

Shown in Table 2 are the non-proprietary statistics for all the 5,226 Plant Assessments performed by the EADC Universities since 1980. The data is grouped by Standard Industrial Classification Code (SIC). It can be seen from the table that the 5,226 companies reviewed had a total annual energy consumption of 446 trillion Btu. For all plants total annual sales are $116 billion, with an average of $22 million per year. Average energy costs are nearly $400,000 per year, and energy cost is on average 1.8% of the gross sales. The number of employees at the plants visited totaled 872,307 with the average plant having 167 employees. Also tabulated in the last column is average Energy Intensity Ratio, the ratio of the energy use in MBtu to the sales in dollars, for EADC clients. Although not tabulated here, the Energy Intensity Ratios are very comparable to those published by EIA [1] for 1993. These data indicate that the EADC plants are typical of mid-sized U.S. Manufacturers. Data for the specific industries being discussed in this conference, food processing, paper processing, chemicals, and fabricated metal products, is given in SIC 20, 26, 28 and 34, respectively. These four categories are heavily represented in the EADC Database by 1,819 plants, or 35% of the 5,226 plants visited.

General Recommendations

Recommendations in EADC reports include estimated energy and cost savings as well as the estimated cost of implementation. This data is included along with actual implementation results obtained from the manufacturers. There are numerous types of recommendations such as heat recovery, lighting, motors, HVAC-systems, boilers, compressed air systems, etc. The recommendations must save at least $300 per year in order to be included in the database. Implementation results are tabulated in Table 3 by two digit ARC along with average energy saving, cost saving and simple payback period. For this data set 53% of the 28,850 recommendations were implemented. The average cost of a recommendation is $7,869 with a corresponding cost saving of $6,025 and a simple payback of 1.3 years. For specific ARCs, implementation rate varies from a low of 20% to a high of 68%.

Results of Heat Recovery Recommendations

Of the 28,850 Assessment Recommendations, there were 1,828 heat recovery recommendations reported. The EADC Assessment Recommendation Code lists five major three-digit categories used for heat recovery. They are:

241 Flue Gas - Recuperation. This category includes applications for using flue gasses to preheat combustion air, boiler feedwater and wastes for incinerator boilers.

242 Flue Gases - Other Uses. This category includes applications for providing direct power, steam, preheating products, hot water heating, space heating, preheating fluids, and radiant heating applications.

243 Heat Recovery from Specific Equipment. The specific equipment items are: transformers, oven exhausts, engine exhausts, air compressors, compressed air dryers, refrigeration condensers, and other equipment.

244 Other Process Waste Heat. Process waste heat is used to preheat boiler makeup water and combustion air. This category also includes the use of hot or cold process exhaust air, hot process fluids, exhausted steam, hot waste water, and applications using exhaust heat to heat water.

245 Miscellaneous. Miscellaneous applications include the heat recovery from air that is used for cooling hot work pieces, "heat wheels," heat from lighting fixtures, recovery from waste domestic hot water, exhaust heat from buildings for snow and ice removal, heat service hot water for air conditioning, and recovery from exhaust air to precondition incoming ventilation air.

Table 4 presents a breakdown of the results of the 1828 heat recovery recommendations for the five Heat Recovery categories listed above. It can be seen that the average implementation rate is 37%, in contrast with the 53% rate for all recommendations. When compared to the other 2 digit ARC codes, Heat Recovery (24) has the third lowest implementation rate. The two having a poorer implementation rate are 34, Cogeneration, usually an expensive recommendation to implement and 13, Waste Product Combustion, a recommendation that may require regulatory permits. The range of Heat Recovery simple payback, based on 4 digit ARC, is from .25 to 3.67 years. The Heat Recovery payback period is comparable to other recommendations, as can be seen in Tables 3 and 4, and the first year cost savings are above average for recommendations. Although an average of 37% of the heat recovery recommendations were implemented, this is 16% lower than the average of all recommendations. Heat recovery recommendations yield greater energy and cost savings than general recommendations. The average heat recovery recommendation saves 3,400 MMBtu/year, which is twice as high as the average energy recommendation. The annual cost saving for heat recovery is $13,567/year, which is over twice the average of all recommendations. The average recommended implementation cost is $18,634, or more than twice the average energy recommendation. In looking at the individual recommendations made by EADCs to manufacturers, there is some correlation between the magnitude of the implementation cost and final implementation rate. This has been observed in other studies of manufacturers implementation rates [5]. This observation suggests that the lower priced heat recovery recommendations are more likely to be implemented. ARC 243, Heat Recovery from Equipment, shows a higher implementation rate than other Heat Recovery categories. Plant personnel are more familiar with this type of application in contrast to other Heat Recovery measures, and these types are easier for plant personnel to implement in house. Uncertainty of a technology has also been cited as a reason for not implementing recommendations [5]. ARC categories 241, 242 and 244 all make use of hot fluid heat recovery, a technology that has greater uncertainty for plant personnel and generally requires a larger investment. It is also one of the technologies that is more difficult for EADC Staff to obtain accurate implementation cost data. It appears that uncertainty in the technology, along with higher implementation costs, leads to a lower implementation rate for Heat Recovery applications by industry.

CONCLUSIONS

It is clear that heat recovery is a very important recommendation for energy audits. However the implementation rate of recommendations for heat recovery is about 16% lower than the rate for all recommendations. Heat recovery represents 5.3% of all recommendations while yielding 11.7% of the recommended cost savings. Uncertainty in technology and higher implementation cost for manufacturers, appears to be the primary reason for a lower implemention rate for these measures.

REFERENCES

1. Energy Information Administration (EIA), INTERNATIONAL ENERGY OUTLOOK 1994, U.S. Department of Energy, Washington, 1994.
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3. The DOE Industrial Assessment Database, Version 4.0b, Rutgers, The State University of New Jersey, Office of Industrial Productivity and Energy Assessment, 1994.
4. The ARC, Assessment Recommendation Code System, Version 4.0, Rutgers, The State University of New Jersey, Office of Industrial Productivity and Energy Assessment, 1994.
5. Understanding the Energy Efficiency Investment Decisions of Smaller Manufacturers, Jones,T. and Verdict, M. Alliance to Save Energy, April 1994.

TABLE 2. 1980-94 EADC/IAC Industrial Plant Assessment Data

SIC Code	SIC Description	Plants Visited	Annual Gross Sales ($)	Employees	Total Annual Energy Cost($)	Total Annual Energy Use MMBtu	Energy Cost as % of Gross Sales	Energy Intensity MBtu/$Sales
20	Food, Kindred Products	645	$20,852,281,137	101,653	$272,341,680	44,513,850	1.31%	2.13
22	Textile, Mill Products	236	$5,626,159,879	54,273	$167,866,667	22,984,903	2.98%	4.09
23	Apparel, Other Textile Products	170	$3,232,015,600	40,405	$25,899,600	2,949,198	0.80%	0.91
24	Lumber, Wood Products	246	$4,048,396,376	31,120	$106,587,177	72,129,506	2.63%	17.82
25	Furniture, Fixtures	129	$2,361,464,992	27,229	$27,173,592	3,794,066	1.15%	1.61
26	Paper, Allied Products	285	$6,339,017,537	38,683	$138,788,143	24,357,976	2.19%	3.84
27	Printing, Publishing	228	$3,853,153,908	39,909	$47,606,442	4,257,024	1.24%	1.10
28	Chemicals, Allied Products	231	$6,845,518,000	33,222	$117,907,203	26,773,235	1.72%	3.91
29	Petroleum, Coal Products	43	$702,589,000	2,703	$23,755,803	5,963,482	3.38%	8.49
30	Rubber, Misc. Plastics Products	516	$8,633,524,123	75,222	$207,703,800	27,519,105	2.41%	3.19
31	Leather, Leather Products	40	$766,800,000	9,198	$10,188,541	1,325,352	1.33%	1.73
32	Stone, Clay, Glass Products	181	$3,168,004,647	24,579	$213,958,573	122,380,621	6.75%	38.63
33	Primary, Metal Industries	318	$5,741,365,000	40,031	$166,366,372	21,545,791	2.90%	3.75
34	Fabricated Metal Products	658	$11,597,999,940	93,063	$190,210,673	24,273,963	1.64%	2.09
35	Industrial, Machinery, Eqpt.	545	$12,474,200,000	98,789	$131,107,829	18,335,799	1.05%	1.47
36	Electronic, Other Electric Eqpt.	324	$8,465,411,145	74,651	$112,840,975	10,926,870	1.33%	1.29
37	Transportation Equipment	208	$5,820,222,207	42,872	$62,338,526	6,665,604	1.07%	1.15
38	Instruments, Related Products	135	$3,687,542,812	29,161	$32,237,104	2,989,588	0.87%	0.81
39	Misc. Manufacturing Industries	88	$2,031,250,000	15,544	$21,112,950	2,547,995	1.04%	1.25
	TOTALS	5226	$116,246,916,303	872,307	$2,075,991,650	446,233,929	1.79%	3.84
	AVERAGES		$22,243,956	167	$397,243	85,387		

TABLR 3. RECOMMENDATIONS BY ARC CATEGORY

ARC	DESCRIPTION	NUMBER RECOMMENDED	PERCENT IMPLEMENTED	AVERAGE COST	AVERAGE SAVED	AVERAGE PAYBACK
11	Furnaces, Ovens, etc.	394	46.45%	$2,412	$3,467	0.70
12	Boilers	1566	63.47%	$2,598	$5,556	0.47
13	Waste Products Combustion	44	20.45%	$98,575	$40,097	2.46
14	Fuel Switching	548	37.59%	$19,710	$17,308	1.14
21	Steam	1221	66.09%	$5,328	$5,535	0.96
22	Heating	66	46.97%	$3,728	$9,363	0.40
23	Heat Treating	1	100.00%	$1,320	$3,182	0.41
24	Heat Recovery	1828	36.98%	$14,449	$10,919	1.32
25	Heat Containment	1472	46.94%	$2,538	$3,809	0.67
26	Cooling	247	40.08%	$15,884	$10,600	1.50
27	Drying	32	46.88%	$4,741	$7,815	0.61
31	Demand Management	870	42.18%	$8,339	$8,923	0.93
32	Power Factor	430	50.00%	$11,492	$8,536	1.35
33	Generation of Power	14	50.00%	$79,772	$39,213	2.03
34	Cogeneration	144	23.61%	$456,711	$162,525	2.81
35	Transmission	62	38.71%	$20,990	$12,510	1.68
41	Motors	3022	57.74%	$5,217	$3,087	1.69
42	Air Compressors	3565	61.35%	$951	$2,571	0.37
43	Other Equipment	1127	44.81%	$9,221	$7,393	1.25
51	Systems	183	37.70%	$21,276	$21,411	0.99
61	Maintenance	348	68.10%	$708	$2,055	0.34
62	Equipment Control	1876	53.30%	$1,485	$3,350	0.44
71	Lighting	5433	56.75%	$4,229	$3,185	1.33
72	Space Conditioning	2420	50.79%	$5,549	$5,360	1.04
73	Ventilation	219	51.60%	$2,582	$4,705	0.55
74	Building Envelope	1207	49.88%	$6,657	$3,668	1.82
81	Administrative	475	52.21%	$8,315	$14,728	0.56
82	Transportation	34	44.12%	$1,341	$2,071	0.65
91	Solar	2	50.00%	$12,000	$637	18.85
	TOTAL /AVERAGE	28850	53.36%	$7,869	$6,025	1.31

TABLE 4. HEAT RECOVERY BY THREE DIGIT ARC

	RECOMMENDATIONS				IMPLEMENTED
ARC CODE	NUMBER MADE	AVERAGE COST($)	AVERAGE SAVED/YEAR	PAYBACK YEARS	PERCENT
241	436	$22,152	$13,414	1.65	27.29%
242	137	$28,108	$25,950	1.08	37.96%
243	718	$4,852	$4,210	1.15	43.31%
244	485	$17,187	$14,483	1.19	37.32%
245	52	$20,869	$9,777	2.13	25.00%
TOTAL/AVERAGE	1828	$18,634	$13,567	1.37	36.98%