POTENTIAL ENERGY CONSERVATION FROM INSULATION IMPROVEMENTS IN U.S. INDUSTRIAL FACILITIES:

Estimates Based on EADC Industrial Energy Audits

William Prindle, Barakat & Chamberlin
Paul Parfomak, Barakat & Chamberlin
Ted Jones, The Alliance to Save Energy

INTRODUCTION

Increasing the energy-efficiency of manufacturing has been an important element of U.S. energy policy since the early 1970s, when fuel shortages and price increases focused national attention on the critical role of energy in the industrial sector. Over the past 10 years, energy efficiency in manufacturing has also become an important element of utility resource planning as a means of meeting growing energy demand without constructing additional power plants. Since the late 1980's, industrial efficiency has also been recognized as a potentially effective means of preventing atmospheric pollution from utility power generation and on-site combustion.

A number of common manufacturing end-uses have been identified as having substantial inefficiencies. Initially, motors and lighting were found to be major energy wasters, followed by space conditioning, and, very recently, industrial compressed air systems. As planners have identified these areas, they have developed programs to encourage manufacturers to improve the operating efficiency of these end-uses. Such programs have been offered by both utilities and government agencies.

Another aspect of manufacturing processes considered to have significant conservation potential involves thermal losses from process heating and cooling systems. Qualitative assessments suggest that conventional insulation practices leave a great deal of thermal process equipment either underinsulated or completely uninsulated. However, recent attempts at survey-based estimation of such thermal losses (discussed later in this report) have been inconclusive. The North American Insulation Manufacturers Association (NAIMA) commissioned this analysis to develop a new approach to estimating the energy efficiency potential in industrial pipe and vessel insulation.

This paper describes the Barakat & Chamberlin/Alliance to Save Energy approach to assessing the economic potential for industrial pipe and vessel insulation. Based on thousands of actual industrial energy audits, it develops rigorous, conservative estimates of the energy efficiency potential for insulation in the U.S. manufacturing sector.

METHODOLOGY

This paper is based on a NAIMA-supported study that estimated the conservation potential for industrial insulation measures based on Department of Energy (DOE) field audit data for over 3,000 facilities throughout the U.S. Relying upon field audit data offers an independent implementation-oriented perspective on the insulation problem. It provides useful data on the cost of these insulation measures, and addresses that portion of the total conservation potential which can be achieved economically. The results of this report provide additional insight into issues relevant to program development and delivery.

The estimates are based on an extrapolation of the DOE field audit data to the U.S. manufacturing sector as a whole. First the study characterizes the industry-specific energy consumption characteristics of the plants which have been served by the DOE audit program. The study next summarizes the industry-specific conservation potential, implementation costs, and energy cost savings that could be realized from the insulation measures contained in these audits. The study then applies these numbers to the baseline energy consumption profile of all U.S. manufacturing plants, thereby providing estimates of conservation potential nationwide. The report performs some additional analysis on the relative frequency and cost-effectiveness of specific thermal insulation measures.

The initial step in studies of this type is a review of the existing literature relevant to the topic. To this end, we conducted searches of engineering, manufacturing, and economic journal databases for citations of relevant insulation-related publications. While were able to find a handful of articles addressing the subject, they were mostly "how to" articles for use by plant engineers for specific installations. We also contacted several manufacturing energy-efficiency experts in the engineering department of leading universities, none of whom were able to identify any useful work in this area. With the exception of earlier NAIMA survey analyses (discussed later in this report), we were unable to find any previous estimates of thermal conservation potential on a large scale.

EADC PROGRAM AUDIT DATABASE

The Energy Analysis and Diagnostics Centers (EADC) Program is administered by the Department of Energy to assist small- and medium-sized manufacturers in improving their overall energy efficiency. The program offers free energy audits of manufacturing plants conducted by engineering faculty and students from 30 major universities throughout the country. The audits contain baseline plant operating characteristics and measure-specific estimates of energy-savings potential, implementation costs, and energy cost savings for a full range of industrial efficiency improvements, including insulation improvements. The audits recommend only those measures considered to be cost-effective from the plant's perspective based on site-specific implementation and energy costs.

Since EADC audits are conducted at the plant level, energy usage and savings are reported in site BTU. This means that electric energy usage is treated as having an energy value of 3,413 BTU per kWh. Source BTU analysis—which assigns a primary energy use value of 10,600 BTU per kWh—is appropriate for macro-level analysis, such as total energy savings at the national level. Hence at the end of our analysis, we convert electricity savings to source BTU to identify national level impacts. For the main part of the analysis, however (and in all of the tables), electricity usage and savings are reported in site BTU

The EADC program has maintained a database of its audit findings since 1981. The audit results are classified by plant Standard Industrial Classification (SIC) code and measure identification code (DIECO). We extracted insulation measures from the database to develop industry-specific summaries of EADC audit findings for these measures. Our search found insulation measures were recommended in 1,190 (39%) of the 3,980 plants contained in the version of the database we used. (The database is continually updated as new audits are completed). Insulation-related measures accounted for 1,689 (8%) of 20,753 efficiency recommendations made in these plants. Table 1 summarizes the number of plants audited and the number with insulation recommendations by SIC code.

Note that the EADC program database generally included at least 20, and as many as 513 plants for the industrial SIC categories. The only exception was SIC 21 (tobacco) for which no data were available.

Table 1
EADC PLANTS WITH INSULATION RECOMMENDATIONS

SIC	Plants in EADC Database	EADC Plants w/Insulation Recommendations	
20	495	215	43.4%
21	0	0	NA
22	191	62	32.5%
23	143	46	32.2%
24	157	43	23.0%
25	94	19	20.2%
26	204	68	33.3%
27	172	39	22.7%
28	170	53	31.2%
29	26	19	73.1%
30	378	158	41.8%
31	22	4	18.2%
32	140	41	29.3%
33	227	63	27.8%
34	513	139	27.1%
35	386	86	22.3%
36	240	65	27.1%
37	152	25	16.4%
38	96	24	25.0%
39	69	18	26.1%
ALL	3,980	1,190	30.5%

Conservation Potential in EADC Plants

Table 2 summarizes EADC plant baseline, on-site electricity and natural gas consumption and conservation potential due to insulation-related measures *in those plants where insulation measures were recommended.* Recall that these plants account for 30% of the sites in the EADC database. When the energy savings from these plants are projected to the national level, they are diluted proportionately. This means that from the perspective of an individual plant owner, the energy savings potential is more fairly represented by the numbers in Table 2, even though average savings nationwide are lower because many plants contain no economic insulation investments.

From an individual plant owner's perspective, insulation investments identified in EADC audits can save, on average, .56% of electricity usage and 2.81% of natural gas and other fuels. These savings potentials vary by SIC; Lumber and Wood (SIC 24) and Furniture and Fixtures (SIC 25) show savings potentials of 7.5% and 12.75% of gas usage.

While many EADC plants used additional types of fuel, reported insulation impacts were almost entirely on electric and natural gas end-uses. The small amount of impacts on other fuels were included in the natural gas category (on a Btu basis) for convenience. We consider the reported conservation potential in Table 2 to be an "economic" potential since only cost-effective improvements were recommended by the EADC program.

Cost-effectiveness in this analysis is calculated from the individual energy user perspective, based on energy costs and utility bills at each site. This perspective is encompassed by the "participant test" in standard utility resource economics. It does not address electric generation capacity avoided costs or environmental externalities, for instance, which are often included in cost-effectiveness analyses from a utility's or society's perspective.

Table 2
EADC PLANT INSULATION ECONOMIC ENERGY EFFICIENCY POTENTIAL
IN PLANTS WITH INSULATION RECOMMENDATIONS

SIC	Industry	ELECTRICITY			NATURAL GAS		
		Base Energy (MMBtu)	Conservation		Base Energy (MMBtu)	Conservation	
			(MMBtu)	(% of Base)		(MMBtu)	(% of Base)
20	Food and kindred products	3,645,395	7,747	0.21	8,856,615	206,547	2.33%
21	Tobacco products	NA	NA	NA	NA	NA	NA
22	Textile mill products	1,384,311	2,565	0.19	3,295,453	54,416	1.65%
23	Apparel and other textile products	277,701	2,535	0.91	532,035	15,411	2.90%
24	Lumber and wood products	870,760	2,113	0.24	948,062	71,652	7.56%
25	Furniture and fixtures	221,176	2,683	1.26	134,746	17,192	12.76%
26	Paper and allied products	1,337,661	8,038	0.60	4,248,985	116,012	2.73%
27	Printing and publishing	379,440	1,595	0.42	382,998	5,995	1.57%
28	Chemicals and allied products	1,009,030	2,179	0.22	2,143,129	26,752	1.25%
29	Petroleum and coal products	173,952	2,487	1.43	1,888,222	37,968	2.01%
30	Rubber and misc. plastics prod.	2,733,876	39,763	1.45	1,857,548	39,305	2.12%
31	Leather and leather products	32,653	61	0.19	170,390	3,739	2.19%
32	Stone, clay and glass products	1,112,347	138	0.01	4,012,578	138,707	3.46%
33	Primary metal industries	1,352,538	8,749	0.65	2,065,759	73,569	3.56%
34	Fabricated metal products	1,696,880	7,025	0.41	4,115,628	157,585	3.83%
35	Industrial machinery and equip.	1,109,294	5,415	0.49	1,124,495	40,281	3.58%
36	Electronic and other elec. equip.	925,486	6,437	0.70	751,278	19,859	2.64%
37	Transportation equipment	470,342	3,133	0.67	505,096	14,343	2.84%
38	Instruments and related products	212,161	1,374	0.65	181,533	6,056	3.34%
39	Misc. manufacturing industries	120,436	1,852	1.54	137,290	3,065	2.23%
ALL	ALL INDUSTRIES	19,056,437	105,889	0.56%	37,351,839	1,048,454	2.81%

Economic potential is typically substantially lower than "technical" potential, which includes all technically feasible improvements regardless of their cost. Table 2 contains potential estimates for all insulation measures combined.

A discussion of specific measure impacts and costs follows in a subsequent section of this report.The "Base Energy" reported in Table 2 reports the total annual energy consumption (based on site BTU) for all of the EADC plants in each SIC category. The savings reported are the total savings for insulation measures in all the plants in each SIC category. Consequently, plant-specific savings estimates may vary from the average percentage savings figures presented.

U.S. CONSERVATION POTENTIAL

We applied the EADC conservation estimates to the U.S. manufacturing sector to estimate the nationwide economic potential for insulation measures. The first step in the process was to characterize baseline U.S. manufacturing energy consumption. To do this, we drew upon the DOE's Energy Information Administration periodic surveys of industrial energy use. The most recent study published was for 1991. Table 3 summarizes annual industrial on-site consumption of electricity, natural gas, and other fuels by 2-digit SIC category.

As Table 4 shows, our analysis produces an estimated overall economic conservation potential for insulation measures of 51 trillion Btu, or 0.34% of total annual industrial energy consumption. This figure is based on site BTU; if we convert electricity savings to source BTU, the 51 trillion Btu would increase to 61 trillion Btu, or the equivalent of 9.5 million barrels of No.4 fuel oil per year. Table 4 also shows that the conservation potential for natural gas alone is 0.85%, compared to 0.19% for electricity alone. This is consistent with the fact that electricity is used for process heating far less frequently than natural gas.

The industrial sectors with the greatest potential in terms of total Btu are SIC 29 (petroleum and coal products) at 13 trillion Btu, , SIC 33 (primary metals) at 8 trillion Btu, , SIC 28 (chemicals) at 7 trillion Btu, and SIC 20 (food and kindred products) at 5 trillion Btu. These four groups account for nearly two-thirds of total conservation potential for insulation.

Strengths and Limitations of the EADC-Based Estimates

The estimates of conservation potential based on the EADC audit data are straightforward. The EADC is the largest source available of field data on industrial energy efficiency potential. With such a large number of audits covering all major SIC sectors, we have confidence that the EADC data can be used to project economic potential nationwide.

Our work with the database has revealed a number of strengths:

- It is based on actual audit findings in working industrial facilities.
- It encompasses a large sample of geographically distributed plants.
- All but one industry group (SIC 21) and all fuel types are included.
- Standardized auditing and reporting protocols supported data collection.
- Implementation cost and savings data are reported.

Table 3
BASELINE U.S. INDUSTRIAL SITE ENERGY CONSUMPTION - 1991[1]

SIC	Industry	ELECTRICITY		NATURAL GAS		OTHER FUELS		ALL FUELS	
		(Trill. Btu)	%	(Trill. Btu)	%	(Trill. Btu)	%	(Trill. Btu)	%
20	Food and kindred products	169	7.1%	512	9.3%	272	3.8%	953	6.3%
21	Tobacco products	3	0.1%	4	0.1%	17	0.2%	24	0.2
22	Textile mill products	101	4.3%	108	2.0%	64	0.9%	273	1.8%
23	Apparel and other textile products	19	0.8%	19	0.3%	6	0.1%	44	0.3%
24	Lumber and wood products	61	2.6%	41	0.7%	321	4.5%	423	2.8%
25	Furniture and fixtures	17	0.7%	19	0.3%	31	0.4%	67	0.4%
26	Paper and allied products	201	8.5%	548	10.0%	1,723	24.1%	2,472	16.5%
27	Printing and publishing	53	2.2%	48	0.9%	7	0.1%	108	0.7%
28	Chemicals and allied products	440	18.6%	1,669	30.3%	931	13.0%	3,040	20.2%
29	Petroleum and coal products	105	4.4%	838	15.2%	2,044	28.6%	2,987	19.9%
30	Rubber and misc. plastics prod.	116	4.9%	96	1.7%	25	0.3%	237	1.6%
31	Leather and leather products	3	0.1%	5	0.1%	4	0.1%	12	0.1%
32	Stone, clay and glass products	105	4.4%	380	6.9%	409	5.7%	894	6.0%
33	Primary metal industries	499	21.1%	686	12.5%	1,107	15.5%	2,292	15.3%
34	Fabricated metal products	102	4.3%	174	3.2%	29	0.4%	305	2.0%
35	Industrial machinery and equip.	101	4.3%	109	2.0%	25	0.3%	235	1.6%
36	Electronic and other elec. equip.	102	4.3%	79	1.4%	15	0.2%	196	1.3%
37	Transportation equipment	118	5.0%	132	2.4%	83	1.2%	333	2.2%
38	Instruments and related products	42	1.8%	25	0.5%	31	0.4%	98	0.7%
39	Misc. manufacturing industries	14	0.5%	15	0.3%	4	0.1%	31	0.2%
ALL	ALL INDUSTRIES	2,369	100%	5,507	100%	7,148	100%	15,024	100%

We applied the SIC-specific estimates of EADC plants with insulation recommendations from Table 1 and the percentage savings potentials in those plants from Table 2 to the baseline U.S. manufacturing consumption of electricity and natural gas from Table 3. This calculation yielded an estimated economic potential for thermal insulation measures nationwide. Table 4 summarizes baseline energy consumption and the potential estimates by SIC. Note that no conservation potential is indicated for fuels other than electricity and natural gas, since the EADC audits did not identify significant savings for these other types of fuels.

[1]1994 U.S. DOE *Manufacturing Energy Consumption Survey: Consumption of Energy 1991*. Energy Information Administration. Washington, D.C. Draft as of March 30, 1994.

Table 4
U.S. INDUSTRIAL CONSERVATION POTENTIAL FOR THERMAL INSULATION MEASURES -1988

SIC	INDUSTRY	BASE CONSUMPTION				ECONOMIC POTENTIAL							
		Electric	Nat. Gas	Other Fuels	All Fuels	Electric		Nat. Gas		Other Fuels		All Fuels	
		Trill. Btu	Trill. Btu	Trill. Btu	Trill. Btu	Bill. Btu	% of Base	Bill. Btu	% of Base	Bill. Btu	% of Base	Bill. Btu	% of Base
20	Food and kindred	169	512	272	953	156.0	0.09	5,186.3	1.01%	N/A	N/A	5,342	0.56%
21	Tobacco*	3	4	17	24	5.1	0.17	34.1	0.85%	N/A	N/A	39	.016%
22	Textile mill	101	108	64	273	60.7	0.06	578.9	0.54%	N/A	N/A	640	0.23%
23	Apparel and other textile	19	19	6	44	55.8	0.29	177.0	0.93%	N/A	N/A	233	0.53%
24	Lumber and wood	61	41	321	423	34.0	0.06	712.5	1.74%	N/A	N/A	747	0.18%
25	Furniture and fixtures	17	19	31	67	43.5	0.26	490.0	2.58%	N/A	N/A	533	0.80%
26	Paper and allied	201	548	1,723	2,472	402.6	0.20	4,987.0	0.91%	N/A	N/A	5,390	0.22%
27	Printing and publishing	53	48	7	108	50.5	0.10	170.4	0.35%	N/A	N/A	221	0.20%
28	Chemicals and allied	440	1,669	931	3,040	296.2	0.07	6,495.2	0.39%	N/A	N/A	6,791	0.22%
29	Petroleum and coal	105	838	2,044	2,987	1,097.2	1.04	12,313.7	1.47%	N/A	N/A	13,411	0.45%
30	Rubber and plastics	116	96	25	237	705.2	0.61	849.1	0.88%	N/A	N/A	1,554	0.66%
31	Leather	3	5	4	12	1.0	0.03	19.9	0.40%	N/A	N/A	21	0.17%
32	Stone, clay and glass	105	380	409	894	3.8	0.00	3,846.9	1.01%	N/A	N/A	3,851	0.43%
33	Primary metal industries	499	686	1,107	2,292	895.8	0.18	6,780.4	0.99%	N/A	N/A	7,676	0.33%
34	Fabricated metal	102	174	29	305	114.4	0.11	1,805.2	1.04%	N/A	N/A	1,920	0.63%
35	Industrial machinery	101	109	25	235	109.8	0.11	869.9	0.80%	N/A	N/A	980	0.42%
36	Electronic and other electric	102	79	15	196	192.1	0.19	565.6	0.72%	N/A	N/A	758	0.39%
37	Transportation equipment	118	132	83	333	129.3	0.11	616.5	0.47%	N/A	N/A	746	0.22%
38	Instruments and related	42	25	31	98	68.0	0.16	208.5	0.83%	N/A	N/A	277	0.28%
39	Misc. manufacturing	14	15	4	11	48.1	0.40	87.4	0.58%	N/A	N/A	135	0.44%
ALL	ALL INDUSTRIES	2,369	5,507	7,148	15,024	4,469	0.19	46,795	0.85%	N/A	N/A	51,264	0.34%

*Due to audit data limitations, the "ALL INDUSTRIES" conservation potential is used for SIC 21.

Nonetheless, the results of this analysis should be interpreted with caution. While the EADC program has collected an impressive dataset for a wide range of measures in a wide range of plants, use of the EADC data requires a thorough understanding of the program's objectives and operations. The database is not without its limitations, and these must be taken into consideration when evaluating the conservation estimates it provides. Some notable limitations follow:

- The audit recommendations are based on the economic perspectives of individual energy users. Auditors typically recommended the fastest-payback measures, based on experience that indicated manufacturers would be less interested in longer-payback measures. This practice likely resulted in understatement of the economic potential of insulation measures. More rigorous economic analysis, based on life-cycle costing over the life of the measures, would likely produce a much higher estimate of economic potential.

- Insulation measures were considered along with hundreds of other conservation measures in a limited period of time (typically 1 or 2 days). It is conceivable that audits focussing on insulation measures alone would identify additional opportunities that a more cursory audit may have missed.

- Only small- and medium-sized plants are audited by the EADC program. The application of the data to larger facilities may introduce some error into the analysis.(Pilot studies by EADC suggest that these errors are probably minor).

The first point, that many cost-effective measures were not included in typical EADC audits, indicates that our analysis is a defensible lower bound for economic potential. Use of more sophisticated methods, such as NAIMA's 3 E economic thickness computer model, would likely produce higher estimates of cost-effective savings at a given plant. However, the EADC database does not contain the plant-level data needed to provide the inputs to run the 3 E model. Even if this level of detail were available, running the 3 E model for each of the 1,190 insulation measures in the EADC database would be prohibitively expensive.

This last point relating to plant size may have rather important implications for interpreting the potential estimates. It could be argued that insulation potential is concentrated not only in a handful of industries, but also in the largest plants. On the other hand, the largest plants may be the best managed and, consequently, may have the lowest potential for insulation efficiency improvements (in percentage terms). Unfortunately, the EADC data does not support analyses of the effects of plant size on conservation potential, so we were unable to draw definitive conclusions on this issue.

Overall, our review of the EADC data indicates that our analysis has produced a conservative estimate of economic potential. We still believe, however, that this data is perhaps the most realistic basis for projecting economic potential on a national scale. It is hard to justify rejecting field data in favor of survey or theoretical engineering data. Manufacturing plants are full of critical production processes, inaccessible spaces, and hazards, which can limit the feasibility of insulation-related efficiency measures. These impediments could also add considerable costs to insulation upgrades, well beyond those costs for the purchase and installation of the insulation itself. These factors limit the true achievable potential for efficiency improvements under field conditions.

Comparisons with Previous Estimates

A previous study by Drexel University estimated a conservation potential for insulation of 4.7% of total industrial energy usage.[2] Our study estimates a potential of 0.34% of total industrial energy - exactly 1/14th of the Drexel result. This is a large difference with considerable policy implications. We believe that both numbers have been estimated reasonably. The difference lies in the methodology employed and in the interpretation of the estimates.

---

[2] H.L Brown and W. Steigelman. 1991. *National Industrial Insulation Survey and Analysis of Energy, Environmental, and Economic Impacts.* Drexel University and RCG/Hagler Bailly for Thermal Insulation Manufacturers Association. Philadelphia.

The Drexel study was based on engineering estimates of conservation. Input data for these estimates was collected by means of an extensive telephone survey of 500 manufacturing plants in the major industrial categories. While this approach is advantageous in that it allows for the collection of primary data from many sources in a short period of time, it is subject to certain limitations. Our experience with telephone surveys of industrial plant staff suggests that they have great difficulty accurately quantifying plant characteristics in response to a survey. Short of working out values from facility drawings, their estimates of piping footage, operating temperature, insulation levels, and other factors are probably subject to substantial errors.

As noted above, the cost-effectiveness and general feasibility of insulation retrofits may depend greatly on site-specific factors. The Drexel study presumes that insulation improvements based on their engineering studies are, in general, cost-effective. This assumption is probably optimistic. Given the methods employed, we consider the Drexel estimates to be reasonable approximations of *technical* potential but not realistic for *economic* potential.

Technical potential is defined as the energy efficiency gains that could be obtained by installing the most efficient measures that are commercially available in the current time frame. It ignores economic considerations and limits on technical feasibility related to site-specific factors. Economic potential is defined as a subset of technical potential; it is that portion of technical potential that is deemed cost-effective. As discussed earlier, cost-effectiveness can be defined from many perspectives: the individual energy user, a utility, all utility ratepayers, and society as a whole.

Our estimate is explicitly based on *economic* potential, and on a conservative definition of economic potential. EADC auditors did not use a classic cost-effectiveness test, in which the present value of savings over the life of the measure is compared to its cost. Rather, they applied "real-world" payback guidelines, which limits their measure recommendations to a subset of the measures that would be theoretically cost-effective.

In this respect, the Drexel study and the current analysis are estimating two different things. In other contexts, economic potential has generally been estimated as 25% to 75% of technical potential. Our value is much smaller than that, which suggest that 1) our estimate is too low, 2) Drexel's estimate is too high, or 3) our estimate is low *and* Drexel's is too high. Given the nature of the data and historic biases in these types of studies, we suspect that option 3) is most likely. Without additional data, however, it is hard to say how much each number should be adjusted. We recommend considering these estimates as upper and lower bounds on conservation potential with the "true" economic potential lying somewhere in between.

MEASURE-SPECIFIC FINDINGS

Having estimated overall conservation potential for thermal insulation measures in general, we now turn to some discussion of the specific types of insulation measures included in the EADC program. A knowledge of the relative importance of different measures may be useful in directing program development and manufacturer education.

EADC audits address 11 distinct insulation-related efficiency measures. The identification code (DIECO) and text description for each of these measures follows in Table 5.

Table 5
EADC INSULATION MEASURES SUMMARY DESCRIPTIONS

DIECO	Measure Description
1411	Repair faulty insulation on boilers, furnaces, etc.
1412	Install boiler insulation, or upgrade to optimal thickness
2122	Cover or insulate condensate storage tanks
2123	Install, upgrade or repair insulation on condensate lines
2131	Install, upgrade or repair insulation on steam lines
5331	Use optimum thickness insulation for low temperatures
5511	Insulate bare tanks, vessels, lines, and process equipment
5512	Increase or repair insulation thickness on process tanks, vessels, lines and equipment
5513	Cover open tanks with floating insulation
6255	Install or upgrade insulation on HVAC distribution systems
6261	Use proper thickness of insulation on walls, ceilings, roofs and doors

In order to gauge the importance of the individual measures, we extracted and summarized the number of times each measure was recommended (frequency), the total recommended savings for each measure, the implementation costs, and the value of energy savings (i.e. energy bill reductions). These summary data are reported in Table 6.

As Table 6 shows, DIECO #5511 (Insulate bare tanks, vessels, lines, and process equipment) was the most frequently recommended insulation measure, accounting for nearly half of all insulation recommendations. DIECO #2131 (Install, upgrade or repair insulation on steam lines) was also very common, accounting for over 18% of recommendations. DIECO #6261 which covers building shell insulation, accounted for around 10% of recommendations. The remaining 8 measures each accounted for substantially less than 10% of total insulation recommendations. The relative contribution of each measure in terms of actual MMBtu savings is very similar to its frequency.

Table 6
EADC INSULATION MEASURES SUMMARY DATA

DIECO	Share of Recommendations	Share of Savings	Implementation Cost ($/MMBtu)	Value of Energy Savings ($/MMBtu)	Payback (years)
1411	1.1%	1.8%	$3.02	$2.63	1.1
1412	6.1%	4.9%	$3.24	$3.79	0.9
2122	7.0%	1.3%	$2.40	$3.93	0.6
2123	3.3%	5.2%	$2.01	$4.12	0.5
2131	18.4%	21.5%	$2.22	$4.10	0.5
5331	0.5%	0.2%	$17.74	$10.71	1.7
5511	46.4%	42.8%	$4.12	$4.45	0.9
5512	2.0%	3.4%	$5.32	$5.37	1.0
5513	4.7%	7.2%	$1.36	$4.80	0.3
6255	1.0%	0.8%	$4.12	$6.33	0.7
6261	9.7%	10.9%	$15.03	$5.21	2.9
ALL	100%	100%	$4.57	$4.45	1.0

Table 6 also summarizes average implementation cost per conserved MMBtu for each insulation measure. According to these data, the overall average implementation cost of these measures (weighted by recommended Btu savings) was $4.57 per lifetime MMBtu (in 1993 dollars). DIECOs #5511 and #2131, the two most common, cost an average of $4.12 and $2.22 per MMBtu respectively. The building shell insulation measure, DIECO #6261, was the most expensive, averaging over $15.00 per MMBtu saved, more than three times the average cost of all insulation measures.. Table 3 summarizes average simple payback for each insulation measure based on plant-specific costs. The overall average payback for insulation measures was almost exactly 1 year. Only three measures had an average payback exceeding 1 year. These were #1411 (Repair faulty insulation on boilers, furnaces, etc.), #5331 (Use optimum thickness insulation for low temperatures) and #6261 (Building shell measures). Of these, all were expected to payback in less than 3 years.

The short payback periods suggest that at least a substantial portion on the insulation improvements were highly cost-effective and, consequently, would probably be attractive to plant managers. This findings supports our earlier assessment that EADC audit recommendations encompass only a subset of measures that would be found cost-effective by classical economic tests. In a given plant, a more thorough analysis, using tools such as NAIMA's 3 E program, could produce higher estimates of potential savings.

EADC reports that the overall implementation rate of recommended insulation measures was 57% (this estimate is not based on hard data, but on self-reported followup surveys, and so this data is not used in our core analysis). Given the absence of other incentives such as utility rebates, this is a fairly high implementation rate. It supports the finding that EADC recommendations are based on measures that are very economically attractive.

If we assumed that EADC recommendations were implemented at a 57% rate, we could subtract this portion savings for EADC-audited plants from our national estimate. Such a revision would reduce national savings by about 1 trillion BTU, or about 2% of the 51 trillion total savings. Since this implementation rate is based only on plant self-reporting, we have not included such an adjustment in our analysis.

CONCLUSIONS

According to our analysis, the estimated economic conservation potential for industrial thermal-insulation related efficiency measures is within the range of 9.5 million to 131 million barrels of oil per year, or .34% to 4.7% of total industrial energy use. We believe that a realistic estimate of economic potential is in the low end of this range.

From the point of view of an individual plant manager, the energy efficiency potential of pipe and vessel insulation is much higher than the national average estimate. Plants audited in the EADC program were shown to have saving potential of 2.81% of natural gas usage on average. Some sectors showed much higher potential, up to 13% of total gas usage. If plant managers applied more thorough economic analysis, using tools such as the NAIMA 3 E model, savings could be even greater.