Energy, the Environment, and Delaware Jobs:

Energy Efficiency and the Manufacturing Sector

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Issued
May 2011

Center for Applied Demography & Survey Research
University of Delaware

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May 25, 2011

Acknowledgements

We would like to thank Keith Goossen and his graduate assistant Tom Battagliese from the University of Delaware Mid-Atlantic Industrial Assessment Center for their guidance on key data issues. Tibor Tóth from our Center and Simon Condliffe from West Chester University also offered valuable comments. We would like to recognize the support of our graduate assistants, Leo-Rey Gordon, Caitlin Olsen, and Stephen Douglas. We are especially grateful to George Sharpley from Delaware's Department of Labor for the instrumental role he played in obtaining labor market data and providing valuable comments throughout the report.

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Executive Summary

The Center for Applied Demography & Survey Research at the University of Delaware conducted this study to understand energy efficiency among Delaware's manufacturers. The study was made possible by a grant from the American Recovery and Reinvestment Act. Although the work was performed in collaboration with the Delaware Department of Labor, the authors are solely responsible for its design and execution.

This report explores the potential demand for a particular group of consumers, Delaware manufacturers. Specifically, we explore what types of energy-saving activities are likely to be found among Delaware manufacturers. We estimate the potential spending that could be considered, and then infer what resources that spending would draw from the labor market. In effect, we develop a process that predicts the specific type and quantity of jobs that a particularly green policy might have. Although the paper's focus is a small part compared to the overall green economy, that focus enables answers to useful questions regarding labor skills.

The model developed in this report predicts that Delaware manufacturers will likely find the energy saving opportunities throughout many different types of processes, including industrial motors, lighting, ventilation, air compressors, combustive processes (i.e. boilers, furnaces, etc.), and heat recovery. There are many opportunities that have relatively cheap solutions, and cheap solutions are the proverbial 'low hanging fruit' for energy efficiency. By the same token, cheap solutions mean that few resources are needed, including labor.

We estimated that the feasible energy efficient investments made by Delaware manufacturers would likely cost $120 million and require nearly 635 workers. This employment estimate largely depends on external factors. For example, that spending would require only 450 workers if such investments turned out to be primarily capital intensive. If the projects were primarily labor intensive, they would likely require 820 jobs.

Technologically, our model predicts that most of the jobs coming out of energy-efficient investments would be in combustive industrial processes, heat recovery design, and air compressors. The model also predicts that more labor will be needed to implement those recommendations that have longer paybacks. Approximately 175 jobs would be needed to make those investments that have paybacks less than 1.4 years in length, while 460 jobs would be needed to make those investments with paybacks between 1.4 and 5 years.

Future training for green jobs requires expectations concerning which jobs are most likely to be demanded in the future, and how many people should receive training. Therefore, research useful to green workforce development should address the gritty details of policy design and consumer demand. The model and algorithms derived in this paper attempt to understand a particular sector with sufficient detail to assist in that regard. The process can be refined with alternative data and extended to other locations.

Introduction

In this report, we evaluate how many jobs would be needed to improve energy-efficiency in the state's manufacturing sector. The report is the first part in a series of reports that the Center for Applied Demography & Survey Research (CADSR) is conducting for the Delaware Department of Labor. The project is funded by a grant from the American Recovery and Reinvestment Act.

Energy efficiency in the manufacturing sector is an oft overlooked component in the green jobs literature. We chose to evaluate it for multiple reasons. First, the environmental impact could be large. Although manufacturing represents just 7% of Delaware's employment, the sector consumes just under a third of the state's energy.[1] Even small percentage improvements in energy-efficiency could have large effects. Second, energy-saving technology has a track record of effectiveness. New and emerging green technologies, on the other hand, remain highly uncertain. Third, manufacturing is very competitive, so rising input costs are not easily absorbed. If and when we transition into an economy of higher energy prices, the manufacturing sector will have a particularly difficult time coping with higher costs. Investments today would help manufacturers compete in that future.

[1] This assumes that the manufacturing sector constitutes 84% of industrial energy use.

Although the specific details are elaborated in the text, the main thrust of this report is that improving energy-efficiency in Delaware's manufacturing sector would employ hundreds of people. Specifically, we find that 635 jobs (full time equivalents) would be needed to implement energy-efficient improvements among Delaware's manufacturers. The largest share of these jobs would work on projects that recover heat from industrial processes within the plant. Combustion processes, like ovens, furnaces, and boilers are also important areas for energy-conscious manufacturers.

The process developed in this report predicts the employment and kind of skills necessary to initiate a particular green goal. The process can be refined and applied to manufacturers in other locations as well. The jobs described in this report are needed to achieve a particular goal. Though these jobs are necessary, they do not guarantee that a particular goal will be reached. Jobs discussed in this report ignore those indirect jobs needed in the supply chain or jobs that are induced by increased income or productivity.

The main distinction of this report is that it estimates the upper limit of specific energy-saving opportunities and infers workforce demands from that limit. The advantage is that workforce projections are kept in realistic ranges. The disadvantage of that approach is its narrow focus; energy efficiency in manufacturing is a small part of the overall green economy. To estimate the potential size and scope of the other components of the green economy would require that each one be analyzed separately. That is beyond the scope of this project.

We caution policy makers that effective policies must carefully consider both supply and demand factors. Most green job reports tend to focus on the supply of particular occupations. However, training programs designed on overly ambitious and unrealistic demand forecasts risk oversupplying the labor force with a surplus of particular skills, unintentionally causing unemployment and dragging down wages. Thus, it is critical that training programs use realistic projections, and we hope that this report provides a useful perspective. Of course, actual results will depend critically on the programmatic details of a policy and the corresponding behavior of all involved parties.

In the next section, we discuss the relevant literature concerning energy saving opportunities in manufacturing. The section after that evaluates the primary data set we use to model those opportunities. The Methodology section is a lengthy and technical description of the process we use to estimate labor requirements. Briefly, the process can be described in three steps

Step 1: For each kind of energy saving recommendation, we develop an econometric model that predicts expected implementation costs given the observed characteristics of any manufacturer.

Step 2: We use available information and derive unavailable information about Delaware manufacturers as inputs to the model developed in **Step 1**. Consequently, potential implementation costs are estimated for each type of recommendation among Delaware's manufacturers.

Step 3: The expenditures developed in **Step 2** are converted into employment requirements. That conversion assumes that dollars are spent on either labor-intensive projects or capital expensive projects.

The more general reader may want to skip the Methodology section and go straight to the results on page 59. The final two sections provide a discussion of those results and offer our concluding remarks.

Literature Review

In this section, we review the literature on energy efficiency in the manufacturing sector. Many reports have addressed the number of green jobs that would be affected as consequence of energy-efficient investments. However, those figures are typically the summation of direct, indirect, and induced effects from an economic simulation. Laitner and McKinney (2008) performed a meta-review on 48 such reports and found that approximately 49 jobs could be created per trillion Btu's of conserved energy.[2]

Ratios from cost-benefit studies like this one are common, but do not answer critical questions concerning workforce development. For example, they do not indicate how many jobs are needed to make energy-efficient repairs, or what particular skills would likely be in greatest demand. Answering these questions depends critically on policy details. But most detailed analytical reports tend to focus on the engineering aspects of particular technologies, the financial decision of making those investments, or the role that such a policy would have in meeting a state's renewable portfolio standards.

[2] For example, one report (Eldridge, et al., 2008) estimated how much Maryland's industrial sector could reduce its energy usage by investing in different industrial technologies. This reduction enters into a macroeconomic simulation as increased investment and reduced energy demands. The simulated change in employment is then reported as a policy outcome of improving energy efficiency.

Pelligrino et al. (2004) addressed the most common technological areas where energy efficiencies were possible in manufacturing. The top three areas of efficiency was estimated to be in waste heat recovery, combined heat and power systems, and advanced industrial boilers. Improvements in these areas were estimated to save nearly 1.9 quadrillion Btu's of energy and nearly $5.4 billion. In general, the report cited heat recovery 5 times in the top 20 areas for improved efficiency. Savings were also forecasted for improved steam practices and better controls for electric motors.

The Industrial Assessment Center (IAC) is a program funded by the Department of Energy that uses university students and professors to give free energy assessments to small and medium-sized manufacturers. Gopalakrishnan, Plummer, and Iskander (2000) summarized the results of West Virginia University's IAC assessments for 1999 and 2000. They concluded that the recommendations which would save the most money took the longest time to recoup the implementation costs. Except for common improvements in lighting, the authors reported that most recommendations were unique to each establishment. The authors also noted an "implementation-gap", whereby companies often did not implement seemingly profitable recommendations.

The ITP also sponsors the Save Energy Now (SEN) initiative, which conducts professional energy audits among the biggest industrial energy users. The scope of these audits was limited to recommendations in piping, process heating, air compressors, and ventilation systems. Summarizing the results of 240 SEN assessments, Wright et al. (2009) found that each plant could save approximately $1 million a year in energy costs via energy saving improvements. Plants receiving process heating recommendations could save nearly twice that amount. As plants used more energy, there were more opportunities to improve efficiency. They too noted evidence of an implementation gap.

Tonn and Martin (2000) describe the different stages a manufacturer experiences in adopting energy-efficient technologies. They assume that management culture is the driving factor behind the implementation gap. Using survey results, they show that companies receiving energy audits tend to have an increased willingness to implement new technology. Whether this correlation reflects culture or a causal effect of the audits is not addressed.

The implementation-gap for energy-saving recommendations has also been widely debated among economists. Some find evidence that irrational behavior best explains the lack of investment, while others find that profitability was not correctly measured. Discovering why this implementation gap exists, and coming up with a solution has important ramifications for the green economy. If the main reason is largely behavioral, then subsidies and cost-sharing policies will be ineffective. Gillingham, Newell, and Palmer (2009) offer an excellent review of the economic factors behind energy saving investments.

Anderson and Newell (2004) used IAC assessments to analyze the manufacturer's decision to implement energy-saving recommendations. Their results suggest that manufacturers are generally willing to wait 1.4 years for energy saving recommendations to pay off. Recommendations with paybacks approaching zero have approximately a 70% chance of implementation, while recommendations with paybacks approaching 5 years in length have a 40% chance of implementation. The results also suggested that some types of recommendations (motors, lights, etc.) are favored by manufacturers and that upfront costs are 40% more important to the decision than annual savings from lower energy usage.

Like Anderson and Newell, we will also make extensive use of the IAC data.   Instead of using the data to explain the implementation gap, we instead use it to forecast the employment requirements that could be created by implementing energy efficient improvements in the manufacturing sector.

Data

Description of the IAC Program

The Industrial Assessment Center (IAC) provides free assessments to small and medium sized manufacturers. Program eligibility stipulates that the plant should have no more than $100 million in annual sales, pay between $100,000 and $2 million in annual energy costs, employ no more than 500 people, and have no technical staff whose primary duty is energy management.[3] The program is intended to spread best energy practices to firms that are less able to pay for an energy audit while simultaneously giving students real-world experience.

Each audit is led by a faculty member from a participating university with expert knowledge on energy usage and industrial processes. Prior to a visit, the auditing team is supplied with the previous year's energy receipts and other relevant information. During the visit, the faculty members and students tour the facility and look for possible efficiency improvements. Afterwards, the team makes a detailed report of potential improvements for the manufacturer to consider. Every recommendation's expected costs and benefits are recorded. The manufacturer is contacted between 6 to 9 months later and asked to identify which recommendations have been implemented or soon will be.

[3] Exceptions do occur.

Non-confidential information from this report is standardized and submitted to a free online database.[4] The database includes each company's employment size, expected sales, floor space, annual production hours, industrial classification (6-digit NAICS/ 4-digit SIC), and a description of the products being made.[5] Annual usage and costs for each energy source are tabulated from the previous year's receipts. The database also reports when the visit occurred and the university that conducted the audit.

Every recommendation in the IAC database is classified into a hierarchical classification system using an Assessment Recommendation Code (ARC). Recommendation level information is available for implementation costs, the recurring annual administrative costs, increased costs or savings from non-energy resources, one time revenue gains, changes in energy usage, and expected annual savings. We also know whether or not each recommendation was implemented.

Description of Manufacturing Establishments in the IAC Database

As of January, 2010, the IAC database included more than 14,000 assessments dating back to 1981. Since the 2000 fiscal year (FY), 5,370 assessments were performed, of which 5,263 were in manufacturing according to their 3 digit NAICS code.[6] We further excluded the sample by 175 assessments due to missing data and outliers in important variables.[7] A further 18 assessments were dropped since the manufacturing plants were located in Puerto Rico. This left a sample size of 5,070 assessments since 2000. Table 1 summarizes the characteristics of the 5,070 manufacturing plants that had been assessed by the IAC program.

[4] http://iac.rutgers.edu/

[5] Unfortunately, many assessments listed an inaccurate or missing 6 digit NAICS code. In these cases, the product description and SIC codes were used to identify the most likely 3 digit NAICS code. Some firms (e.g. publishers) are technically not considered in the manufacturing sector.

[6] Companies with an inaccurate or missing NAICS code were assigned one based on their SIC code (also reported) and/or the description of the product they make. Due to changes in the definition of the manufacturing sector, some establishments are in non-manufacturing sectors, like publishing, mining, and agriculture.

[7] 5 assessments did not report any employees, 112 assessments did not report a plant size, 5 assessments were excluded since their floor area was reported to be more than 10,000,000 square feet, and 53 were excluded because they either did not report any electricity use (26) or because they used less than 150 mmbtu's of electricity (27).

Table 1 Characteristics of Manufacturing Assessments, by Type of Industry: 2000-2010 (FY)

NAICS	Median Employment	Median Sales (2008 $)	Median Plant Area	Median Electricity Use (mmbtu)	Median Natural Gas Use (mmbtu)	Number of Assessments: Northeast	Midwest	South	West	Total
311	125	37,295,608	100,000	19,008	23,724	58	100	207	181	546
312	115	42,328,904	121,000	15,473	13,992	10	11	35	28	84
313	127	25,434,224	171,000	25,595	23,944	18	7	56	5	86
314	152	37,771,072	145,000	11,899	12,451	6	4	29	2	41
315	160	22,677,468	94,973	6,585	6,694	2	7	28	9	46
316	210	21,124,216	127,785	4,075	811	3	3	4	1	11
321	115	25,850,036	120,000	11,753	696	26	41	97	76	240
322	120	35,079,576	168,125	16,732	16,727	74	72	96	61	303
323	148	24,815,826	100,000	10,431	4,428	23	44	44	23	134
324	51	31,916,456	177,625	9,753	65,556	4	9	25	22	60
325	96	36,054,008	120,000	18,683	18,546	42	91	154	58	345
326	120	23,637,470	100,000	21,769	3,195	54	176	172	97	499
327	100	19,488,652	140,000	14,817	21,674	24	28	78	45	175
331	120	25,000,000	112,700	21,671	28,179	60	162	94	63	379
332	120	23,179,954	102,000	10,183	9,045	91	248	247	143	729
333	137	30,084,054	116,620	9,591	4,876	56	142	164	55	417
334	218	38,166,448	93,618	13,188	1,715	25	38	61	68	192
335	210	36,175,448	113,700	11,788	4,682	23	28	56	17	124
336	209	36,599,928	130,000	13,475	6,383	15	124	141	57	337
337	160	24,852,018	160,000	7,328	3,324	17	29	85	36	167
339	175	28,579,820	110,000	9,686	5,889	31	46	46	32	155
Total	128	29,279,942	115,000	13,936	8,357	662 13.1%	1410 27.8%	1919 37.9%	1079 21.3%	5,070

- Source: IAC Database

The median establishment in the sample employed 128 people and made approximately $29.3 million (2008 $) in sales.[8] It had a plant size of 115,000 sq. ft. and used nearly 14,000 mmbtu's of electricity and 8,350 mmbtu's of natural gas.[9] These characteristics varied greatly by industry. Textile mills (NAICS 313) had the second highest plant size and the highest electricity usage, while petroleum and coal product (NAICS 324) and primary metal (NAICS 331) manufacturing used the most natural gas. Most assessments occurred in the South and Midwest.[10]

[8] Nominal figures adjusted with the Producer Price Index for finished goods.
[9] Very few manufacturers also used other forms of energy, such as coal, paper, fuel oil, etc. However, this applied to only a small group of manufacturing plants.
[10] States in the Northeast include: ME, NH, VT, MA, RI, CT, NJ, PA, and NY
States in the South include: TX, OK, AR, LA, KY, TN, MS, AL, WV, DE, MD, DC, VA, NC, SC, GA, and FL
States in the Midwest include: ND, SD, NE, KS, MN, IA, MO, WI, IL , IN, MI, and OH
States in the West include: WA, OR, CA, AK, HI, MT, ID, WY, NV, UT, CO, AZ, and NM

Table 2 Number of IAC Assessments by Employment Size and Industry: 2000-2010 (FY)

NAICS	1-4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	1000+
311	1		18	73	118	206	91	30	9
312		1	1	15	17	29	17	4	
313				4	25	35	16	6	
314				3	8	19	8	3	
315				2	5	23	16		
316				1	2	5	3		
321		1	7	28	59	119	23	3	
322			3	28	82	163	21	3	3
323				11	30	61	23	8	1
324	1	4	8	15	13	16	2		1
325	1	4	12	65	95	124	29	10	5
326	1		4	51	137	227	64	12	3
327			4	28	49	62	25	6	1
331		1	6	48	105	145	58	15	1
332		1	14	93	180	313	105	20	3
333			4	34	97	184	68	23	7
334			1	8	33	61	69	13	7
335				12	15	45	43	7	2
336			2	15	51	120	111	31	7
337			1	12	35	62	44	11	2
339			1	8	28	62	44	8	4
Total	4	12	86	554	1184	2081	880	213	56
	0.1%	0.2%	1.7%	10.9%	23.4%	41.0%	17.4%	4.2%	1.1%

- Source: IAC Database

In Table 2, we decompose the employment size of our sample by industry. Between 2000 and 2010, 93% of visits were to companies with an employment size of between 20 and 499. According to the Quarterly Census of Employment and Wages (QCEW), the number of medium sized establishments (Table 3) represented only 29% of US manufacturing establishments in the first quarter of 2005. Relative to all manufacturers in the population, the IAC sample is clearly overrepresented by medium sized businesses. However, medium sized manufacturing plants constitute nearly 60% of manufacturing employment in the population (results derived from QCEW data), so medium sized firms are clearly important.

Table 3 Number of Manufacturing Firms in the US by Employment Size and Industry: 2005

NAICS	1-4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	1000+
311	9,921	4,845	4,426	3,913	1,977	1,840	776	338	177
312	1,638	695	621	587	312	278	104	42	11
313	1,457	645	540	641	397	400	166	46	9
314	3,758	1,455	1,010	774	305	220	96	33	4
315	4,863	1,959	1,840	1,501	618	388	102	35	6
316	675	238	204	202	74	62	24	5	1
321	5,713	2,953	3,034	3,125	1,399	1,044	236	38	8
322	1,329	618	785	1,299	1,026	1,075	211	103	36
323	18,545	7,676	5,112	3,745	1,473	886	225	69	15
324	893	412	332	297	161	146	56	26	14
325	4,920	2,254	2,342	2,696	1,429	1,098	410	179	82
326	3,643	1,914	2,155	2,857	1,975	1,539	411	119	43
327	5,692	3,122	3,269	3,172	1,226	788	219	47	8
331	1,486	748	802	1,103	725	684	296	107	40
332	21,730	11,330	10,626	9,854	3,983	2,316	535	119	35
333	10,558	5,405	5,425	5,258	2,414	1,603	503	185	87
334	6,993	2,695	2,659	3,165	1,794	1,415	529	261	198
335	2,346	1,022	1,038	1,176	679	610	255	100	41
336	4,790	1,978	1,925	2,230	1,401	1,547	779	379	270
337	11,178	4,611	3,462	2,587	1,080	689	268	95	33
339	17,137	5,964	3,924	3,035	1,150	870	267	106	37
Total	139,265	62,539	55,531	53,217	25,598	19,498	6,468	2,432	1,155
	38.1%	17.1%	15.2%	14.6%	7.0%	5.3%	1.8%	0.7%	0.3%

- Source: Establishment Size Data from the Quarterly Census of Employment and Wages, 2005

We approach the IAC database with the caution that the sample may not be representative of the population of manufacturing establishments. Small and large manufacturing establishments may use different technologies than medium sized establishments. In addition, plants receiving an assessment may be more energy inefficient than plants not receiving an assessment. If true, energy-saving opportunities may be more frequent in the sample than in the population.

Since establishment level data are not available for firms outside the database, it is difficult to tell whether the establishments in the IAC database are statistically different from the population. Ratios available from the Manufacturing Energy Consumption Survey (MECS) enable us to at least make limited comparisons between the IAC sample and the larger population of manufacturers.

Table 4 Comparison of Energy Usage (mmbtu) per Employee

	Under 50 Employees		50-99 Employees		100-249 Employees		250-499 Employees	
NAICS	MECS	IAC	MECS	IAC	MECS	IAC	MECS	IAC
311	1,267	1,607	1,587	1,387	932	763	1,313	809
312	757		702		460		621	
313	1,318		N.A.		769		909	
314	292		261		673		358	
315	58		50		77		102	
316	72		117		146		69	
321	600		414		1,451	823	892	
322	564		1,706	3,047	1,811	942	10,240	
323	72		94		169	240	339	
324	4,554		5,774		18,705		40,228	
325	3,565	3,605	3,532	1,469	N.A.	8,893	5,347	
326	371	362	292	475	417	365	324	318
327	1,276		2,374	1,427	5,055	1,584	2,888	
331	1,030		1,091	1,127	1,470	1,963	2,566	708
332	242	885	345	383	335	341	222	202
333	325		103	166	166	166	150	440
334	172		127		79	174	125	177
335	196		210		282	658	298	310
336	206		138	176	172	195	201	214
337	121		59		61	159	117	
339	93		137		102	161	119	
Total	563	1,878	673	1,015	1,073	1,095	1,564	647

- Sources: 2006 MECS, Table 6.4 and IAC database (selected assessments between 2004 and 2008)

Table 4 compares energy consumption data from the 2006 MECS to energy consumption among manufacturers receiving an IAC assessment between 2004 and 2006. The IAC ratios are only reported if 20 or more assessments had been conducted for that group. In general, the IAC ratios imply that manufacturers in the sample use more energy than manufacturers in the population. The correlation of energy ratios for these two groups is 0.72.

We do not know if these differences are meaningful or how they affect the predictions. For example, the IAC ratios are based on assessments that occurred between 2004 and 2008, while the MECS ratios apply to firms in 2006. Thus, time differences could affect the comparison. Similarly, the differences in regional and industrial composition could explain the difference. If in fact, the differences are based on observable characteristics, like time, employee size, and industry, an econometric model will control for these differences. Unfortunately, we simply do not know how the nonrandomness will affect the model's predictions.

For now, we proceed with the caution that the predictions could be biased owing to the effects of the unobservable parameters. Of course, given the advance of technology and the fact that firms will face higher energy prices in the future, even a random sample of today's manufacturers may not apply to the future.

Description of the Recommendations in the IAC Database

Next we consider the 41,513 recommendations that were made during the 5,070 assessments. Of these, 85.7% of the recommendations were intended to reduce energy consumption, 7.0% address pollution and waste minimization, and 7.2% recommend a productivity improvement. This report will address the 35,579 recommendations intended to reduce energy consumption.[11]

[11] Future research may want to explore the pollution reducing and productivity enhancing suggestions.

Prior to sending the formal report to the manufacturer, the IAC team categorizes all recommendations into a formal system of codes, called Assessment Recommendation Codes (ARCs). There are five hierarchical levels to the ARC system. At the highest level (Level 1), recommendations are classified into energy efficiency, pollution reduction, and productivity enhancements. Approximately 4 out of 5 recommendations fall under the first category, which is the focus of this report.

The energy-saving recommendations are classified into one of the following Level-2 categories:

1. Combustion Systems
2. Thermal Systems
3. Electrical Power
4. Motor Systems
5. Industrial Design
6. Operations
7. Building and Grounds
8. Ancillary Costs
9. Alternative Energy Usage

At the most detailed level (Level 5), there are 362 energy saving recommendations. For example, ARC 2.1111 recommends that the manufacturer control the pressure of the steamer operations.

Table 5 Average Energy-Saving Recommendations Made per Audit, by Year and ARC-Class (Level 2)

Year	Combustion Systems	Thermal Systems	Electrical Power	Motor Systems	Industrial Design	Operations	Building and Grounds	Ancillary Costs	Alternative Energy Usage	Total Audits
1999	0.29	0.61	0.31	1.51	0.03	0.11	1.75	0.17	0.00	134
2000	0.32	0.76	0.26	1.90	0.01	0.21	1.71	0.21	0.00	610
2001	0.33	0.89	0.39	2.11	0.03	0.28	1.91	0.15	0.00	636
2002	0.34	0.99	0.36	2.32	0.04	0.30	2.10	0.15	0.01	628
2003	0.39	1.08	0.35	2.64	0.04	0.37	2.33	0.17	0.01	600
2004	0.39	1.15	0.28	2.57	0.03	0.32	2.19	0.23	0.01	625
2005	0.35	1.15	0.34	2.77	0.04	0.32	2.47	0.15	0.05	539
2006	0.44	1.47	0.30	2.63	0.05	0.30	2.31	0.13	0.06	443
2007	0.43	1.38	0.25	2.65	0.05	0.34	2.49	0.13	0.06	376
2008	0.42	1.27	0.32	2.76	0.02	0.40	2.53	0.09	0.09	398
2009	0.39	1.18	0.23	2.78	0.02	0.48	2.93	0.09	0.03	274
Rec. per Audit	0.37	1.09	0.32	2.44	0.03	0.31	2.22	0.16	0.03	5,263

- Source: IAC Database

Table 5 shows the average number of energy-saving recommendations made per assessment for each level-2 ARC.[12] The most frequent recommendations occur in the establishment's motor systems (2.44 rec. per audit) and building and grounds (2.22 rec. per audit). Thermal systems recommendations were also made frequently (1.09 rec. per audit). Recommendations for combustion systems, electrical power, and operations were made in approximately 3 out of every 10 audits. Few recommendations are made in industrial design, ancillary costs, and alternative energy usage.

[12]. Only assessments conducted since the 2000 fiscal year are included in Table 1.

For the purposes of this research, recommendations need to be classified based on the similarity of necessary skills. However, the ARC system classifies recommendations by the technological area where inefficiencies are found. This does not always translate into labor skills. For example, some recommendations listed as “Industrial Design” recommend replacing or modifying a furnace, despite the fact that most furnace-related recommendations fall into the “Combustion Systems” ARC codes. Thus, the skills needed to install, repair, or modify furnaces could apply to at least two different level-2 ARCs.

Furthermore, the ARC system occasionally groups together behavioral recommendations with recommendations that require some training. For example, “Make a Practice of Turning Off Lights When Not Needed” (ARC 2.7124) and “Disconnect Ballasts” (ARC 2.7122) share the same Level 4 ARC hierarchy. To an electrical engineer, disconnecting ballasts and turning off lights might both be rather trivial changes to a system. However, safely disconnecting ballasts clearly requires some electrical training, while turning off lights does not.

Despite these minor exceptions, the necessary skills are heavily influenced by the physical technology behind each recommendation. Thus, our reorganization of the ARC system was not severe. In addition, we needed to use an organizational system that had sufficient sample sizes for later econometric models, but not so broad that unrelated skills would be grouped together.

We took the following steps to modify the existing ARC system. First, we identified those ARCs that primarily suggested changing behavior or administrative processes (turning off the lights, rescheduling employee shifts, etc).[13] Then the 2007 NAICS index of goods and services identified which industries would perform each of the remaining recommendations. Most recommendations matched the services provided by Building Equipment Contractors (NAICS 2382xx).

- Electrical Contractors and Other Wiring Installation Contractors – 238210
- Plumbing, Heating, and Air Conditioning Contractors – 238220
- Other Building Equipment Contractors – 238290

Within these three industries, most recommendations were classified as work that was performed by electrical and other wiring contractors or by plumbing, heating, and air conditioning contractors. Recommendations matching services provided by other building equipment contractors generally referred to installing power generating equipment or insulating HVAC equipment. A handful of recommendations matched the following industries: Glass and Glazing Contractors (238150), Roofing Contractors (238160), Drywall and Insulation Contractors (238310), Other Building Finishing Contractors (238390), and Landscaping Services (561730). Three major classifications were chosen as a result of this process: HVAC, Electrical, and other facility improvements.

[13] Most of these recommendations were clearly labeled in the ARC classification.

Table 6 Major Classifications of Training Required in Each

Major Classification	Skill Class	Primary Industry
HVAC	Furnaces, Heating, Boilers	238220
	Heat Recovery	238220
	Steam, hot water, process piping, refrigeration, and cooling	238220
	Space heating, ventilation, and conditioning	238220
	Insulating Machines, Equipment, and Piping	238290
Electrical	Motors and other electrical equipment	238210
	Air Compressors	238210
	Lights	238210
	Electrical Power	238210 & 238290
Other facility improvements	Windows, Doors, Roofs, Walls, Landscape	Multiple (see text)
Employee behavior / administrative	Employee behavior / administrative	n.a.

Within each of the three categories, we used the ARC system to refine the classification further. Occupational descriptions from the BLS, promotional material, as well as course descriptions and degree sequences from community college websites identified similarities in the training skills needed to perform the recommendations. Table 6 reports which recommendation groups were chosen, and Tables A.1 through A.11 report the particular ARC recommendations that makeup each group.[14]

While we believe that the modification of the ARC system better aligns the recommendation to skills, there is still ambiguity. For example, cogeneration is listed under electrical power although the technology uses heat and pressure from the combustion processes to generate electricity. Similarly, optimizing furnace temperature could be as simple as adjusting the settings on a control panel. However, that recommendation might also require that the furnace undergo expensive modifications.

[14] Most of the recommendations under "Industrial Design / Systems / Miscellaneous" did not fit into any skill class and were subsequently dropped from the analysis.

Despite the ambiguity, we maintain that each group has a reasonable degree of internal congruence. For example, workers who install new lights, make motor repairs, or install transformers must have technical knowledge of electrical systems. Similarly, labor that performs work in process piping, steam systems, and refrigeration must have knowledge of fluid dynamics and material science. Recommendations made to replace, repair, or modify furnace, boiler, and heating systems will require workers trained in thermodynamics. Heat recovery can require a deeper understanding of multiple technological processes.

Table 7 shows how many recommendations were made per assessment under the new classification system. Recommendations in the Electrical Power and Other Facility Improvements are made least often, while recommendations in air compressors and lights are made most often.

Table 7 also shows how the recommendations differ by industry. For example, petroleum product manufacturers (NAICS 324) receive relatively few energy saving recommendations for air compressors, but more for furnaces, process heating, and boilers. Similarly, food and beverage manufacturers NAICS 311 and 312) receive more recommendations in steam, hot water, process piping and refrigeration than other industries.

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Table 7 Total Number of Recommendations made, by Industry and Skill Type: 2000-2010 (FY)

NAICS	Furnaces, etc.	Heat Recovery	Steam, hot water, etc.	Insulating Equipment	Space conditioning	Power	Lights	Motors and other equipment	Air Compressors	Other facility	Behavioral & Admin.	Number of Assessments
311	0.57	0.45	0.52	0.16	0.55	0.22	1.64	1.02	1.37	0.14	0.59	583
312	0.53	0.49	0.53	0.16	0.42	0.18	1.48	1.19	1.35	0.16	0.73	88
313	0.69	0.60	0.38	0.30	0.47	0.06	1.17	0.98	1.18	0.05	0.64	87
314	0.62	0.33	0.29	0.43	0.48	0.14	1.62	0.81	1.52	0.07	1.00	42
315	0.61	0.48	0.22	0.52	0.43	0.15	1.17	0.48	1.09	0.13	0.80	46
316	0.45	0.27	0.00	0.09	0.36	0.09	1.27	0.45	1.45	0.36	0.45	11
321	0.27	0.26	0.14	0.16	0.34	0.35	1.23	1.28	1.53	0.05	0.73	270
322	0.50	0.57	0.43	0.34	0.42	0.31	1.41	1.13	1.50	0.14	0.73	304
323	0.24	0.32	0.29	0.55	0.15	0.14	1.66	0.92	1.57	0.18	0.83	139
324	0.74	0.37	0.49	0.12	0.94	0.24	1.50	1.10	0.76	0.01	0.66	68
325	0.53	0.49	0.60	0.26	0.52	0.22	1.38	1.00	1.26	0.12	0.73	360
326	0.29	0.28	0.33	0.34	0.48	0.18	1.57	1.16	1.63	0.13	0.92	515
327	0.39	0.40	0.17	0.22	0.38	0.27	1.38	1.11	1.40	0.09	0.79	193
331	0.57	0.67	0.17	0.33	0.53	0.17	1.48	1.02	1.67	0.16	0.63	386
332	0.37	0.41	0.14	0.37	0.40	0.17	1.53	0.80	1.67	0.21	0.82	747
333	0.23	0.29	0.17	0.49	0.21	0.21	1.66	0.69	1.62	0.22	0.92	429
334	0.30	0.21	0.23	0.50	0.24	0.24	1.50	0.78	1.33	0.16	0.94	197
335	0.29	0.39	0.23	0.46	0.27	0.19	1.56	0.73	1.60	0.23	1.02	124
336	0.25	0.41	0.15	0.38	0.28	0.15	1.65	0.64	1.70	0.25	1.00	343
337	0.23	0.37	0.07	0.40	0.16	0.24	1.30	0.78	1.73	0.24	0.81	172
339	0.40	0.31	0.23	0.33	0.37	0.24	1.61	0.86	1.51	0.13	0.91	159
Total	0.40	0.41	0.28	0.33	0.40	0.21	1.51	0.94	1.52	0.16	0.80	5,263

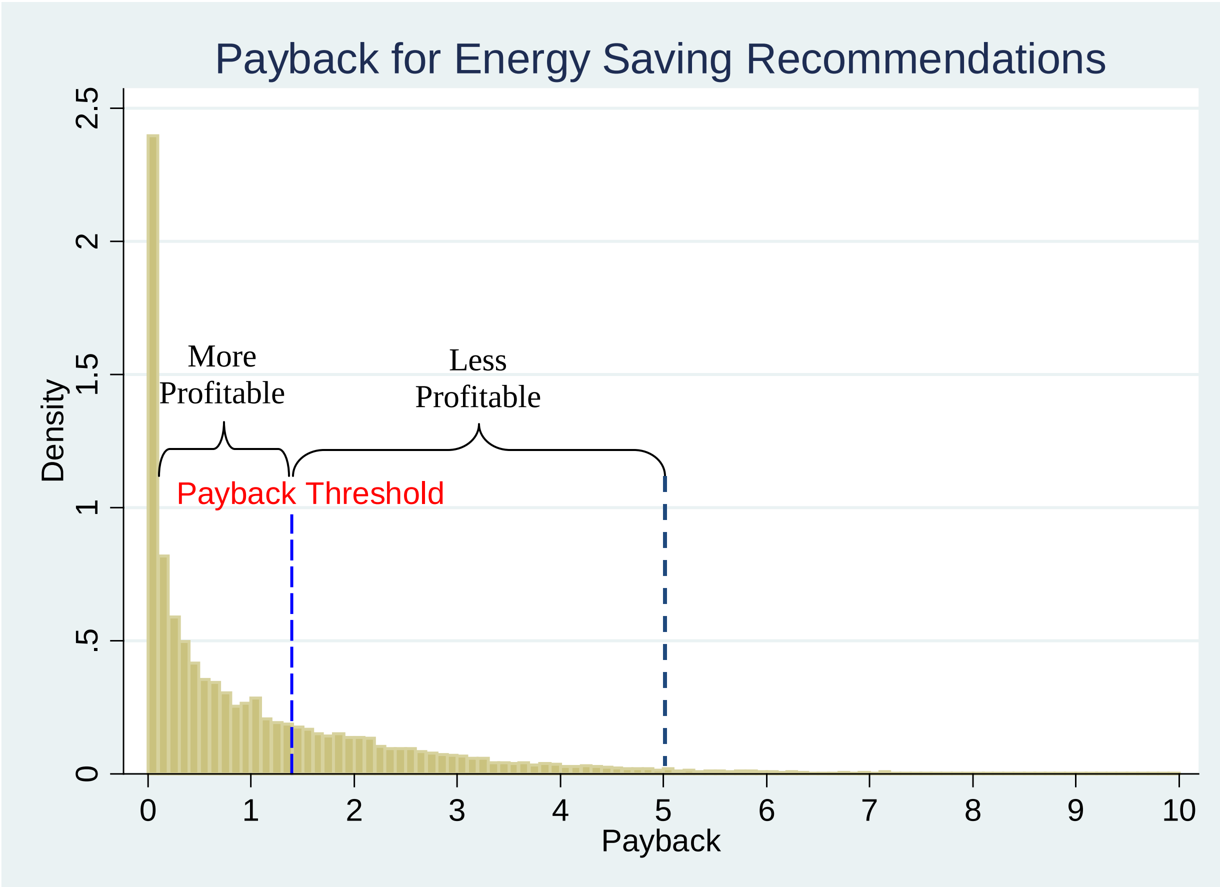
- Source: IAC Database

Theoretically, the profitability of each recommendation should determine whether the recommendation will be adopted. However, since we do not know important information like the opportunity cost of capital, we cannot construct net present values for each recommendation. We rely on each recommendation's payback as a proxy for profitability. Payback refers to the length of time a firm must wait before the annual savings from each recommendation exceeds the implementation costs. It is calculated as the net implementation costs divided by the net annual savings.[15]

Figure 1 is a histogram of the recalculated paybacks for all energy saving recommendations made since 2000. The large spike at zero indicates primarily those recommendations that have no reported implementation costs and therefore a zero payback. We ignore these recommendations since we derive labor estimates from positive implementation costs. The majority of recommendations have paybacks less than 1 year, and 96.7% of the recommendations have paybacks less than or equal to 5 years.

[15] The reported payback on file does not appear to be estimated consistently. For example, some recommendations list positive capital, material, and other implementation costs separately, though these costs do not sum to the total implementation cost. The payback variable also occasionally had missing values or obvious errors. Therefore, we recalculated each recommendation's payback, typically as the sum of capital, material and other implementation costs divided by the sum of total savings. When missing values mode this impossible, we also used the reported total implementation costs (adjusted for one time revenues) divided by the sum of total savings. Recommendations with paybacks that could not be duplicated within rounding precision were recalculated with the reported costs and benefits.

Figure 1 Histogram of the Payback Period for all Energy Saving Recommendations: 2000-2010 (FY)



- Source: IAC Database

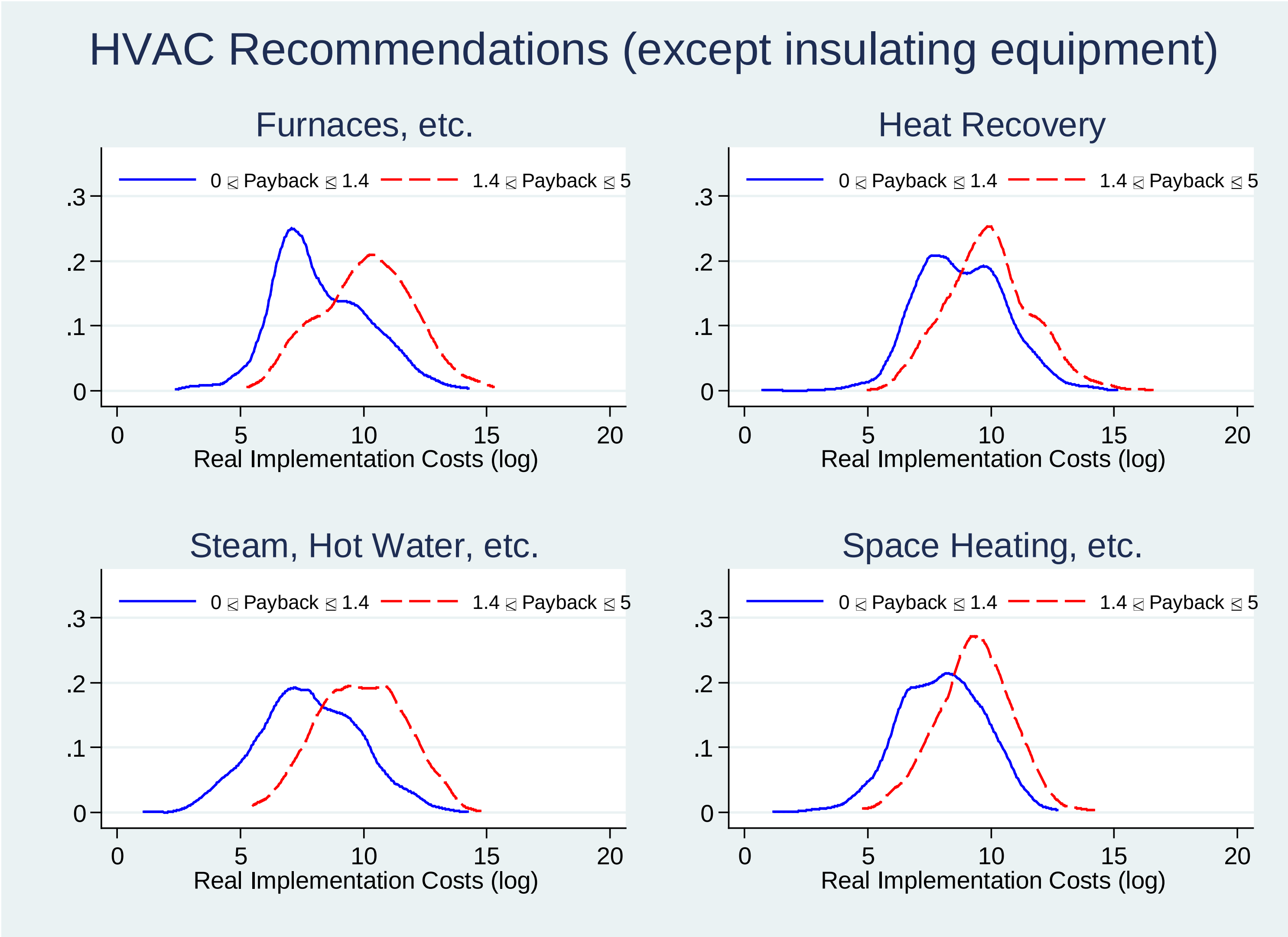
We estimated the implied "payback threshold" using the methodology of Anderson and Newell (2004). The payback threshold is the average between the minimum payback of rejected recommendations and the maximum payback of implemented recommendations. Consistent with Anderson and Newell's results, the mean payback threshold across establishments was approximately 1.4 years. This implies that on average, firms are less likely to implement recommendations with paybacks greater than 1.4 years. The authors estimated that recommendations with relatively low paybacks have approximately a 70% chance of being implemented while recommendations with 5 years of payback have approximately a 40% chance of implementation.

We summed the potential implementation costs of all recommendations with similar paybacks (i.e. below or above the payback threshold) in each recommendation group. Recommendations with a positive payback less than or equal to 1.4 years are referred to as "more profitable", and recommendations with paybacks greater than 1.4 years and less than or equal to 5 years are referred to as "less profitable".

Figure 2 plots kernel density estimates of HVAC-related implementation costs per assessment.[16] The more profitable (solid blue line) recommendations typically have less implementation costs than the less profitable recommendations (dashed red line). Since the scale of implementation costs is reported in natural logarithm, the figures indicate that substantial variation exists in both types of recommendations. Figure 3 and Figure 4 show similar kernel density estimates for all other recommendation groups.

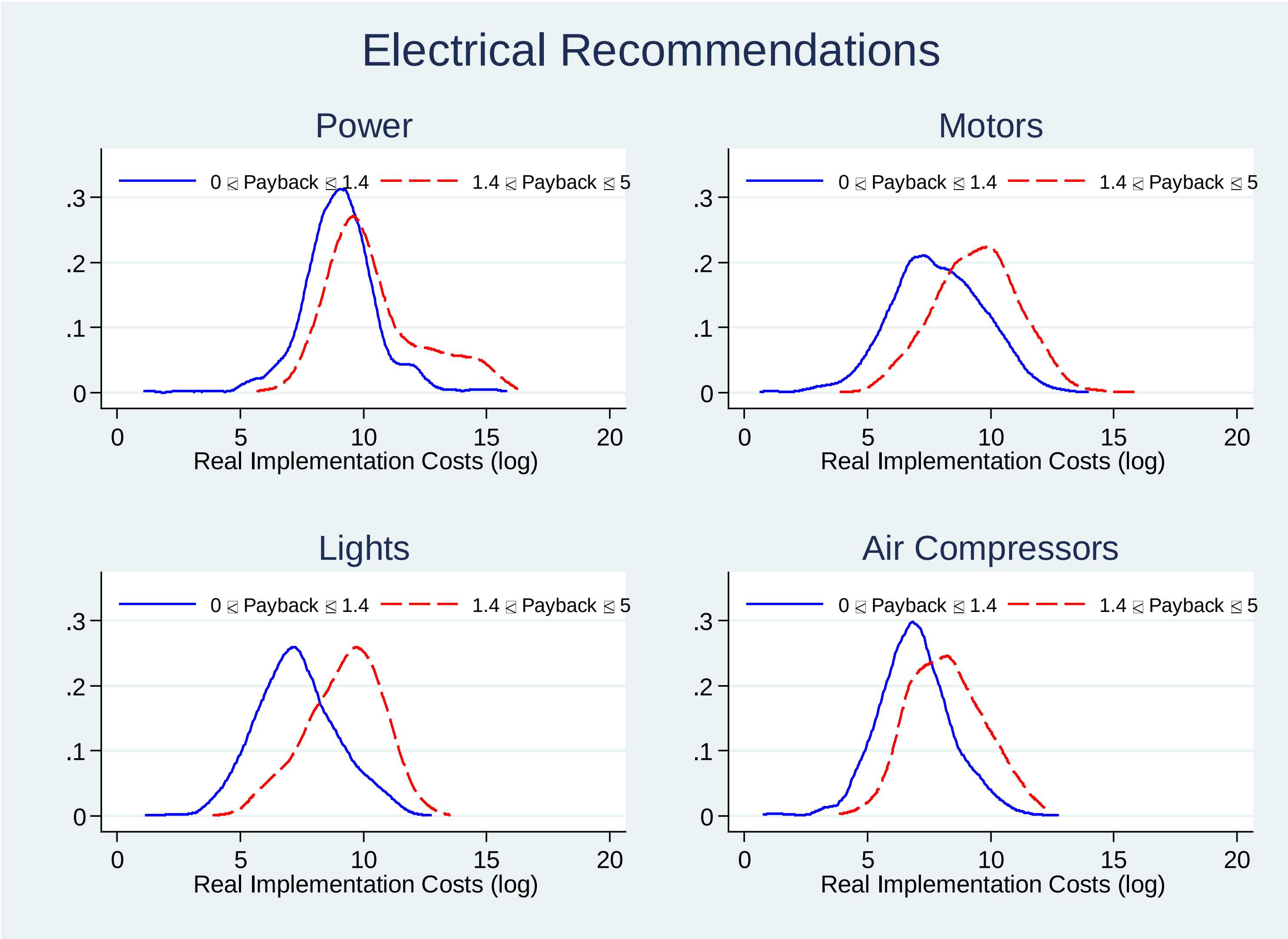
[16] Conceptually, a kernel density estimates is a histogram that has been represented by a continuous function.

Figure 2 Kernel Density Estimates of the Sum of Implementation Costs per Assessment, by HVAC Related Skills and Payback



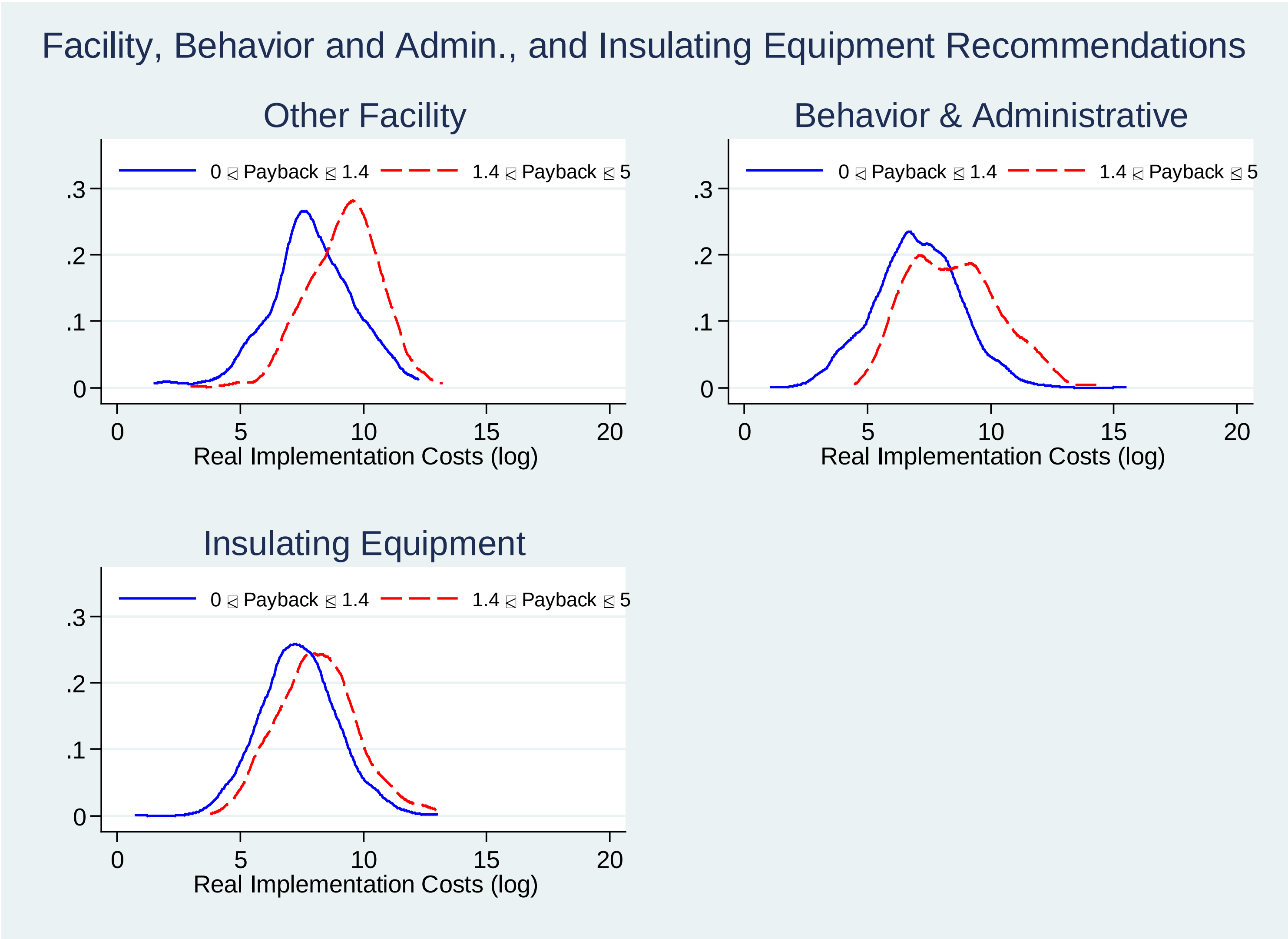
- Source: IAC Database

Figure 3 Kernel Density Estimates of the Sum of Implementation Costs per Assessment, by Electrical Related Skills and Payback



- Source: IAC Database

Figure 4 Kernel Density Estimates of the Sum of Implementation Costs per Assessment, by Miscellaneous Skills and Payback



- Source: IAC Database

Table 8 and Table 9 report different points for the distributions plotted in Figures 2 through 4. As the figures indicate, recommendations with higher paybacks carry larger costs than those recommendations with lower paybacks. For example, the more profitable recommendations in the furnaces, heating, and boilers have a median implementation cost of only $2,700, while the median implementation cost for recommendations with longer paybacks is approximately $25,000.[17]

[17] $\ln(2700) \approx 7.9$, $\ln(25000) \approx 10.12$

Table 8 Distribution of the Natural Logarithm of the Sum of Implementation Costs for Recommendations with Relatively Short Paybacks: 2000-2010 (FY)

	Percentiles										
Recommendation Skill Class	10	20	30	40	50	60	70	80	90	Average	Count
Furnaces, Heating, Boilers	6.31	6.81	7.07	7.47	7.90	8.52	9.25	9.89	10.97	8.26	1,045
Heat Recovery	6.67	7.23	7.72	8.17	8.68	9.24	9.78	10.26	11.09	8.77	1,151
Steam, hot water, etc.	5.09	6.07	6.66	7.14	7.64	8.24	8.75	9.49	10.22	7.74	725
Space conditioning, etc.	6.00	6.56	7.01	7.58	8.04	8.49	9.01	9.52	10.22	8.03	876
Insulating Equipment, etc.	5.43	6.11	6.59	6.96	7.33	7.76	8.15	8.67	9.37	7.38	1,316
Electrical Power	7.39	7.98	8.35	8.71	8.98	9.35	9.63	10.02	10.59	9.03	326
Motors etc.	5.52	6.27	6.88	7.23	7.77	8.27	8.81	9.44	10.25	7.81	1,722
Air Compressors	5.13	5.75	6.19	6.55	6.90	7.22	7.60	8.07	8.84	6.93	3,624
Lights	5.21	5.91	6.41	6.85	7.20	7.62	8.08	8.72	9.61	7.31	2,468
Other Facility	5.66	6.66	7.17	7.47	7.82	8.20	8.80	9.27	10.10	7.89	371
Behavior & Administrative	4.73	5.55	6.19	6.59	6.98	7.44	7.94	8.43	9.12	6.99	1,483

- Source: IAC Database

Table 9 Distribution of the Natural Logarithm of the Sum of Implementation Costs for Recommendations with Relatively Long Paybacks: 2000-2010 (FY)

	Percentiles										
Recommendation Skill Class	10	20	30	40	50	60	70	80	90	Average	Count
Furnaces, Heating, Boilers	7.48	8.39	9.15	9.70	10.12	10.61	11.10	11.73	12.50	10.10	464
Heat Recovery	7.67	8.52	9.03	9.51	9.89	10.28	10.66	11.40	12.18	9.93	596
Steam, hot water, etc.	7.60	8.38	8.86	9.34	9.94	10.39	10.88	11.44	12.17	9.89	316
Space conditioning, etc.	7.35	8.08	8.57	9.05	9.32	9.74	10.14	10.56	11.22	9.32	483
Insulating Equipment, etc.	6.13	6.79	7.24	7.72	8.03	8.47	8.90	9.37	10.25	8.12	361
Electrical Power	8.33	8.96	9.32	9.58	9.96	10.37	10.99	12.26	13.71	10.47	481
Motors etc.	7.13	7.96	8.48	8.93	9.44	9.86	10.31	10.81	11.63	9.39	1,279
Air Compressors	6.36	6.88	7.25	7.75	8.10	8.52	8.98	9.51	10.27	8.20	725
Lights	7.00	7.89	8.46	8.97	9.38	9.77	10.13	10.58	11.15	9.22	2,362
Other Facility	7.27	8.04	8.54	9.03	9.40	9.66	10.01	10.41	10.92	9.24	297
Behavior & Administrative	6.31	6.82	7.28	7.73	8.45	8.94	9.41	10.01	10.94	8.47	412

- Source: IAC Database

Methodology

Below is a brief description of the process we use to identify the potential jobs needed to improve energy efficiency in Delaware’s manufacturing sector. There are essentially three steps to the process.

Step 1: For each type of recommendation, develop a model that predicts expected implementation costs given the observable characteristics of any manufacturer.

Step 2: Use the characteristics of Delaware manufacturers to determine the potential expenditures of each recommendation type.

Step 3: Use industry sales to employment ratios to convert recommended expenditures into potential employment.

Step 1

Discussion of the Predictive Model

In this section, we develop the empirical model that predicts total recommendation costs per assessment. First, we review those factors that are theoretically important predictors of total potential implementation costs. Then we discuss the econometric specification of the hurdle model in the context of potential implementation costs. Finally, we specify the model with variables from the IAC database.

Factors that Predict the Recommended Implementation Costs

The most important predictor of the costs of energy-saving improvements is likely to be the energy usage itself. In general, the more energy-intensive is a plant's operations, the more opportunities exist for energy-saving improvements. In addition, energy may also be positively related to implementation costs if higher energy use signals that the plant is less efficient than other firms. The quantity and composition of energy use could also signal what kind of technology is being used at a plant. For example, plants that demand relatively large quantities of electricity may signal that they rely heavily on motors and air compressors. All of these reasons indicate that energy use should be strongly correlated with the potential savings and implementation costs.

The manufacturer's size is also potentially important. All else equal, one would expect that more improvements are possible at larger plants and implementation costs increase. However, size could be measured in different ways. The physical floor space is one measure, while employee size and firm sales are alternative measures. However, plants with more employees may reduce external labor costs by performing more recommendations in-house. Thus, we have no clear expectation concerning the relationship between employee size and reported costs.

Energy prices are also expected to be important. Holding energy use constant, higher prices imply energy-efficiency is more profitable. Since assessment teams are more likely to make profitable recommendations, we expect energy prices to positively impact the probability of making a recommendation. However, energy use cannot be held constant in an econometric specification since firms adjust energy use in response to prices. As a result, energy prices are not included in our model.

If, on the other hand, energy use is relatively fixed in the short run, then recent changes in the energy prices are less likely to be correlated with energy usage. The historical trends in price could also reflect a naïve forecast of future price changes. Price increases are expected to increase the probability of making particular recommendations, and as a result, raise the total implementation costs per assessment.

Another predictor of the energy-saving recommendations is the establishment's industry since specific technologies tend to concentrate within certain industries. For example, food manufacturing requires heating and refrigeration equipment, so one would expect these plants to have relatively high probabilities of receiving "Steam, Hot Water, Process Piping, and Refrigeration" recommendations. Similarly, petroleum products manufacturing requires very high temperatures, so one would expect many recommendations to fall into the "Furnaces, Process Heating, and Boilers" category.

Idiosyncrasies in each assessment team could also affect which recommendations get made and the reported implementation costs. Differences in program specialization, faculty personalities, or the quality and quantity of eligible students could all be important factors.

Geography is another important factor that could influence the probability a recommendation is made or its cost. For example, the regional price of labor would likely imply different implementation costs. Regional variation in temperature or humidity could also impact which recommendations get made.

Time is another important factor to consider. For example, certain recommendations may be suggested more frequently once a technological barrier is overcome. In addition, general macroeconomic conditions change over time, which could affect the relative profitability of certain recommendations. For example, recommendations made during recessions may be qualitatively different from the recommendations made in better times.

In summary, we hypothesize that the following factors are important predictors of which energy-saving recommendations get made and what their implementation costs are.

- *USE* Energy Usage
- *SIZE* Size of Manufacturer
- *ΔP* Change in Energy Prices
- *IND* Industry effects
- *IAC* IAC specific effects
- *GEO* Region specific effects
- *TIME* Time specific effects

Econometric Specification of the Potential Implementation Costs

In this section, we discuss econometric issues behind our predictive model. We assume that the factors listed in the last section combine linearly to affect implementation costs. Letting IC_s represent the sum of implementation costs for all recommendations made in a particular group, 's', the predictive model is written as:

$$IC_s = \gamma_0 + USE'\gamma_1 + SIZE'\gamma_2 + \Delta P'\gamma_3 + IND'\gamma_4 + IAC'\gamma_5 + GEO'\gamma_6 + TIME'\gamma_7 + \varepsilon \quad (1)$$

where $\varepsilon \sim N[0,\sigma_\varepsilon^2]$, the *USE*, *SIZE*, …, *TIME* are vectors listed in the previous section, and γ_0 through γ_7 are coefficient vectors. Ideally, Equation 1 could be estimated using ordinary least squares (OLS) for all assessments once the model is specified.

Since companies do not normally receive every type of recommendation, total implementation costs for a particular type of recommendation is censored. Therefore we use a hurdle model to estimate the implementation costs for each recommendation type. The model consists of two steps. In the first step, a probit regression models the probability that a firm receives at least one recommendation with positive implementation costs. In the second step, we use ordinary least squares regression to predict the magnitude of those positive implementation costs (Cameron and Trivedi, 2009).

For notation, let D_s equal 1 if an assessment resulted in at least one recommendation in group 's' was made with a positive implementation cost and 0 otherwise. Assuming the probability that a recommendation is made, $Pr[D_s=1]$, is independent from the implementation costs (conditional on the covariates), the expected size of implementation costs is derived by the following equation:

$$E[IC_s] = Pr[D_s = 0] \times 0 + Pr[D_s = 1] \times E[IC_s | D_s = 1] \quad (2)$$

where E[.] denotes the expectations operator. This equation says that the expectation of potential implementation costs equals the probability a firm receives a recommendation multiplied by the expected implementation costs of those recommendations.

The probability that a plant receives the recommendation is estimated with a model similar to Equation 1.

$$Pr[D_s = 1] = \Phi(\beta_0 + USE'\beta_1 + SIZE'\beta_2 + \Delta P'\beta_3 + IND'\beta_4 + IAC'\beta_5 + GEO'\beta_6 + TIME'\beta_7) \quad (3)$$

$$D_s^* = \beta_0 + USE'\beta_1 + SIZE'\beta_2 + \Delta P'\beta_3 + IND'\beta_4 + IAC'\beta_5 + GEO'\beta_6 + TIME'\beta_7 + u \quad (4)$$

Where Φ represent the cumulative normal density function and β_0 through β_7 are coefficient vectors, $u \sim N[0,\sigma_u^2]$ and D_s^* is a continuous variable such that $D_s = 1$ when $D_s^* > 0$ and $D_s=0$ when $D_s^* \leq 0$.

Equation 2 can now be rewritten as:

$$E[IC_s] = \Phi\left[\boldsymbol{X}'\widehat{\boldsymbol{\beta}}\right] \times [\boldsymbol{X}'\widehat{\boldsymbol{\gamma}}\ ] \tag{5}$$

where the $\boldsymbol{X}$ signifies a vector containing predictor variabless, and $\widehat{\boldsymbol{\gamma}}$ and $\widehat{\boldsymbol{\beta}}$ are vectors of estimated coefficients.

Model Specification

The predictor variables described earlier were:

- *USE* Energy Usage
- *SIZE* Size of Manufacturer
- *ΔP* Change in Energy Prices
- *IND* Industry effects
- *IAC* IAC specific effects
- *GEO* Region specific effects
- *TIME* Time specific effects

In this section, we detail what variables in the IAC database will specify these factors. The *USE* vector includes both the type and quantity of energy use. Almost every manufacturer in the sample purchased electricity and nearly 82.5% of the manufacturers used natural gas. Therefore, we include the natural logarithm of annual electricity usage (*ELEC*) and natural gas (*NATG*) usage measured in millions of British thermal units (mmbtu's). We account for firms that do not use natural gas with an indicator variable (*NATX*).

Other forms of energy were also used by firms in the IAC database, such as LPG (5.2%), distillate fuel oil (4.0%), residual fuel oil (1.2%), coal (0.5%), wood (0.8%), other gases (0.6%), and other energy sources (0.8%). An indicator variable reports whether the plant used at least one of these energy sources (*OTHR*).

The firm's average power demand is likely an important component of the *USE* vector. However, since we are unable to measure or derive the power demands for firms outside the sample, we omit this variable from the specification. We expect that *ELEC* is strongly correlated with power demand.

Two variables capture the size of the manufacturers, the number of employees (*EMPL*) and the plant's floor area (*AREA*). Sales could be another important predictor, but since many firms did not provide this information, it has been omitted.[18]

The annual percent change in industrial electricity (*ΔPEC*) and natural gas (*ΔPNG*) prices were obtained from the State Energy Data System (SEDS). Updated prices for 2009 were constructed from EIA's database of industrial electricity and natural gas prices. The Producer Price Index for all finished goods converted nominal dollars into 2008 dollars.

We controlled for industry effects using a set of indicator variables for three digit NAICS codes (*D3xx*). Due to small sample sizes, we grouped apparel manufacturers (*D315*) with leather and allied product manufacturing (*D316*). Food manufacturers are the omitted group.

[18] There was no substantial loss in predictive ability by omitting this variable.

Information is not available for each IAC center, so we control for their effects with a set of indicator variables (*IACxx*). Since universities only assess manufacturers within a reasonable distance from their campus, the IAC indicator variables implicitly control for geographical effects as well.[19] Consequently we do not control for geography separately due to multicollinearity.

Finally, we model the effects of time with indicator variables (*20xx*), and set the omitted group to be the assessments performed in 2000.

In summary the following variables will be used in the model specification:

- *ELEC* Natural logarithm of electricity usage (mmbtus)
- *NATG* Natural logarithm of natural gas usage (mmbtus)
- *XNAT* Dummy variable indicating that natural gas is not used at the plant
- *OTHR* Dummy variable indicating if another energy source is used[20]
- *EMPL* Natural logarithm of the number of employees
- *AREA* Natural logarithm of the square footage of establishment area
- *ΔPEC* Percent change in industrial electricity price (2008 $)
- *ΔPNG* Percent change in industrial natural gas price (2008 $)
- *D3xx* Indicator variables for each 3 digit NAICS code
- *IACxx* Indicator variables for the particular IAC performing the assessment
- *20xx* Indicator variables for the year the plant was assessed

[19] In fact, some IAC teams have never performed an assessment outside of their own state.
[20] This includes LPG, coal, wood, distillate fuel oil, residual fuel oil, paper, other gasses, and other energy sources.

Table 10 Summary Statistics for all Observations

		ELEC	NATG	OTHR	NATX	EMPL	AREA	ΔPEC	ΔPNG
2000-2010 (FY) (N=5070)	Average	9.562	7.884	0.093	0.169	4.851	11.690	0.023	0.106
	Std. Dev	1.278	3.961	0.291	0.375	0.872	0.957	0.104	0.242
	Min	5.059	0	0	0	0.693	7.076	-0.451	-0.561
	Max	15.242	17.942	1	1	8.434	16.059	0.618	0.947

Table 10 lists the summary statistics for all assessments in the sample.[21] The average logged electricity use is 9.562, which corresponds to approximately 14,200 mmbtu's. Similarly, 9.3% of businesses used some other energy source in the first time period, and 16.9% did not use any natural gas. The average employment corresponds to 128 persons, and the average plant size corresponds to 120,000 square feet.[22]

Table 11 shows summary statistics for firms receiving at least one recommendation with a payback greater than 0 but less than 1.4 years. Relative to the average firm in the sample, establishments that received HVAC recommendations tended to consume more electricity and natural gas and also used more sources of energy. Table 12 lists similar figures for firms receiving at least one recommendation with a payback between 1.4 and 5 years. These firms tended to use less electricity and natural gas than firms receiving more profitable recommendations.

[21] This sample excludes any assessments performed in Puerto Rico and any establishments which had outliers for electricity usage.
[22] Averages taken in natural logarithms.

Table 11 Summary Statistics for Assessments Receiving "More Profitable" Recommendations, by Skill Class: 2000-2010 (FY)

Recommendation Group	# of Assessments	ELEC	NATG	OTHR	NATX	EMPL	AREA
Furnaces, Heating, Boilers	1,045	9.868	9.358	0.140	0.099	4.888	11.876
Heat Recovery	1,151	9.879	9.378	0.115	0.077	4.951	11.839
Steam, hot water, process piping, refrigeration, and cooling	725	10.104	9.438	0.106	0.092	4.973	11.948
Space heating, ventilation, and conditioning	876	9.634	8.118	0.100	0.140	4.951	11.780
Insulating Machines, Equipment, and Piping	1,316	9.830	8.752	0.122	0.134	4.763	11.732
Electrical Power	326	9.711	8.069	0.092	0.144	4.951	11.783
Motors and other electrical equipment	1,722	9.761	8.165	0.093	0.157	4.864	11.763
Air Compressors	3,624	9.605	7.997	0.079	0.156	4.907	11.733
Lights	2,468	9.613	7.941	0.066	0.162	4.890	11.712
Windows, Doors, Roofs, Walls, Landscape	371	9.446	7.413	0.073	0.208	4.947	11.655
Employee behavior / administrative	1,483	9.578	7.457	0.092	0.203	4.895	11.668

- Source: IAC Database

Table 12 Summary Statistics for Assessments Receiving "Less Profitable" Recommendations, by Skill Class: 2000-2010 (FY)

Recommendation Group	# of Assessments	ELEC	NATG	OTHR	NATX	EMPL	AREA
Furnaces, Heating, Boilers	464	9.705	8.783	0.179	0.123	4.896	11.802
Heat Recovery	596	9.782	9.227	0.138	0.099	4.936	11.793
Steam, hot water, process piping, refrigeration, and cooling	316	9.986	8.384	0.117	0.149	4.992	11.838
Space heating, ventilation, and conditioning	483	9.365	7.872	0.085	0.139	4.869	11.663
Insulating Machines, Equipment, and Piping	361	9.565	8.699	0.163	0.119	4.797	11.673
Electrical Power	481	9.780	8.071	0.121	0.185	4.841	11.843
Motors and other electrical equipment	1,279	9.803	7.880	0.097	0.186	4.884	11.761
Air Compressors	725	9.457	7.747	0.098	0.159	4.847	11.647
Lights	2,362	9.551	8.045	0.077	0.141	4.874	11.701
Windows, Doors, Roofs, Walls, Landscape	297	9.252	7.426	0.067	0.178	4.845	11.553
Employee behavior / administrative	412	9.635	7.527	0.112	0.194	4.900	11.739

- Source: IAC Database

Step 2

Deriving Characteristics for Delaware Manufacturers

The second step aims to use the model developed in step to predict likely expenditures for Delaware manufacturers. However, because such company-specific information is not available to the public, we develop a process of deriving that information. Future estimates could likely be substantially improved with access to establishment level manufacturing data.

The Delaware Department of Labor (DOL) provided employment and industry data for all manufactures in the state. This data set establishment information for the Quarterly Census of Employment and Wages (QCEW), and is the only establishment level data we have outside of the IAC database.[23] Records were obtained for the fourth quarter of 2009. There were 394 manufacturers in Delaware with at least 1 but less than 20 employees and 155 establishments with at least 20 but less than 500 employees. 11 manufacturing establishments had 500 or more employees.

In order to predict total implementation costs, we need estimates of the remaining variables. Although the Department of Energy's Manufacturing Energy Consumption Survey (MECS) collects this data, it is not disclosed. We show how the MECS data was integrated with data from the Annual Survey of Manufacturers (ASM), the State Energy Data System (SEDS), the Economic Census (EC), the Economic Research Service at the United States Department of Agriculture (ERS/USDA), and the QCEW to predict energy to employment ratios for each industry in Delaware.

[23] Other private data sources were available for a fee, but they contained too few establishments for the scope of this analysis.

Electricity Use to Employment Ratios

For sake of notation, let there be 'J' industries in the manufacturing sector and 'I' states in a particular region. In addition, let $ELEC_{ij}$ represent the total purchased electricity of the j^{th} industry in the i^{th} state, while EMP_{ij} represents the total employment for the j^{th} industry in the i^{th} state. Finally, let $\lambda_{ij} = ELEC_{ij} / EMP_{ij}$. λ_{ij} tells us how much total electricity is purchased per employee in the j^{th} industry in the i^{th} state. If λ_{ij} were known, we would simply multiply the appropriate ratio by the employment at any establishment to estimate the electricity use. The main difficulty is that $ELEC_{ij}$ and EMP_{ij} are not known.

The QCEW provides employment data by industry and state, so EMP_{ij} is well populated at the 3 digit NAICS code. For confidentiality reasons, the employment in some industries in certain states is not disclosed. Some states were willing to provide us with this data directly. When these private sources were unavailable, we exploited all implicit constraints in each state and spread any remaining employment over the unaccounted establishments.[24] The result of this process was an estimate of EMP_{ij} at the 3-digit NAICS industry in every state. Imputations were more common among the smaller industries in the western states.

[24] For example, suppose we know that 50 people are employed at 10 establishments in a particular 5-digit NAICS industry, but 2 different 6-digit industries within that 5-digit industry are not disclosed. If one of these 6-digit industries had only 1 establishment and the other had 9 establishments, we assumed that the industry with 1 establishment received 10% of the known employment (5 employees) and the industry with 9 establishments received 90% of the known employment (45 employees).

Data was not publicly available for $ELEC_{ij}$. However, the MECS data reports purchased electricity for each industry in a region but not for each state.[25] Similarly, the ASM reports electricity usage for each state's manufacturing sector, but not for each industry.[26] Theoretically, both datasets measure electricity usage, so they should sum to the same amount in each region. This can be expressed mathematically:

$$\sum_{j=1}^{J}\left(\sum_{i=1}^{I} ELEC_{ij}\right) = \sum_{i=1}^{I}\left(\sum_{j=1}^{J} ELEC_{ij}\right) \tag{6}$$

where the inner summation on the left is the regional purchased electricity use for an industry and it is identified in the MECS. The inner summation on the right is the purchased electricity for all manufacturers in a particular state, and it is is identified in the ASM. Since both the MECS and the ASM are surveys, sampling differences will cause discrepancies. The MECS reported that US manufacturers purchased 854 billion kwh of electricity in 2006 and the ASM, reports 894 billion kwh.[27]

[25] MECS – 2006: Tables 4.1 & 4.2

[26] ASM – 2006: Geographic Area Statistics: Supplemental Statistics for the United States and States

[27]Northeast region	92,174 mkwh (MECS) / 107,073 mkwh (ASM) = 86.1%
Midwest region	273,828 mkwh (MECS) / 267,111 mkwh (ASM) = 102.5%
South region	383,995 mkwh (MECS) / 402,522 mkwh (ASM) = 95.4%
West region	104,188 mkwh (MECS) / 114,334 mkwh (ASM) = 91.1%

We assume that every industry in a particular region and every state in a particular region has a unique parameter. Let θ_j represent the unique parameter for the j[th] industry, and let φ_i represent the unique parameter for the i[th] state. Moreover, we assume that these parameters interact with one another such that $\theta_j \times \varphi_i = \lambda_{ij}$. Under these assumptions,

$$ELEC_{ij} = \lambda_{ij} \times EMP_{ij} \quad (7)$$

$$ELEC_{ij} = \theta_j \times \varphi_i \times EMP_{ij} \quad (8)$$

This critical assumption simplifies the problem down to identifying I + J parameters, not I × J parameters. The I + J parameters are identified by the following constraints:

$$\left(\sum_{i=1}^{I} \theta_j \times \varphi_i \times EMP_{ij} \right) = MECS_j \quad for \;\; j = 1, 2, \ldots, J \quad (9)$$

$$\left(\sum_{j=1}^{J} \theta_j \times \varphi_i \times EMP_{ij} \right) = \widetilde{ASM}_i \quad for \;\; i = 1, 2, \ldots, I \quad (10)$$

Where $MECS_j$ is the total electricity purchased by the j[th] industry according to the MECS, and ASM_i is the total electricity purchased in the i[th] state's manufacturing sector according to the ASM.

The constraints listed in equations 9 and 10 will only be true if equation 6 holds. As we noted earlier, discrepancies exist between the two data sources. Therefore, each state's ASM_i was adjusted to account for the percent difference between the two data sets (see footnote 27).

$$ASM_i \times \left(\frac{\sum_{j=1}^{J} MECS_j}{\sum_{i=1}^{I} ASM_i} \right) = \widetilde{ASM}_i \quad for \;\; i = 1, 2, \dots, I \tag{11}$$

The system of equations implied by equations 9 and 10 were solved to determine θ_j and φ_i parameters for each US region.

Natural Gas Use to Employment Ratios

Next, we estimated the natural gas used at each manufacturing establishment. The MECS data set again provided information on the usage per industry for every region. Unfortunately, we did not have data on the level of natural gas consumption within each state's manufacturing sector. If such data existed, we could apply the previous methodology using $NATG_{ij}$ instead of $ELEC_{ij}$.

However, the State Energy Data System (SEDS) provides total industrial natural gas use and prices in each state. "Industrial" refers to manufacturing, construction, mining, and agriculture. In the detailed methodology that follows, natural gas usage is estimated in each state's mining, construction, and agricultural sector and then subtracted from industrial consumption to identify $NATG_{ij}$.

The Economic Census (EC) provides the total expenditures made in natural gas and manufactured gas for businesses in construction in 2007. We divided these expenditures by the average industrial price of natural gas in each state (obtained from the SEDS) to determine the total natural gas used in the construction sector.[28] For most states, the construction sector accounted for between 2% and 5.5% of industrial natural gas energy use in 2007.

The EC was also used to calculate mining's share of natural gas use. Unlike construction, the EC does not report natural gas purchased separately. Instead, it reports total expenditures for purchased fuels in each state's mining sector.[29] According to a 2004 report published by the Energy Efficiency & Renewable Energy (EERE) office in the Department of Energy, 50% of the total energy from purchased fuels comes from fuel oil, 32% comes from natural gas, 15% comes from coal, and 3% comes from gasoline.[30] Using these proportions and relevant prices, mining's proportion of industrial natural gas usage was between 1% and 5.5% for most states. Exceptions were Nevada, Arizona, West Virginia, Wyoming, North Dakota and Hawaii.

[28] The Economic Census did not disclose natural gas use for some states. For these states, we assumed that construction's share of industrial natural gas use was an average of neighboring states.
[29] http://www1.eere.energy.gov/industry/mining/analysis.html
[30] Fuel oil was proportioned evenly between distillate and residual fuel oil.

For the agricultural sector, the USDA/ERS reports annual fuel and oil expenditures in each state. "Fuel and oil" primarily refers to diesel, LPG, gasoline, and natural gas. The USDA's Farm Production Expenditure report decomposes fuel and oil expenditures by energy source for each agricultural region of the country (USDA/NASS, 2007). These proportions and energy prices in each state were used to estimate agriculture's share of industrial natural gas.[31] We estimated that the sector uses between 0.75% and 2.5% in most states. Exceptionally high proportions were estimated for South Dakota, North Dakota, Nebraska, and Vermont.

Table 13 lists the proportion of industrial-level natural gas consumption we assume for each state's non-manufacturing sector. The estimated natural gas consumption in manufacturing was, on average, 23% larger than reported in the MECS sample. Midwestern states were estimated to consume 1,535 billion btu's of natural gas, while the MECS data estimated this figure to be 1,644 billion btu's. Manufacturing natural gas consumption in the Northeast was estimated to be 400 billion btu's, though the MECS estimated this to be 493 billion btu's. In the South, 3,871 billion btu's were estimated from the process and while the MECS estimates were 3,117 billion. For Western states, natural gas consumption was estimated to be 1,467 billion btu's, whereas the MECS reported a much lower estimate of 656 billion btu's. Since mining and agriculture are relatively large components of the western states' industrial sectors, this is not surprising. We scale each region's natural gas consumption using a formula similar to equation 11.

Using equations similar to (6)-(11) we calculate national consumption per employee ratios (λ_{ij}). These ratios were combined with employment from the Delaware Department of Labor to estimate the electricity and natural gas of each Delaware manufacturing establishment.

[31] Each state was assumed to make the same proportion of expenditures as its region. The regional composition and the industrial energy prices from the SEDS and EIA were used to estimate the average price of energy in the agricultural sector. Total energy expenditures were divided by this average price to estimate the total quantity of fuel and oil. Finally, the regional energy composition determined how much natural gas contributed to fuel and oil.

Table 13 Estimated Proportion of Non-Manufacturing Natural Gas Consumption in the Industrial Sector

	Construction	Mining	Agriculture	Total
Alabama	3.2%	2.1%	0.3%	5.7%
Arizona	0.5%	1.0%	6.8%	8.4%
Alaska	9.6%	36.1%	n.a.	45.7%
Arkansas	1.5%	1.8%	1.6%	4.9%
California	1.8%	2.5%	1.4%	5.7%
Colorado	1.2%	4.5%	1.1%	6.8%
Connecticut	3.1%	1.2%	0.9%	5.2%
Delaware	4.1%	0.4%	1.0%	5.5%
Florida	5.3%	2.8%	1.0%	9.0%
Georgia	3.6%	3.5%	0.6%	7.8%
Hawaii	34.5%	14.1%	n.a.	48.6%
Idaho	3.9%	6.2%	7.8%	17.9%
Illinois	2.7%	1.5%	0.8%	5.0%
Indiana	1.2%	1.7%	0.5%	3.4%
Iowa	1.5%	1.0%	2.5%	5.0%
Kansas	2.8%	2.1%	4.8%	9.7%
Kentucky	2.6%	5.3%	1.5%	9.3%
Louisiana	0.8%	1.3%	0.1%	2.1%
Maine	9.9%	1.1%	5.4%	16.4%
Maryland	6.4%	3.8%	1.8%	12.0%
Massachusetts	16.9%	0.7%	0.4%	18.0%
Michigan	2.0%	2.2%	0.5%	4.7%
Minnesota	3.5%	7.2%	2.6%	13.3%
Mississippi	1.5%	1.3%	0.8%	3.5%
Missouri	1.5%	1.9%	1.7%	5.1%
Montana	2.2%	8.0%	5.0%	15.1%
Nebraska	2.0%	0.7%	11.6%	14.2%
Nevada	6.0%	79.4%	1.5%	87.0%
New Hampshire	6.0%	0.9%	1.3%	8.3%
New Jersey	4.3%	0.9%	0.6%	5.8%
New Mexico	0.8%	7.8%	1.1%	9.8%
New York	7.9%	2.1%	2.1%	12.0%
North Carolina	5.1%	1.8%	2.7%	9.6%
North Dakota	3.8%	18.6%	19.9%	42.3%
Ohio	1.0%	1.1%	0.3%	2.3%
Oklahoma	0.8%	5.3%	1.1%	7.2%
Oregon	3.3%	0.8%	2.5%	6.6%
Pennsylvania	1.7%	3.2%	0.8%	5.7%
Rhode Island	4.5%	1.5%	0.3%	6.3%
South Carolina	2.7%	0.8%	0.5%	4.0%
South Dakota	5.5%	3.1%	24.1%	32.7%
Tennessee	2.9%	1.5%	1.4%	5.8%
Texas	0.8%	2.8%	0.8%	4.4%
Utah	5.5%	8.8%	1.6%	15.9%
Vermont	9.0%	5.2%	10.0%	24.1%
Virginia	4.6%	5.9%	1.6%	12.1%
Washington	4.2%	2.1%	3.8%	10.1%
West Virginia	3.3%	24.1%	0.7%	28.1%
Wisconsin	2.6%	1.4%	1.3%	5.3%
Wyoming	0.7%	20.7%	0.9%	22.3%

Deriving Other Characteristics for Delaware Manufacturers

Next, we estimated which manufacturers do not use natural gas and which ones use other sources of energy. Again, establishment level data would be ideal, but was not available. Therefore, the predictive model uses the naïve probability that an establishment uses natural gas based on its industrial classification.[32] For example, the MECS reports that 172 out of 185 establishments in the Aluminum and Die-Casting Foundries industry (NAICS 331521) use natural gas. Thus, any Delaware establishment in this industry is assumed to have a 7% chance of not using natural gas.

Our predictions also used naïve industry proportions to estimate whether a company uses an energy source other than electricity or natural gas (*OTHR*). The MECS reports the number of establishments using residual fuel oil, distillate fuel oil, LPG and NGL, coal, coke and breeze, and other sources for 2006. The naïve industry proportion of firms using each energy source was calculated first, and the highest proportion was chosen as our imputed estimate.[33] We also adopt the average floor space per establishment from the MECS Table 9.1.[34] Finally, we assume that there is no change in electricity and natural gas prices for 2010.

These assumptions were used to derive characteristics of Delaware manufacturers. In turn , those characteristics were used to predict total implementation costs. Next we describe how costs were converted into potential employment.

[32] MECS Table 3.4: Number of Establishments Using Energy Consumed as a Fuel
[33] For example, 62 of the 185 establishments in the Aluminum and Die-Casting Foundries industry used LPG and 32 used some other energy source. The remaining energy sources were used less frequently in this industry. Since 34% of establishments used LPG and 17% used another energy source, we assumed that OTHR equals 0.34 for any establishment in that industry.
[34] At the time this report was written, the latest figures are from 2002.

Step 3

Converting Implementation Costs to Employment

The two previous steps detail the methods used to predict the potential energy efficient expenditures for each manufacturer in Delaware. This section describes the methodology we use to estimate the employment from those expenditures. This conversion depends fundamentally on how the implementation costs are spent. On one extreme, the expenditures could reflect repairs, modifications, maintenance and other services that require relatively high labor costs and low capital costs. At the other extreme, the expenditures could primarily reflect capital purchases. Both situations are modeled.

The labor-intensive situation assumes that all of the expenditures will be spent on contract labor from one of the industries listed in "Building Equipment Contractors" (NAICS 238xxx). Potential expenditures on heat recovery, process piping, equipment insulation, and space conditioning are assumed to be performed by plumbing, heating, and air conditioning contractors. Expenditures in electrical power, motors, lights, and air compressors are treated as sales to the electrical and other wiring installation contractors (NAICS 238210). Expenditures in other facility improvements are assumed to come from a composite group made up of drywall and insulation contractors (NAICS 238310), glass and glazing contractors (NAICS 238150), roofing contractors (NAICS 238160), and other building finishing contractors (NAICS 238390). We ignore the recommendations related to behavioral and administrative reasons.

By treating all implementation costs as sales, we implicitly assume that the necessary capital is purchased by contractors as inputs to their service they perform. Therefore, capital purchases are assumed to occur during a second round of spending. Of course, that second round of spending will require a third round of spending.[35]

[35] The cumulative economic effect from these multiple rounds of spending is captured by the multiplier effect.

We estimate the direct employment needs from the first round of spending using sales to employment ratios for different equipment contractors. For example, if 5 employees are typically needed for every $1 million in sales to the HVAC contractors, $10 million in sales are assumed to require 50 jobs. The estimate relies on the assumption of fixed technology, which is standard in regional modeling.

The second method assumes that energy efficient investments will spend a majority of its costs on capital equipment. In this framework, manufacturing establishments purchase capital and employment directly, so expenditures would be divided between wages and capital purchases. Both types of payments will impact employment differently.

We assume that the skilled labor needed to do these recommendations is still represented by workers in the Building Equipment Contractors industry (NAICS 2382xx). However, the expenditures are now considered wage payments instead of sales, and wages are assumed to have a 35% premium for benefits. The potential employment from labor expenditures was obtained by dividing wage payments by the average wage plus benefit premium.

Money spent on capital purchases will impact employment of those companies that make the equipment. However, since Delaware's manufacturing sector is relatively small, it was not appropriate to assume that capital would be purchased from other Delaware manufacturers. Instead, we assumed that Delaware wholesalers would supply the capital equipement. The 2007 NAICS index of goods and services was used to identify seven relevant wholesale industries. Table 14 shows which wholesale industries were assumed to supply capital for each type of recommendation.

Table 14 Wholesale Suppliers of Capital Equipment, by Recommendation Type[36]

Major Classification	Skill Class	Primary Wholesale Industry
HVAC	Furnaces, Heating, Boilers	423830
	Heat Recovery	423830
	Steam, hot water, process piping, refrigeration, and cooling	423720 & 423740
	Space heating, ventilation, and conditioning	423730
	Insulating Machines, Equipment, and Piping	423830
Electrical	Motors and other electrical equipment	423610
	Air Compressors	423830
	Lights	423610
	Electrical Power	423610
Other facility improvements	Windows, Doors, Roofs, Walls, Landscape	423310 & 423330
Employee behavior / administrative	Employee behavior / administrative	n.a.

The two wholesale industries most likely to be affected were assumed to be the Electrical Apparatus and Equip., Wiring Supplies, and Related Equip. Merchant Wholesalers (NAICS 423610) and the Industrial Machinery and Equipment Merchant Wholesalers (NAICS 423830). These particular wholesalers often employ staff with the technical skills needed to install, repair, and maintain the equipment.

36

- 423310 Lumber, Plywood, Millwork, and Wood Panel Wholesalers
- 423330 Roofing, Siding, and Insulation Material Wholesalers
- 423610 Electrical Apparatus and Equip., Wiring Supplies, and Related Equip. Wholesalers
- 423720 Plumbing and Heating Equipment and Supplies (Hydronics) Wholesalers
- 423730 Warm Air Heating and Air-Conditioning Equipment and Supplies Wholesalers
- 423740 Refrigeration Equipment and Supplies Wholesalers
- 423830 Industrial Machinery and Equipment Wholesalers

Deriving Capital and Labor Expenditures

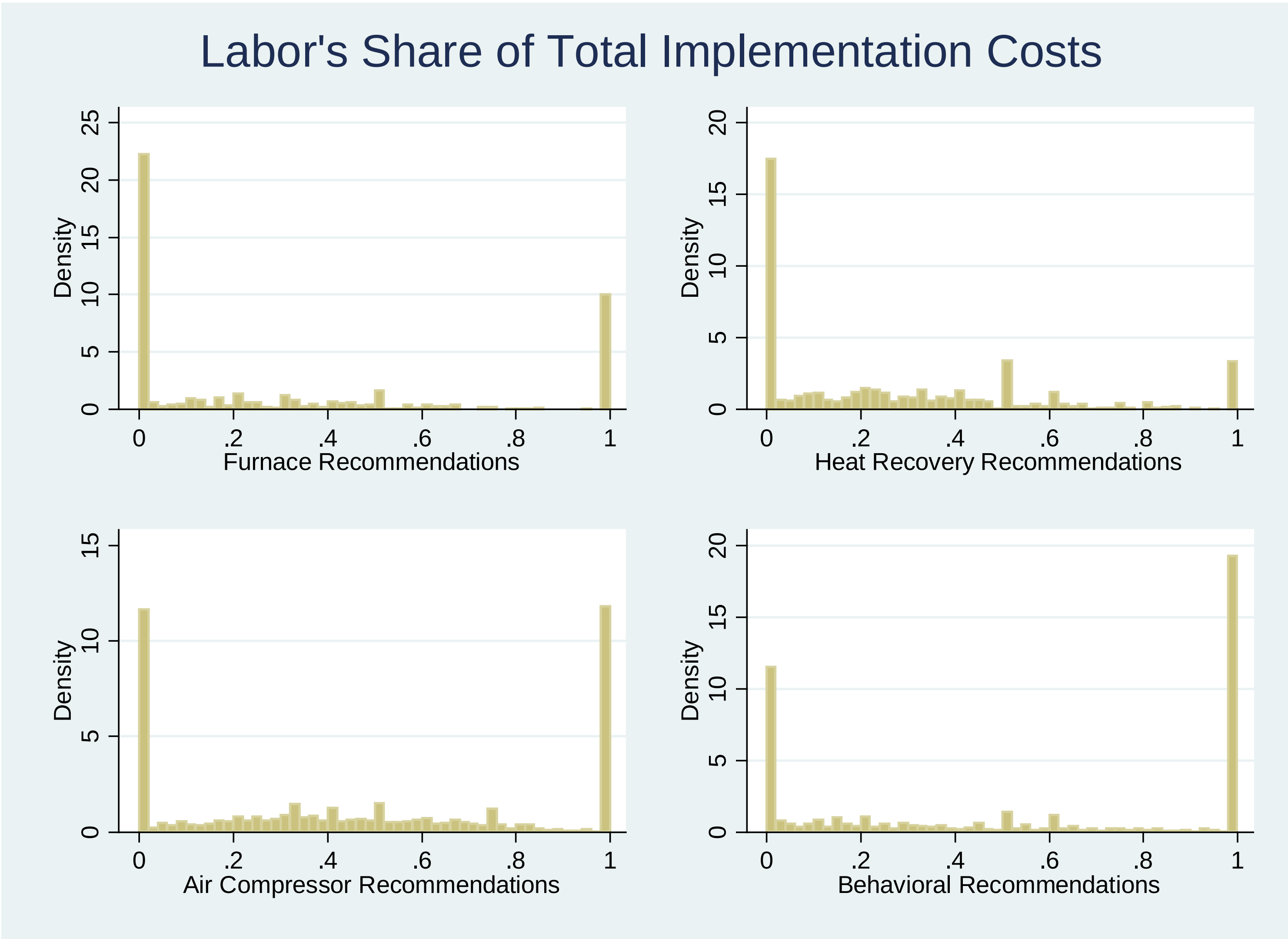
Under the capital intensive assumption, implementation costs must be divided between capital and labor expenditures. Since 2003, the IACs database reports capital and material implementation costs separately from other implementation costs. We assume that labor is the primary factor in the other implementation costs.

Figure 5 is a histogram showing labor's share of total implementation costs for four recommendation groups with paybacks less than 1.4 years. The most striking feature of these histograms is the dichotomous nature of these reported expenditures. Most firms either receive recommendations requiring just labor costs or recommendations requiring just capital costs. Since we expect almost every recommendation should have some positive labor cost, the histograms likely reveal classification error.[37] The problem is likely made worse by industrial equipment manufacturers and wholesalers that bundle the cost of service and equipment together. To address this issue, we derived the probability that the implementation costs would be classified as either labor only or capital only.

Figure 6 plots labor's share of implementation costs against the size of total implementation costs. Each plot corresponds to recommendations in a particular group that have paybacks between 0 and 1.4 years. The observations at 1 and 0 indicate those assessments that had all implementation costs going entirely to labor or entirely to capital. Although many "labor only" recommendations have higher implementation costs than some "capital only" recommendations, the share generally falls as implementation costs increase. The downward sloping line in each plot corresponds to an estimated relationship between the labor's share of implementation costs and the total size of those implementation costs.

[37] As an anecdotal observation, one manufacturer received a $750,000 capital-only recommendation to replace a furnace. Of course, labor is necessary to install the furnace, so the observation inaccurately records zero labor cost.

Figure 5 Percent of Total Implementation Costs attributed to Labor for Recommendations with Paybacks≤ 1.4 Years, Select Recommendatio ns



• Source: IAC Database

To generate the downward sloping relationships plotted in Figure 5, labor's share of total implementation costs is interpreted as a probability that the establishment would have been classified as labor-only recommendations. For example, an assessment with $25 going to labor and $75 going to capital was assumed to have a 25% chance of being classified as a labor-only recommendation. Next, 5,000 data sets were generated by randomly assigning each establishment as either a capital-only or labor-only designation. A probit model fit each random set of (binary) outcomes on the natural logarithm of total implementation costs, and the coefficients were recorded. The coefficient averages are shown in Table 15, and the average of these coefficients plotted the relationships in Figure 6 and Figure 7.[38],[39]

[38] We manually calculate the two-tailed tests of significance from the simulated distribution of coefficients.
[39] Figure 7 shows the estimated relationships for recommendations with paybacks between 1.4 and 5 years.

Figure 6 Labor's Proportion of Total Implementation Costs (2008 $), Recommendations with 0 < Payback ≤ 1.4

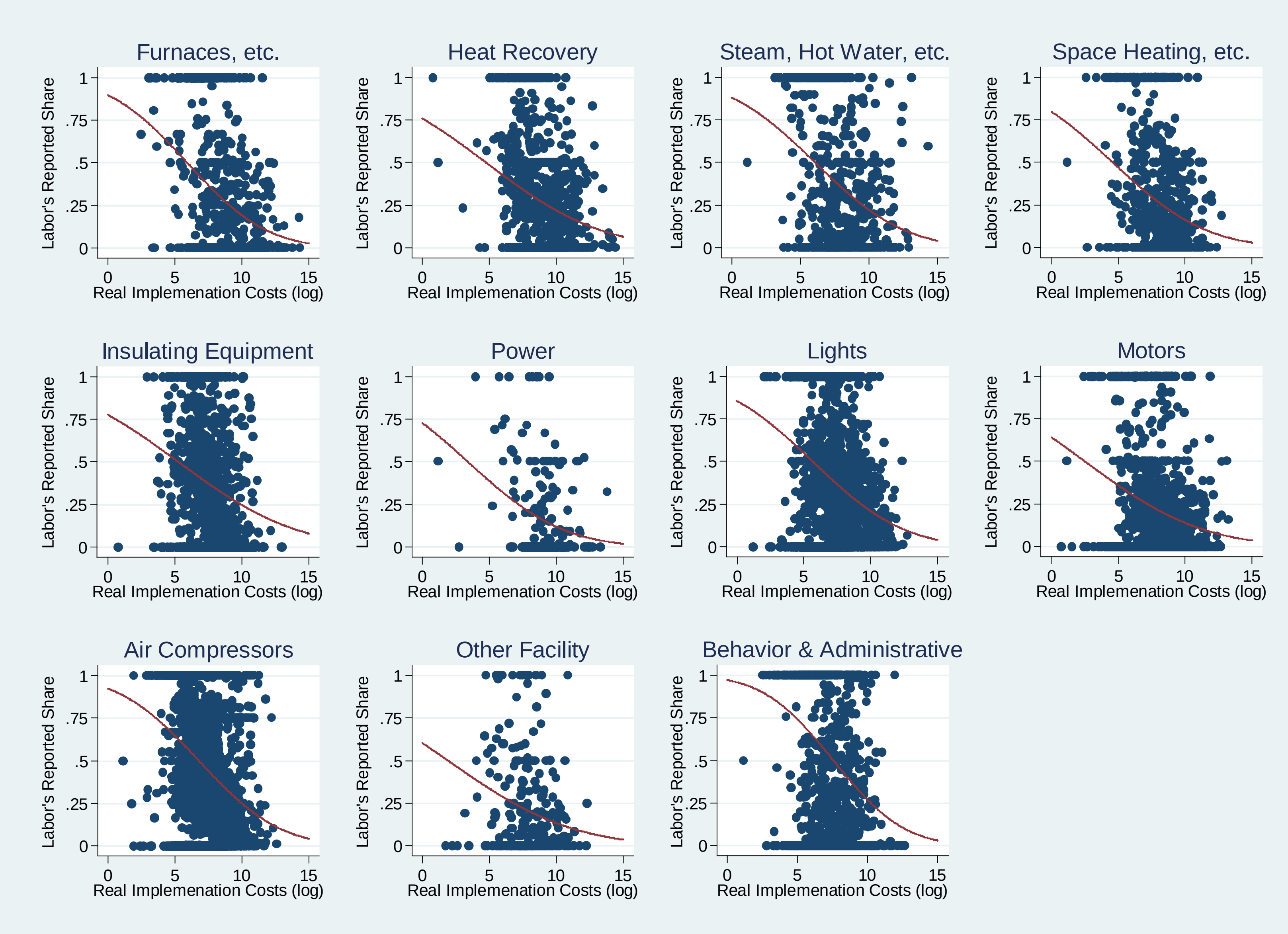


Figure 7 Labor's Proportion of Total Implementation Costs (2008 $), Recommendations with 1.4 < Payback≤ 5

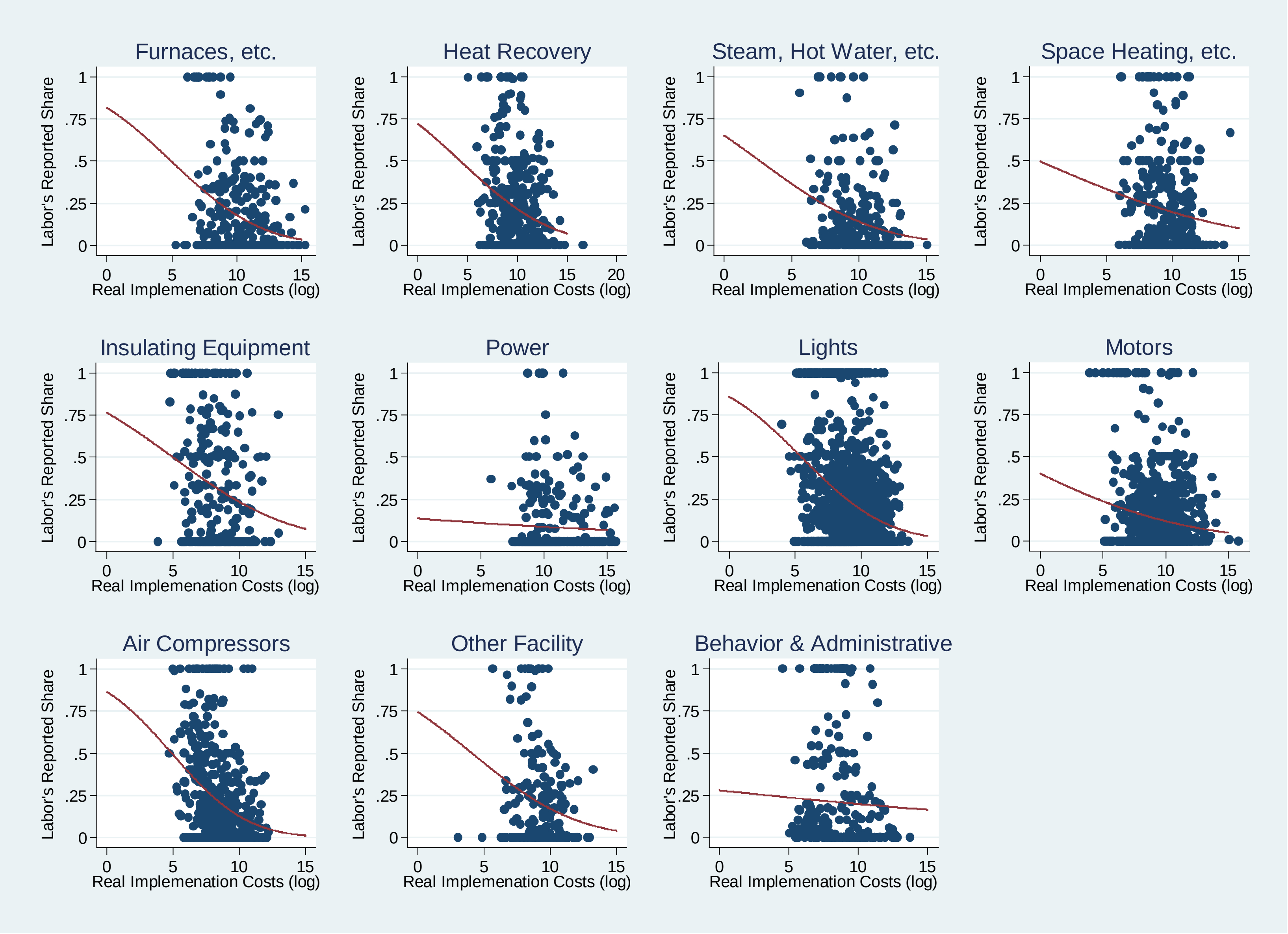


Table 15 Average Probit Coefficients between Labor's Share of Implementation Costs and the Magnitude of Implementation Costs

	0 < Payback ≤ 1.4		1.4 < Payback ≤ 5	
	Constant	Slope	Constant	Slope
Furnaces, etc.	1.2603***	-0.2134***	0.9011***	-0.1819***
Heat Recovery	0.7011***	-0.1477***	0.5838*	-0.1372***
Steam, Hot Water, etc.	1.1782***	-0.1948***	0.3879	-0.1469***
Space Heating, etc.	0.8327***	-0.1818***	-0.0077	-0.0849**
Insulating Equipment	0.7632***	-0.1449***	0.7230**	-0.1443***
Power	0.6042	-0.1787***	-1.0943**	-0.0264
Motors	0.3625***	-0.1450***	-0.2510	-0.0930***
Air Compressors	1.4256***	-0.2107***	1.0945***	-0.2243***
Lights	1.0600***	-0.1873***	1.0729***	-0.1967***
Other Facility	0.2592	-0.1373***	0.6537	-0.1610***
Behavior & Administrative	1.9136***	-0.2534	-0.5846**	-0.0264

legend: * p<.1; ** p<.05; *** p<.01

The coefficients in Table 15 are used to estimate the probability that all labor costs are attributable to labor. The formula to make that calculation is:

$$Pr[D_L = 1] = \Phi(CON_S + SLP_S \times E[IC_s | D_s = 1 \ ]) \qquad (12)$$

Where D_L indicates whether the assessment resulted only in labor recommendations ($D_L = 1$), and the constant (CON_S) and slope (SLP_S) coefficients are reported in Table 15 for each recommendation group, s. Multiplying the probability in Equation 12 by the expected implementation costs yields the portion of these costs attributable to labor.

The implementation costs attributable to labor ($IC_{S,L}$) and capital ($IC_{S,K}$) are estimated by the following equations:[40]

$$E\left[IC_{s,L}\right] = Pr[D_L = 1] \times Pr[D_s = 1] \times E[IC_s \mid D_s = 1] \qquad (13)$$

$$E\left[IC_{s,K}\right] = (1 - Pr[D_L = 1]) \times Pr[D_s = 1] \times E[IC_s \mid D_s = 1] \qquad (14)$$

[40] See equations 2 and 3 for definitions.

Results

Step 1

Modeling Implementation Costs

In this section, we discuss the econometric equations of implementing the implementation costs. The first stage of the hurdle model estimates the probability that a firm receives a particular recommendation. Equation 4 can be rewritten as the following:

$$D_s^* = \beta_0 + ELEC'\beta_1 + NATG'\beta_2 + \mathrm{XNAT}'\beta_3 + OTHR'\beta_4 + EMPL'\beta_5 + AREA'\beta_6 + \Delta PEC'\beta_7 + \Delta PNG'\beta_8 + \boldsymbol{D3xx'\delta} + \boldsymbol{IACxx'\zeta} + \boldsymbol{20xx'\eta} + u \qquad (15)$$

Where, D_s^* indicates whether a recommendation with positive implementation costs was made, and the bolded variables represent vectors of industry, IAC, and time effects respectively.

Table 16 reports the econometric estimates of the probability that an assessment received at least one recommendation with a payback less than 1.4 years. The omitted group includes food manufacturers assessed in 2000 (FY). χ^2 tests of joint significance for IAC effects are statistically significant in each specification.[41,42]

[41] There is no practical difference between estimating a means-differenced fixed effects model and an OLS model with dummy fixed effects, but the analogy does not hold with binary regression techniques. Katz (2001) shows Monte Carlo evidence that bias of the unconditional fixed effects model is negligible when there are 16 or more observations per group. In our case, the minimum number of observations is 20.

[42] Some IAC centers did not vary whether certain types of recommendations were made. These centers were excluded from the sample, causing the sample size to decrease modestly in some specifications. This had virtually no effect on the estimated coefficients from the unreported conditional fixed effects estimates.

Table 16 Probit Estimates for the Probability of Receiving at least one “More Profitable” Recommendation, 2000-2010 (FY)

	HVAC Recommendations					Electrical Recommendations				Other Recommendations	
Variables	Furnaces, etc.	Heat Recovery	Steam, hot water, etc.	Space heating, etc.	Insulating, Equipment,	Electrical Power	Motors	Air Compressors	Lights	Other Facility	Behavior & Admin.
ELEC	-0.0281	0.0109	0.0891**	-0.0111	0.1139***	0.0717**	0.1865***	0.0164	0.0372	-0.0669*	0.0069
NATG	0.1904***	0.1580***	0.1213***	-0.0114	0.1449***	-0.0424**	0.0121	-0.0401**	-0.0181	-0.0031	-0.0219
OTHR	0.5629***	0.4905***	0.1888*	0.0819	0.3412***	-0.1447	0.0432	-0.0849	-0.2429**	-0.0402	-0.0833
NATX	1.2501***	0.9246***	0.7305***	-0.1259	1.0075***	-0.4133*	0.0368	-0.4162**	-0.0816	-0.0005	-0.1683
EMPL	-0.0496	0.0107	0.0166	0.0303	-0.1899***	0.0300	-0.0959**	0.1559***	0.0694**	0.1101**	0.0855**
AREA	0.0322	-0.0409	-0.0299	0.0482	-0.0790**	0.0289	-0.0144	0.0218	-0.0432	-0.0020	-0.0707**
ΔPEC	0.2457	0.4681**	-0.1389	0.1574	0.0637	0.0215	0.2283	0.2750	0.4509**	0.4533	0.3271
ΔPNG	0.1892	0.1944	-0.2407*	0.0026	0.1524	0.1528	-0.0167	0.0154	-0.0469	0.3191*	0.1582
D312	0.1274	-0.0360	0.0628	0.0086	-0.1160	-0.0166	0.3353**	0.1714	-0.0220	-1.3573**	0.1824
D313	-0.2404	0.0226	0.0163	0.1248	0.0168	-0.5658	0.1504	0.1128	-0.1245	-0.8576*	-0.0471
D314	0.0277	-0.2872	-0.7681**	0.1547	-0.1226	0.0537	-0.1612	0.3741	-0.3367	-0.4629	0.1583
D315_316	-0.0606	-0.3962*	-0.3462	0.5427**	0.0103		-0.1281	-0.0262	0.0637	0.2698	0.1430
D321	-0.5122***	-0.2361*	-0.5386***	-0.1153	-0.1998*	0.0558	0.1454	0.5691***	-0.2919**	-0.6123**	0.3395**
D322	-0.0950	0.1449	0.0887	0.2730**	-0.1311	0.1549	0.0926	0.3126**	-0.1258	-0.1563	0.1990*
D323	-0.5763***	-0.2540	-0.4150**	0.7073***	-0.7510***	-0.3387	0.1195	0.2177	0.1678	-0.1779	0.2020
D324	0.3810**	-0.2773	0.0099	-0.0016	0.4601**	0.2638	0.0439	-0.2728	0.1915	-0.9039**	0.4274**
D325	-0.0691	-0.2772**	0.1396	0.0695	-0.1997**	0.0174	-0.0434	0.0169	-0.1696*	-0.4828**	0.1362
D326	-0.2743**	-0.2389**	-0.1733*	0.3131**	0.1885**	0.0255	0.0572	0.3026**	-0.0617	-0.1828	0.3027**
D327	-0.1966	-0.2567*	-0.6625***	0.1047	-0.2416**	-0.1905	0.0649	0.2665**	-0.0266	-0.3184	0.2904**
D331	-0.1864*	-0.0435	-0.7192***	0.3203**	-0.2140**	-0.0814	-0.1314	0.4393***	-0.1093	-0.2242	0.1842*
D332	-0.2308**	-0.1012	-0.6324***	0.4052***	-0.1033	-0.0123	-0.0588	0.4239***	0.0069	-0.1223	0.2502**
D333	-0.3920***	-0.2814**	-0.6111***	0.5365***	-0.4382***	0.1308	-0.0681	0.3779***	-0.0185	0.0611	0.3114**
D334	-0.1323	-0.4111**	-0.3701**	0.7109***	-0.1583	0.0250	-0.1063	-0.0923	-0.0083	-0.2115	0.3336**
D335	-0.3481**	-0.0540	-0.4464**	0.5532***	-0.3312**	-0.3307	-0.0781	0.1219	-0.0645	0.1510	0.4594**
D336	-0.3308**	-0.0081	-0.6167***	0.2465**	-0.4542***	0.0176	-0.1485	0.1990*	-0.0314	-0.0013	0.4778***
D337	-0.4226**	-0.1649	-0.9652***	0.2915*	-0.5310**	0.1841	-0.0555	0.6109***	-0.1184	0.0858	0.3356**
D339	-0.1884	-0.1760	-0.3912**	0.2503	0.0453	0.1224	0.0948	-0.0665	0.2166*	-0.2660	0.3653**
2001	0.0064	0.1106	0.1940	0.0491	0.2869**	0.1564	0.2641**	0.0454	-0.0256	0.0724	0.0718
2002	0.1490	0.1964*	0.0820	0.1086	0.3422**	0.2971*	0.2718**	0.2217**	0.1194	0.3621**	0.0820
2003	0.2719**	0.0860	0.3793**	0.2162**	0.3590***	-0.0457	0.4305***	0.2798**	0.2861**	0.0899	0.1425
2004	0.1914*	0.3075**	0.4462***	0.2029**	0.5072***	0.0612	0.5460***	0.5188***	0.1094	0.1153	0.2604**
2005	0.1613	0.1504	0.3876**	0.3079**	0.3489***	0.0923	0.4235***	0.5563***	0.1026	0.0634	0.2052**
2006	0.3035**	0.2777**	0.4473***	0.2111*	0.5781***	0.1493	0.2202**	0.3504***	0.0519	0.2066	0.0726
2007	0.3113**	0.4416***	0.4195**	0.3581**	0.5074***	-0.0813	0.2897**	0.3183**	0.1974*	0.4846**	0.3040**
2008	0.1334	0.3887***	0.4693***	0.2688**	0.5422***	0.0662	0.3509***	0.3596***	0.1767*	0.4006**	0.2602**
2009	0.0969	0.3909**	0.3215**	0.5601***	0.5171***	-0.1416	0.1582	0.4029**	0.2288**	0.4237**	0.2374*
2010	-0.2118	0.2590	0.0686	0.2481	0.4521**		0.2111	0.4058*	0.1186	0.6920**	0.0566
IACxx χ^2	204.0***	412.9***	189.9***	319.0***	249.3***	186.7***	493.9***	451.7***	638.2***	264.8***	588.3***
(df)	(40)	(37)	(36)	(37)	(36)	(34)	(40)	(41)	(41)	(36)	(40)
Constant	-2.0669***	-0.9617**	-1.7653***	-1.7887***	-0.7715**	-2.2880***	-1.1523***	0.2489	0.3265	-1.2088**	0.8538**
N	5058	4997	4978	5002	4966	4551	5058	5070	5070	4949	5055
Pseudo R^2	0.141	0.174	0.174	0.111	0.135	0.103	0.114	0.132	0.131	0.154	0.128

legend: * p<.1; ** p<.05; *** p<.01

Table 17 Probit Estimates for the Probability of Receiving at least one "Less Profitable" Recommendation, 2000-2010 (FY)

	HVAC Recommendations					Electrical Recommendations				Other Recommendations	
Variables	Furnaces, etc.	Heat Recovery	Steam, hot water, etc.	Space heating, etc.	Insulating, Equipment,	Electrical Power	Motors	Air Compressors	Lights	Other Facility	Behavior & Admin.
ELEC	-0.0469	-0.0478	0.1124**	-0.1217***	-0.0660*	0.0859**	0.1896***	-0.0529*	-0.0263	-0.0957**	0.0237
NATG	0.0859***	0.1598***	0.0062	-0.0347*	0.0706***	0.0270	-0.0099	-0.0480**	-0.0577***	-0.0314	-0.0467**
OTHR	0.4863***	0.2517**	0.0150	-0.1035	0.3638***	-0.0142	-0.0858	-0.0768	-0.1015	0.0353	-0.0214
NATX	0.3676*	1.1294***	0.0411	-0.4699**	0.3068	0.3555*	-0.0185	-0.3281*	-0.5143***	-0.3409	-0.3978**
EMPL	0.0090	0.0457	0.0171	0.0727	0.0032	-0.1067**	-0.0455	0.0604	0.0522*	0.0904*	0.0031
AREA	0.0378	-0.0625*	-0.0022	0.0395	-0.0312	0.0873**	-0.0287	-0.0039	-0.0009	-0.0175	0.0384
ΔPEC	0.0691	-0.7097**	0.0664	-0.1221	0.1156	-0.2397	0.1474	-0.0040	0.2617	0.2507	0.4365
ΔPNG	0.0786	-0.1365	-0.2485	-0.0092	0.1881	-0.2872*	-0.0068	0.0511	0.1538	-0.2230	-0.1699
D312	-0.0011	0.2155	0.1500	-0.6083*	-0.0819	-0.0771	-0.3018*	-0.0554	-0.4542**	0.3763*	0.3102
D313	0.1475	-0.0842	-1.1266***	0.0772	-0.0992	-0.2464	-0.2012	-0.0001	0.0541	-0.0653	-0.3516
D314	-0.2736	-0.4124	-0.7963**	0.5576**	0.2528	0.4349	-0.2757	-0.0822	0.5366**	-0.0970	0.1620
D315_316	0.1182	0.2154	-0.6179*	0.4235*	-0.0467	0.3637	-0.3162	0.0335	-0.1820	-0.1069	0.0486
D321	-0.2262	-0.0939	-0.6847***	0.0111	-0.1464	0.2042	0.2150*	-0.0399	-0.0638	-0.3849*	0.2721*
D322	-0.1656	-0.1939	-0.4835**	0.3670**	-0.5023**	0.2689**	-0.1291	0.0736	0.0153	0.0104	0.1089
D323	-0.2365	-0.0654	-0.1055	0.4225**	-0.4000*	-0.3213	-0.0625	0.0208	-0.0328	0.1258	-0.0274
D324	-0.3526	0.1293	0.1293	-0.4441	-0.3359	-0.0979	0.1528	-0.4070	-0.1348		-0.6713
D325	-0.0986	0.0621	0.0069	0.0982	-0.2707**	-0.0483	-0.0853	0.0504	-0.1464	0.2078	-0.1003
D326	-0.2076*	-0.2917**	-0.2590**	0.2646*	-0.2802**	-0.0148	0.1305	0.1649	-0.0778	-0.0536	0.2180*
D327	-0.2124	-0.1061	-0.7730***	0.2850	-0.2016	0.3300**	-0.0107	0.2056	-0.0237	-0.0811	0.2549
D331	-0.0480	0.0944	-0.6344***	0.2923**	-0.0641	-0.1189	0.0760	0.1304	-0.1774*	0.2846*	-0.0504
D332	-0.1951*	-0.0333	-0.5716***	0.2878**	-0.2726**	0.0113	-0.1816**	0.1584	-0.0911	0.2829**	0.0704
D333	-0.4168**	-0.1077	-0.3013**	0.4156**	-0.4517**	0.0160	-0.2273**	0.2628**	-0.0646	0.2137	-0.0284
D334	-0.0167	0.0346	-0.1633	0.3707**	-0.4607**	-0.0195	-0.2548**	-0.0856	-0.0419	0.0975	-0.0035
D335	-0.1298	0.0283	-0.2582	0.3841**	-0.5267**	-0.0223	-0.1901	0.1884	-0.0942	-0.0758	0.1208
D336	-0.3776**	-0.2608*	-0.6110***	0.2790*	-0.1347	-0.2520	-0.1904*	0.1706	-0.0228	0.3440**	-0.0978
D337	-0.5236**	0.1673	-0.7323**	0.2448	-0.2842	0.1908	0.0564	0.1466	-0.1400	0.3902**	0.1215
D339	0.1071	-0.1598	-0.3904*	0.1360	-0.3449*	-0.1281	-0.1038	-0.0164	-0.0811	-0.2882	-0.0368
2001	-0.0318	-0.1097	-0.1641	0.1119	0.0466	0.1103	0.0569	0.0032	0.0987	0.2290*	-0.1036
2002	-0.0175	-0.0424	-0.3939**	0.1466	0.1309	-0.0133	0.1612	0.0170	0.3192**	-0.1317	-0.1422
2003	0.0351	0.0659	-0.2557*	0.2250*	0.2781**	-0.1325	0.3104**	0.1683	0.4525***	0.0022	-0.2564*
2004	0.1088	0.1073	-0.1458	0.2399**	-0.0559	-0.1940	0.1531	0.1684	0.4377***	-0.1186	-0.2215*
2005	-0.0030	0.0670	0.0308	0.0959	-0.1308	-0.1175	0.1778*	0.3390**	0.4836***	0.0306	0.0290
2006	-0.0889	0.0379	-0.0226	0.0788	0.0422	-0.0549	0.2500**	0.2350**	0.4822***	-0.0499	-0.0459
2007	0.1281	0.1400	-0.1929	0.2498*	-0.2314	-0.2067	0.1681	0.1818	0.7180***	0.3101*	0.0976
2008	-0.0030	0.0717	-0.1880	0.4173**	-0.0844	-0.1630	0.2276**	0.2310*	0.7840***	0.3048*	0.0357
2009	0.0685	0.0907	-0.0002	0.3273**	0.0398	-0.4695**	0.1966	0.0993	0.7648***	0.2568	0.1491
2010	0.3075	0.1428	-0.5814	0.3329	0.1894	0.1968	0.0599	0.3935*	0.8370***	0.6183**	0.2463
IACxx χ^2	189.9***	157.8***	138.7***	207.6***	109.3***	318.0***	569.2***	177.1***	807.3***	121.0***	251.3***
(df)	(35)	(37)	(32)	(35)	(38)	(34)	(39)	(37)	(41)	(35)	(35)
Constant	-2.1997***	-1.5089***	-1.6296***	-0.8208**	-1.1854**	-3.0734***	-2.5243***	-0.5452	0.2076	-0.8335*	-2.3679***
N	4835	4893	4883	4939	5016	4683	5033	4991	5070	4874	4915
Pseudo R^2	0.112	0.107	0.132	0.110	0.089	0.132	0.140	0.063	0.149	0.102	0.119

legend: * p<.1; ** p<.05; *** p<.01

Analogous to the R^2 measures of least squares regression, the pseudo-R^2 measure indicates how well the model fits the data.[43] These goodness of fit measures range between 0.11 and 0.17, which is not surprising given the inherent heterogeneity of cross-section data.

Though the probit models listed in Table 16 are not causal, we do gain confidence that many of our prior expectations are met. For example, the more a firm uses natural gas, the more likely it is to have a recommendation made in the HVAC skill classes. Similarly, lighting recommendations are more likely to be made after the price of electricity increases. In addition, the more electricity a firm consumes, the more likely it was to receive positive recommendations in motors and electrical power.

Table 17 lists the probit results for the recommendations with paybacks greater than 1.4 years but less than 5 years. The signs and significance of these coefficients are similar to the previous results, though the magnitudes are not directly comparable. We use the results from Table 16 and Table 17 to form expected probabilities over which manufacturing establishments receive positive recommendations.

[43] Pseudo R^2 is calculated as the $1-(LL_{model})/LL_{naive}$, where LL_{model} represents the log likelihood of the fully parameterized model, and LL_{naive} represents the log likelihood of a model with just the constant.

Next we report the econometric results of the second step of the hurdle model. The step predicts the implementation costs of a particular recommendation per assessment, conditional on receiving a recommendation with positive implementation costs. We assumed the same specification as in the previous section:

$$IC_s = \gamma_0 + ELEC'\gamma_1 + NATG'\gamma_2 + \mathrm{XNAT}'\gamma_3 + OTHR'\gamma_4 + EMPL'\gamma_5 + AREA'\gamma_6 + \Delta PEC'\gamma_7 + \Delta PNG'\gamma_8 + \boldsymbol{D3xx}'\widetilde{\widetilde{\boldsymbol{\delta}}} + \boldsymbol{IACxx}'\widetilde{\widetilde{\boldsymbol{\zeta}}} + \boldsymbol{20xx}'\widetilde{\boldsymbol{\eta}} + u \tag{16}$$

Where IC_s is the sum of implementation costs for skill class ‘s’. The equation is estimated using a standard fixed effects model.

Table 18 shows the regression estimates for the recommendations that have a payback less than 1.4 years. As expected, the quantity and type of energy a firm uses is a very important predictor of the potential expenditures. In general, the more electricity and natural gas a firm uses, the greater its potential costs will be. However, firms that do not use any natural gas also have substantially higher recommended expenditures in the area of furnaces and heat recovery. The employee and plant size variables are significant predictors for lights and air compressors. The industry and time specific effects are significant for most recommendations. The adjusted R^2 measures range from a low of 0.16 to a high of 0.44. These fits are quite good, considering again the cross-sectional nature of the data and its limited specification.

Table 18 Regression Estimates for the Sum of Implementation Costs for "More Profitable" Recommendations, 2000-2010 (FY)

	HVAC Recommendations					Electrical Recommendations				Other Recommendations	
Variables	Furnaces, etc.	Heat Recovery	Steam, hot water, etc.	Space heating, etc.	Insulating, Equipment,	Electrical Power	Motors	Air Compressors	Lights	Other Facility	Behavior & Admin.
ELEC	0.3035***	0.3478***	0.3434***	0.1207*	0.2220***	0.3750***	0.5378***	0.2523***	0.2526***	0.0719	0.2067***
NATG	0.1617***	0.3963***	0.0405	0.0176	0.1301***	0.1089**	0.0470*	-0.0080	-0.0256	0.1813**	0.0269
OTHR	-0.3814*	0.4024**	0.0543	0.0334	0.5212***	0.3199	-0.1602	0.0630	0.0932	-0.3750	0.1612
NATX	2.5768***	3.6375***	1.1727**	0.2143	1.0388**	0.7033	0.4493	-0.1346	-0.3241	2.1728**	0.1484
EMPL	-0.0570	-0.1679**	0.0476	0.1428	-0.1274**	0.1742	-0.1145*	0.0844**	0.1737***	0.2031	0.1985**
AREA	0.0958	0.0685	0.1449*	0.2190**	0.0592	0.0763	0.1372**	0.1781***	0.1409**	-0.1699	0.1052*
ΔPEC	-0.5472	-0.4092	-0.6586	0.7107	0.7334*	0.3936	0.2210	-0.3000	0.5387*	0.4880	0.1660
ΔPNG	0.1523	-0.0327	-0.0758	-0.1765	-0.2448	-0.1615	-0.1522	0.1319	0.2737	0.2252	0.4138
D312	-0.0608	0.0714	0.2665	0.2145	-0.4404	-1.2611*	-0.0637	0.0695	0.2194	2.9726*	-0.0925
D313	0.2065	0.2293	0.1623	0.5483	0.1809	2.0895	0.2622	0.2100	0.4521	-1.2680	-0.0783
D314	0.5300	-0.5874	1.0947	1.0231	-0.1573	0.2566	-0.0319	0.0928	0.6915	-2.8842*	0.4520
D315_316	0.4601	0.5860	-0.3559	0.6925	0.8928**	0.0000	-0.1271	-0.2801	0.6248*	-1.0894	-0.0481
D321	-0.2470	-0.4680*	-0.1736	0.5961	0.3111	-0.0175	0.5172**	0.3698**	0.0659	0.3649	-0.0391
D322	0.2683	-0.0171	-0.3629	0.5423	-0.0247	-0.0911	0.2673	0.2430**	0.3457**	0.7147	-0.3082
D323	-0.0406	0.1343	0.1371	0.5830	0.7077*	0.2647	0.2604	0.2285	0.3452*	-0.8036	-0.1500
D324	0.7276**	-0.0768	0.4859	0.8882	0.7308**	0.6581	-0.2107	-0.0549	0.0550	0.7401	-0.9639**
D325	0.0057	-0.2954	0.5746**	0.4253	0.2899	0.2306	0.2360	0.1359	0.1609	0.7244	0.4773**
D326	0.1164	-0.6820***	0.0177	0.7503**	0.4160**	0.3163	0.0436	0.1759*	0.0040	0.4778	0.0104
D327	0.6237**	0.3063	-0.3527	-0.2860	0.3574	0.9064	0.3838*	0.1848	0.1656	0.6050	0.0563
D331	0.3584*	-0.1782	-0.2694	0.5465*	0.5556**	0.1442	0.2849	0.3515***	0.1225	-0.1644	0.1259
D332	-0.0980	-0.4352**	-0.1335	0.4997*	0.3258**	0.3364	0.0995	0.4584***	0.2498*	0.4066	-0.1000
D333	0.1343	-0.4730**	0.1122	0.4223	0.1586	0.2287	0.1092	0.2577**	0.2552*	0.2925	-0.1916
D334	-0.1479	-0.1852	1.1232**	0.8039**	0.0030	-0.0947	-0.2779	0.2004	0.0182	1.1640**	0.0649
D335	0.9895**	-0.6021**	-0.0451	0.4211	0.4433	0.9713	0.0941	0.4294**	-0.1251	0.0327	0.1613
D336	0.1021	-0.2589	0.1136	0.7688**	-0.2162	-0.3284	-0.2858	0.4787***	0.1238	-0.3254	-0.1734
D337	1.2519**	-0.3604	-0.8123	0.2262	-0.5868	-0.1765	0.2692	0.3019**	0.0953	1.0024*	-0.3064
D339	0.4139	-0.9509***	0.6358	0.0256	0.1224	-0.4518	-0.1119	-0.0689	0.2890	-0.4174	-0.3140
2001	0.2908	0.1655	-0.2180	0.1296	-0.3834*	0.0605	0.1509	-0.0974	-0.1852	0.3339	0.2183
2002	0.1475	0.0735	-0.0499	0.3596	-0.2614	-0.2806	-0.1324	-0.0594	-0.1590	0.3604	0.8385***
2003	-0.2241	0.0449	0.1506	-0.1695	-0.3825*	-0.4870	-0.2463	0.0519	-0.1280	0.2019	0.6640**
2004	0.1604	0.1735	-0.1834	-0.0502	-0.2799	-0.0980	0.0037	0.0580	0.3263**	0.0538	0.5380**
2005	-0.0094	0.2270	0.0139	-0.1409	-0.0507	-0.2104	-0.2231	0.1907*	0.3230**	-0.3568	0.4193**
2006	0.3490	0.3027	0.2727	-0.0554	-0.1194	-0.1189	0.0714	0.2279**	0.2841*	0.0308	0.7335**
2007	0.2515	0.1018	0.1509	0.2165	-0.2873	-0.4711	-0.2578	0.1552	0.3398*	0.0131	0.5306**
2008	0.4405	0.3886*	0.2267	0.3254	-0.4820**	0.3802	0.3739*	0.2732**	0.3869**	-0.3415	0.8016***
2009	0.1103	0.0328	-0.0092	0.2704	-0.3113	-0.3490	0.2954	0.2631*	0.4883**	0.3157	0.9738***
2010	0.6564	0.5301	0.0450	0.1460	-0.5521	0.0000	0.2332	0.5828**	0.2971	0.1561	1.7597**
IACxx F-stat	5.30***	4.11 ***	5.09***	3.63***	4.02***	2.10***	8.09***	18.45***	6.38***	2.27***	4.79***
(df1,df2)	(40, 967)	(37, 1076)	(36, 651)	(37, 801)	(36, 1242)	(34, 256)	(40, 1644)	(41, 3545)	(41, 2389)	(36, 297)	(40, 1405)
Constant	2.4336***	1.4633**	1.7527**	2.8804***	3.8511***	2.7228**	1.0266*	1.7701***	2.3411***	6.1452***	2.0738***
N	1045	1151	725	876	1316	326	1722	3624	2468	371	1483
RMSE	1.5943	1.3352	1.7153	1.5457	1.3998	1.2428	1.5906	1.2657	1.5335	1.5581	1.5732
Adj. R^2	0.264	0.438	0.257	0.174	0.178	0.306	0.263	0.272	0.160	0.201	0.188

legend: * p<.1; ** p<.05; *** p<.01

Table 19 Regression Estimates for the Sum of Implementation Costs for "Less Profitable" Recommendations, 2000-2010 (FY)

	HVAC Recommendations					Electrical Recommendations				Other Recommendations	
Variables	Furnaces, etc.	Heat Recovery	Steam, hot water, etc.	Space heating, etc.	Insulating, Equipment,	Electrical Power	Motors	Air Compressors	Lights	Other Facility	Behavior & Admin.
ELEC	0.4479***	0.4499***	0.5274***	0.1995**	0.1887*	0.6573***	0.5898***	0.3380***	0.1348***	0.2092**	0.1775*
NATG	0.1701**	0.2919***	-0.0204	0.0640	0.2000**	0.1529**	0.0224	0.0997**	-0.0008	0.0180	0.0018
OTHR	0.6418**	0.1667	0.1584	-0.1506	0.1078	0.7332**	0.0165	0.0339	0.0177	0.0126	0.3580
NATX	1.7217**	2.7495***	-0.5406	0.7477	1.9611**	1.5605**	0.2201	1.0595**	-0.1297	0.1798	-0.0473
EMPL	-0.1425	-0.1206	0.0950	0.1518	-0.0752	-0.0611	-0.0498	0.0475	0.2597***	0.2811*	0.0803
AREA	-0.1025	0.0592	0.0263	0.2037**	0.0511	-0.1093	0.0056	0.1145	0.2587***	0.2607**	0.1855*
ΔPEC	-0.0281	-1.2513	1.3332	-0.6197	0.0404	0.2934	0.6529*	0.3660	0.1757	-0.5791	0.7473
ΔPNG	0.5242	-0.5668	-0.5867	-0.5512	0.1341	-0.8580*	0.3533	0.4122	0.2203	0.1930	0.0074
D312	-0.2205	-0.1560	0.9454*	-0.3850	-0.5531	-1.5188**	0.0873	-0.0890	0.0963	1.1910**	0.2255
D313	0.4289	-0.1477	-0.6827	0.1381	0.0460	0.1330	0.5110	0.6213	0.4262*	-0.7519	0.2072
D314	0.5805	0.0395	-0.5539	0.8315	-0.9360	0.0979	0.5533	1.4175**	0.2077	2.3411*	-0.0996
D315_316	0.8284	0.3837	-0.8939	-0.2401	0.0343	-0.9782	0.5623	0.1529	0.2500	0.5108	-0.5574
D321	0.3485	-0.8878**	0.4910	0.0019	0.0335	0.7094**	0.4719**	0.2110	-0.3050*	2.2583**	-0.0373
D322	0.7273**	-0.0099	-0.2207	0.6262	-0.2586	-0.0680	0.2666	0.4566*	0.1917	0.9930*	-0.0893
D323	-0.6388	-0.2877	0.3393	-0.0432	-1.1691*	0.3635	0.2175	0.2009	0.2290	0.6269	0.0102
D324	1.3345*	0.1772	1.1091	0.1974	0.0074	-0.5328	0.0916	-0.8257	-0.5019*	0.0000	-0.6243
D325	-0.0516	-0.3101	0.0019	0.3637	-0.4208	0.1199	0.5153**	0.6110**	0.1264	0.8644*	-0.1510
D326	-0.5044	-0.2683	0.5937	0.3933	0.0372	-0.3929	0.5843***	0.4347*	0.2521**	0.8331*	-0.1343
D327	0.5975	-0.2125	-0.6036	-0.2481	0.3838	-0.0749	0.2347	0.5963**	-0.3104*	-0.2787	-0.0166
D331	0.4949	-0.1545	0.2271	0.1303	0.5910*	-0.1036	0.4599**	0.1704	0.0462	0.7583*	-0.2883
D332	0.1335	-0.4221*	0.1521	0.5050	-0.2154	-0.1618	0.2085	0.4264**	0.3361**	0.7596*	-0.0914
D333	-0.2547	-0.6786**	-0.2281	0.8324**	0.4117	-0.2396	0.2473	0.5368**	0.4864***	1.0535**	0.0701
D334	-0.1765	-1.3062***	0.3200	1.0295**	-0.7190	-0.4831	-0.0484	-0.3122	-0.0142	0.9229*	-0.1872
D335	-0.3304	-0.5006	0.0493	0.1903	-1.1816	0.4859	-0.1936	0.4112	0.0372	1.4260**	0.3069
D336	0.1774	-0.2135	-0.0491	0.2574	0.1452	-0.0640	-0.0367	0.4140	0.2310*	0.2613	0.0347
D337	-0.3651	-0.4688	-1.0795	0.0705	-0.6040	0.3980	0.2407	0.6062*	0.4584**	0.2959	-1.2172**
D339	0.4535	-0.2889	0.1031	0.1945	-0.7298	0.3186	0.1018	0.4004	-0.0582	0.3763	-0.4965
2001	-0.3302	-0.1180	-0.0950	-0.2522	-0.0953	0.0189	0.0667	0.2682	-0.0721	-0.3378	0.6197*
2002	0.2317	-0.2058	-0.8101	-0.4691	-0.1691	-0.2013	0.2875	0.2512	-0.0049	0.1684	0.1416
2003	0.4283	-0.4978*	-0.7513*	-0.1840	-0.3885	0.0915	0.1721	0.6546**	0.1647	-0.0876	0.5463
2004	-0.2492	-0.0928	-0.6524	-0.4677	-0.2108	-0.0348	0.2819	0.2693	0.2045	0.2947	0.0914
2005	0.3544	-0.2848	-1.1409**	-0.2657	0.0222	0.6941**	0.0124	0.4678**	0.3260**	0.3677	-0.0278
2006	0.8933**	-0.0741	-0.7516*	-0.0960	-0.9836**	0.3323	0.4734**	0.3877	0.4137**	-0.3091	0.0235
2007	0.6370	-0.4634	-0.9526*	-0.3705	0.4561	-0.2887	0.0437	0.5160*	0.7649***	-0.0924	-0.0922
2008	0.4536	-0.2938	-0.3987	-0.2695	-0.1408	-0.0456	0.1352	0.1844	0.7630***	-0.0250	-0.2057
2009	-0.2620	-0.4387	-0.4955	-0.2109	-0.1820	-0.0705	0.3343	0.6149**	0.9212***	0.5536	-0.0913
2010	0.5174	-0.5464	-0.0642	-0.7557	0.2411	-1.0767*	-0.2699	1.2729**	1.2522***	0.0241	-0.5001
IACxx F-stat	2.36***	2.14***	2.26***	3.39***	1.48**	6.02***	6.55***	4.39***	11.19***	2.24***	6.36***
(df1,df2)	(35, 391)	(37, 521)	(32, 246)	(35, 410)	(35, 285)	(34, 409)	(39, 1202)	(37, 650)	(41, 2283)	(35, 225)	(35, 339)
Constant	5.4999***	3.0842***	4.6245***	3.7442***	4.3853***	4.1445***	3.1121***	1.7633**	3.2026***	2.0919*	4.2038***
N	464	596	316	483	361	481	1279	725	2362	297	412
RMSE	1.5627	1.3858	1.4679	1.3027	1.4291	1.4483	1.3872	1.2351	1.3194	1.2417	1.3696
Adj. R^2	0.306	0.366	0.286	0.270	0.190	0.466	0.343	0.328	0.292	0.295	0.409

legend: * p<.1; ** p<.05; *** p<.01

Table 19 predicts the sum of implementation costs for recommendations that have a payback greater than 1.4 years and less than 5 years. Energy use remains one of the most important predictors of how expensive the recommended investments would be. For example, the total implementation costs in Furnaces, Process Heating, and Boilers is expected to increase 4.5% for every 10% increase in electricity use. Employment is no longer statistically significant for most types of recommendations, except lights and other facility improvements.

Step 2

Estimating the Potential Implementation Costs for Delaware Manufacturers

In this section, we first derive the characteristics of Delaware's manufacturing establishments and then incorporate those characteristics into the models developed in step 1 to predict the possible implementation costs.

The energy to employment ratios were derived using data obtained primarily from the MECS, the ASM, the SEDS, and the EC. Table 20 shows the estimated industry and state parameters for purchased electricity. Table 21 shows similar parameters for natural gas consumption. Both energy sources were estimated in billions of btu's. Multiplying any industry parameter by a corresponding state parameter yields our estimate for the energy usage per employee in that state's industry. For example, food manufacturing in Delaware is estimated to have an industry parameter of 0.257 and a state parameter of 0.475. Therefore, each employee in Delaware food manufacturing is estimated to use (0.257 0.475) 0.122 billion btu's of electricity. Each establishment's employment interacts with the parameters from these two tables to derive the expected energy use.

Table 20 Parameter Estimates from Estimating Purchased Electricity Use per Employee Ratios, 2006

Midwest		Northeast		South		West	
Industry	θ_j	Industry	θ_j	Industry	θ_j	Industry	θ_j
311	0.303	311	0.253	311	0.257	311	0.305
312	0.183	312	0.460	312	0.326	312	0.261
313	n.a.	313	0.491	313	0.781	313	0.071
314	n.a.	314	0.220	314	0.328	314	0.034
313/314	0.034	313/314	n.a.	313/314	n.a.	313/314	n.a.
315	0.011	315	0.019	315	0.119	315	0.016
316	0.060	316	0.168	316	0.045	316	0.028
321	0.263	321	0.265	321	0.282	321	0.262
322	0.483	322	0.840	322	1.112	322	1.928
323	0.111	323	0.142	323	0.160	323	0.061
324	1.875	324	2.655	324	2.228	324	1.809
325	0.845	325	0.503	325	1.728	325	0.586
326	0.347	326	0.547	326	0.390	326	0.275
327	0.445	327	0.668	327	0.533	327	0.429
331	1.039	331	2.049	331	2.252	331	1.552
332	0.142	332	0.189	332	0.163	332	0.154
333	0.170	333	0.263	333	0.109	333	0.071
334	0.088	334	0.183	334	0.149	334	0.162
335	0.133	335	0.188	335	0.225	335	0.118
336	0.181	336	0.408	336	0.144	336	0.105
337	0.084	337	0.092	337	0.137	337	0.034
339	0.070	339	0.172	339	0.099	339	0.071

State	φ_i	State	φ_i	State	φ_i	State	φ_i
Illinois	0.695	Connecticut	0.220	Alabama	0.769	Alaska	0.353
Indiana	0.893	Maine	0.414	Arkansas	0.676	Arizona	0.453
Iowa	0.818	Massachusetts	0.252	Delaware	0.475	California	0.339
Kansas	0.771	New Hampshire	0.214	D.C.	0.102	Colorado	0.483
Michigan	0.676	New Jersey	0.273	Florida	0.346	Hawaii	0.109
Minnesota	0.685	New York	0.528	Georgia	0.518	Idaho	0.975
Missouri	0.772	Pennsylvania	0.378	Kentucky	1.094	Montana	1.596
Nebraska	0.858	Rhode Island	0.194	Louisiana	0.930	Nevada	0.609
North Dakota	0.948	Vermont	0.370	Maryland	0.376	New Mexico	0.655
Ohio	0.819			Mississippi	0.589	Oregon	0.638
South Dakota	0.573			North Carolina	0.431	Utah	0.666
Wisconsin	0.640			Oklahoma	0.674	Washington	0.871
				South Carolina	0.709	Wyoming	2.127
				Tennessee	0.647		
				Texas	0.652		
				Virginia	0.513		
				West Virginia	0.726		

Table 21 Parameter Estimates from Estimating Natural Gas Use per Employee, 2006

Midwest		Northeast		South		West	
Industry	**θ_i**	**Industry**	**θ_i**	**Industry**	**θ_i**	**Industry**	**θ_i**
311	0.355	311	0.136	311	0.327	311	0.512
312	0.130	312	0.236	312	0.273	312	0.191
313	0.034	313	0.217	313	0.942	313	0.188
314	0.012	314	0.041	314	0.715	314	0.062
315	0.015	315	0.008	315	0.128	315	0.008
316	0.065	316	0.054	316	0.037	316	0.117
321	0.176	321	0.078	321	0.116	321	0.236
322	0.329	322	0.614	322	1.564	322	2.418
323	0.032	323	0.039	323	0.129	323	0.027
324	2.625	324	2.314	324	4.543	324	8.754
325	0.608	325	0.255	325	4.088	325	0.532
326	0.093	326	0.142	326	0.211	326	0.063
327	0.569	327	0.625	327	1.020	327	0.789
331	0.877	331	0.777	331	1.387	331	1.400
332	0.123	332	0.088	332	0.135	332	0.096
333	0.054	333	0.061	333	0.049	333	0.021
334	0.025	334	0.031	334	0.027	334	0.049
335	0.048	335	0.031	335	0.208	335	0.095
336	0.118	336	0.177	336	0.069	336	0.103
337	0.036	337	0.025	337	0.023	337	0.014
339	0.026	339	0.035	339	0.059	339	0.018

State	**φ_i**	**State**	**φ_i**	**State**	**φ_i**	**State**	**φ_i**
Illinois	1.720	Connecticut	0.899	Alabama	0.859	Alaska	7.501
Indiana	2.126	Maine	0.282	Arkansas	0.799	Arizona	0.182
Iowa	2.177	Massachusetts	1.047	Delaware	0.415	California	0.722
Kansas	3.302	New Hampshire	0.615	D.C.	0.912	Colorado	1.624
Michigan	1.748	New Jersey	1.214	Florida	0.280	Hawaii	0.014
Minnesota	1.603	New York	1.016	Georgia	0.461	Idaho	0.475
Missouri	1.071	Pennsylvania	1.680	Kentucky	0.615	Montana	0.951
Nebraska	2.224	Rhode Island	1.043	Louisiana	4.591	Nevada	0.052
North Dakota	2.857	Vermont	0.511	Maryland	0.191	New Mexico	2.387
Ohio	1.717			Mississippi	1.057	Oregon	0.467
South Dakota	1.117			North Carolina	0.193	Utah	0.499
Wisconsin	1.257			Oklahoma	3.103	Washington	0.279
				South Carolina	0.333	Wyoming	2.344
				Tennessee	0.333		
				Texas	2.046		
				Virginia	0.361		
				West Virginia	0.409		

These derived ratios are clearly less preferable to establishment level energy usage. To check their credibility, we correlated each state's estimated parameter (φ_j) with the industrial price of each energy source. For purchased electricity, the correlations were relatively strong and negative in every industry (Midwest: -0.31, Northeast: -0.72, South: -0.68, West: -0.58). For natural gas, the correlations were high and negative for all but the Northeast, which exhibited very weak positive correlation (Midwest: -0.78, Northeast: 0.06, South: -0.56, West: -0.65). The correlations indicate that the estimates are well behaved, given that the law of demand would predict high and negative correlations.

Next, we used the econometric models and the derived characteristics of Delaware manufacturers to predict the probability that each Delaware manufacturer would receive a recommendation.[44] Table 22 summarizes these probabilities. The table is composed of two rows and three columns. The top row applies to recommendations with paybacks less than 1.4 years and the bottom row applies to recommendations with paybacks greater than 1.4 and less than or equal to 5 years. The three columns divide the predictions based on employment size. The first column applies to the firms that have less than 20 employees. The second column applies to medium sized firms with at least 20 but no more than 499 employees, and the third column applies to manufacturers employing 500 or more employees.[45]

[44] We chose the University of Delaware to represent the IAC-specific effect for the state.
[45] The IAC sample consists mostly of medium sized manufacturing firms (see Table 2). Therefore, the predictions in the first and third columns of Table 22 are extrapolating out of the sample.

Table 22 Predicted Probabilities of Recommendations for Delaware Manufacturing Establishments

	0<Employment<20 (N=394)			20≤Employment<500 (N=155)			500≤Employment (N=11)		
	Paybacks less than 1.4			Paybacks less than 1.4			Paybacks less than 1.4		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Furnaces, etc.	23.5%	20.9%	0.136	37.8%	33.8%	0.148	51.9%	49.3%	0.135
Heat Recovery	20.6%	18.9%	0.092	37.4%	36.4%	0.123	54.4%	57.5%	0.112
Steam, hot water, etc.	1.0%	0.3%	0.019	5.6%	2.6%	0.065	15.8%	15.3%	0.069
Insulating, Equipment,	20.5%	19.9%	0.070	18.6%	19.3%	0.064	17.1%	12.9%	0.076
Space heating, etc.	21.9%	22.1%	0.134	34.9%	35.7%	0.138	41.9%	38.2%	0.137
Electrical Power	1.8%	1.9%	0.007	3.0%	3.1%	0.010	4.8%	5.0%	0.015
Lights	19.8%	19.0%	0.067	31.0%	29.9%	0.084	41.2%	39.8%	0.077
Motors	59.2%	59.4%	0.089	68.1%	69.0%	0.078	75.1%	76.4%	0.043
Air Compressors	27.9%	27.3%	0.058	31.7%	31.2%	0.050	41.9%	44.0%	0.042
Other Facility	31.4%	32.5%	0.084	31.2%	32.6%	0.094	35.0%	43.0%	0.128
Behavior & Admin.	2.9%	2.9%	0.008	3.7%	3.7%	0.013	4.2%	3.7%	0.016
	Paybacks less than 5			Paybacks less than 5			Paybacks less than 5		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Furnaces, etc.	23.8%	23.9%	0.062	30.4%	30.8%	0.062	38.5%	37.9%	0.047
Heat Recovery	12.1%	10.7%	0.064	25.0%	22.6%	0.102	37.4%	35.9%	0.051
Steam, hot water, etc.	1.4%	0.9%	0.014	3.8%	3.1%	0.029	10.4%	11.4%	0.042
Insulating, Equipment,	22.5%	23.5%	0.076	14.2%	13.6%	0.057	8.0%	7.3%	0.039
Space heating, etc.	9.0%	9.0%	0.033	9.4%	9.5%	0.028	11.0%	13.1%	0.032
Electrical Power	15.7%	14.4%	0.066	18.5%	16.9%	0.061	17.9%	16.5%	0.035
Lights	12.6%	11.5%	0.056	24.0%	23.4%	0.079	36.5%	38.1%	0.070
Motors	20.6%	20.4%	0.046	16.4%	16.5%	0.040	11.8%	13.1%	0.028
Air Compressors	61.3%	62.1%	0.062	54.8%	56.3%	0.066	54.9%	57.6%	0.055
Other Facility	17.5%	17.6%	0.063	11.7%	10.1%	0.045	8.9%	9.1%	0.018
Behavior & Admin.	3.0%	3.0%	0.008	2.3%	2.3%	0.007	1.7%	2.0%	0.006

In general, the probability that a firm receives a recommendation with larger paybacks between 1.4 and 5 years is less than the probability that the firm receives a recommendation with shorter paybacks. For example, medium size manufacturers have a 30.4% chance of receiving a "Furnaces, Process Heating, and Boilers" recommendation with longer paybacks, which is nearly 7 percentage points lower than the probability of receiving one with a shorter payback. Few medium sized manufacturers in Delaware are expected to receive behavioral/administrative (3.7%) or power related (3.0%) recommendations with short paybacks.

Table 23 summarizes the expected value of implementation costs for Delaware manufacturers.[46] The results are again composed by payback length and the employment of each manufacturer. For example, the results in the top left box show that each small Delaware manufacturer is expected to have $5,811 worth of implementation costs apply to Furnaces, Process Heating, and Boilers recommendations. The average medium sized manufacturer in Delaware is expected to have $27,665 worth of similar recommendations.

The model predicts that medium sized Delaware manufacturers could spend $19.5 million on energy-saving improvements that have paybacks less than or equal to 1.4 years. Approximately $8.7 million could be spent in heat recovery recommendations, $4.3 million in combustive processes, and $2.1 million on facility repairs.

Small manufacturers are predicted to have approximately $8.7 million of energy-efficient recommendations with paybacks less than 1.4 years. Large manufacturers could spend nearly $4.4 million on such improvements. Overall, Delaware manufacturing plants are estimated to have approximately $32.5 million of energy efficient repairs that would likely be recovered in 1.4 years or less.

[46] Since the natural logarithm was modeled instead of the actual sum of implementation costs, the expected value of the conditional implementation costs is calculated as $\exp\{ \mathbf{X'\gamma} + \frac{1}{2}\sigma^2 \}$ and the expected value of the unconditional implementation costs are $\exp\{ \mathbf{X'\gamma} + \frac{1}{2}\sigma^2 \} \times \Phi(\mathbf{X'\beta})$, where σ^2 is the conditional model's error variance. Expected values were calculated as that cost multiplied by the probability of receiving the recommendation.

Table 23 Expected Value of Implementation Costs for Delaware Manufacturing Establishments, by Recommendation Category and Payback Class

	0<Employment<20 (N=394)				20≤Employment<500 (N=155)				500≤Employment (N=11)			
	0≤Payback≤1.4				0≤Payback≤1.4				0≤Payback≤1.4			
	Mean	Median	Std. Dev.	Sum	Mean	Median	Std. Dev.	Sum	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$5,811	$1,960	$13,714	$2,289,709	$27,665	$12,086	$37,801	$4,288,139	$70,370	$39,952	$65,630	$774,074
Heat Recovery	$6,386	$1,255	$18,642	$2,516,246	$55,987	$15,051	$93,175	$8,678,031	$199,993	$116,348	$176,705	$2,199,919
Steam, hot water, etc.	$413	$37	$1,495	$162,802	$7,954	$1,196	$16,404	$1,232,831	$43,535	$22,983	$44,807	$478,887
Insulating, Equipment,	$1,613	$1,545	$846	$635,437	$3,224	$3,059	$1,796	$499,647	$6,703	$3,133	$4,860	$73,735
Space heating, etc.	$1,740	$888	$3,151	$685,487	$4,782	$3,346	$4,951	$741,229	$10,251	$4,440	$14,034	$112,766
Electrical Power	$6	$3	$9	$2,182	$63	$31	$80	$9,699	$556	$323	$634	$6,111
Lights	$905	$459	$1,313	$356,421	$6,729	$3,038	$8,589	$1,042,923	$22,315	$15,031	$17,776	$245,468
Motors	$982	$867	$509	$386,733	$3,390	$2,766	$2,000	$525,504	$8,187	$7,522	$2,124	$90,052
Air Compressors	$267	$234	$133	$105,266	$953	$801	$548	$147,764	$3,587	$3,516	$940	$39,452
Other Facility	$3,872	$2,826	$3,256	$1,525,502	$13,791	$10,983	$10,704	$2,137,678	$38,059	$32,440	$26,872	$418,644
Behavior & Admin.	$50	$42	$32	$19,705	$266	$201	$185	$41,161	$840	$766	$306	$9,242
			Total	$8,685,492			Total	$19,344,606			Total	$4,448,349

	0<Employment<20 (N=394)				20≤Employment<500 (N=155)				500≤Employment (N=11)			
	1.4<Payback≤5				1.4<Payback≤5				1.4<Payback≤5			
	Mean	Median	Std. Dev.	Sum	Mean	Median	Std. Dev.	Sum	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$16,923	$6,045	$44,336	$6,667,777	$91,494	$35,040	$143,341	$14,181,512	$360,806	$150,323	$542,287	$3,968,864
Heat Recovery	$7,662	$1,560	$28,921	$3,018,663	$94,447	$23,881	$178,182	$14,639,302	$408,911	$250,541	$423,386	$4,498,024
Steam, hot water, etc.	$499	$109	$1,663	$196,630	$5,571	$1,909	$9,445	$863,470	$76,659	$42,749	$125,131	$843,244
Insulating, Equipment,	$2,841	$2,340	$1,697	$1,119,202	$6,759	$5,718	$4,109	$1,047,622	$13,209	$7,812	$11,664	$145,294
Space heating, etc.	$585	$320	$738	$230,390	$1,642	$1,234	$1,508	$254,567	$3,570	$3,699	$1,639	$39,271
Electrical Power	$3,160	$967	$5,784	$1,244,892	$33,413	$9,295	$50,405	$5,179,090	$118,394	$75,555	$114,053	$1,302,329
Lights	$1,437	$591	$2,674	$566,003	$16,497	$7,238	$23,605	$2,557,042	$64,512	$44,995	$51,878	$709,627
Motors	$4,426	$3,477	$3,092	$1,743,871	$16,335	$13,040	$10,977	$2,531,861	$29,412	$26,546	$19,027	$323,537
Air Compressors	$21,367	$19,955	$8,178	$8,418,707	$60,745	$52,602	$28,873	$9,415,494	$173,058	$177,824	$38,366	$1,903,634
Other Facility	$340	$282	$241	$134,093	$1,198	$1,007	$833	$185,643	$2,511	$1,881	$1,593	$27,617
Behavior & Admin.	$82	$74	$43	$32,210	$135	$120	$66	$20,969	$211	$257	$69	$2,320
			Total	$23,372,439			Total	$50,876,573			Total	$13,763,760

Table 23 also shows that much more money could potentially be spent on energy saving investments that require more time before becoming profitable. Medium sized manufactures are estimated to have nearly $14.6 million of potential expenditures in the area of Heat Recovery, $14.2 million in Furnaces, Process Heating, and Boiler systems, and another $9.4 million in air compressor systems. Substantial expenditures could also be made on electrical power improvements, including cogeneration. Qualitatively similar results hold for small and large Delaware manufacturers. Overall, the model finds that nearly $120 million could potentially be spent on energy-saving recommendations with paybacks less than 5 years, $32 million of which could be recouped in less than 1.4 years.

Although Delaware's manufacturing is small (approximately 27,000 employees), there are reasons why the predicted expenditures could yield low estimates. First, each assessment performed by an IAC center typically lasts less than 1 day, while a private energy audit typically lasts longer and could find less obvious recommendations. Second, IAC centers may make relatively optimistic assumptions that understate actual expenditures. Finally, if the implementation rate influences funding for the IAC program, centers may respond by making fewer high cost recommendations that are less likely to be implemented.

Next, we analyze how these potential expenditures could translate into employment demand.

Step 3

Converting the Implementation Costs into Employment

This section presents the results of converting the $120 million of potential expenditures into employment. Under one scenario, we assume that the recommendations are primarily labor intensive projects, and money flows to building equipment contractors as sales. Under the alternative scenario, the recommendations are primarily capital intensive, and money flows are divided between wage payments and wholesale receipts.

Table 24 lists relevant industry statistics for Delaware's building equipment contractors, with dollars adjusted for inflation.[47] Assuming fixed-proportions technology, every $1 million (2008 $) of net receipts corresponds to approximately 5.3 construction jobs and 1.7 non-construction jobs in the HVAC related building equipment contractors.[48] The average Delaware worker in this industry earned approximately $50,000 each year. Approximately 4.7 construction workers and 1.5 other workers were hired for every $1 million in sales. Other facility improvements employed 5.0 construction workers and 1.6 other workers for every $1 million of sales.

Table 25 reports similar ratios for select Delaware wholesalers. Overall, the wholesale industry employs far fewer workers as a ratio to sales than the building equipment contractors. Industrial machinery and equipment merchant wholesalers (NAICS 423830) employ approximately 2.6 workers per $1 million of sales. Wholesalers selling electrical apparatuses (NAICS 423610) employ 1.3 workers per $1 million in sales. The total wholesale industry, however, only employs 0.65 workers per $1 million, so these particular wholesalers actually use relatively high amounts of labor.

[47]Inflation derived from the Producer Price Index for all finished goods
[48] Receipts net of subcontracted work.

Table 24 Industry Ratios for Selected Construction Sectors (2008 $)

	HVAC (238220)	Electrical † (238210)	Other Facility † (multiple)
Annual Wages of Construction Workers	$46,878	$50,391	$38,377
Annual Wages of Other Workers	$59,434	$52,987	$62,843
Annual Wages of All Workers	$50,017	$51,093	$43,968
Construction Workers per $1 million of Net Receipts	5.32	4.73	4.97
Other Workers per $1 million of Net Receipts	1.73	1.54	1.55
Components, Materials, and Supplies per $1 million of Net Receipts	$369,261	$370,810	$359,276

† Employment and sales derived from neighboring states.

- Source: 2007 Economic Census

Table 25 Industry Ratios for Selected Wholesale Sectors (2008 $)

	Wholesale Industry NAICS Code[49]						
	423310	423330	423610†	423720†	423730	423740†	423830
Total Receipts (000's)	$287,512	$2,577,283	$12,136,867	$166,214	$84,531	$334,827	$236,677
Change in Inventory (000's)	-$1,749	-$2,898	$42,398	-$560	$674	$3,088	$1,503
Gross Margin as % of Sales*	23%	23%	23%	30%	30%	30%	28%
Cost of Resold Goods (000's)	$224,283	$1,997,715	$9,290,853	$117,741	$58,920	$232,965	$168,431
Total Employment	410	3459	16136	241	171	770	622
Employment / $1 million Sales	1.43	1.34	1.33	1.45	2.02	2.30	2.63
Cost of Resold Goods / $1 million Sales	$780,082	$775,124	$765,507	$708,370	$697,027	$695,777	$711,649

† Estimates derived from neighboring states

* Source: Table 4, Annual Wholesale Trade Report – 2008, US Census Bureau

- Source: Table EC0742A1 – 2007 Economic Census

[49] See Table 14 for which wholesalers were assumed to supply the capital for each recommendation type.

423310 Lumber, Plywood, Millwork, and Wood Panel Merchant Wholesalers
423330 Roofing, Siding, and Insulation Material Merchant Wholesalers
423610 Electrical Apparatus and Equip., Wiring Supplies, and Related Equip. Merchant Wholesalers
423720 Plumbing and Heating Equipment and Supplies (Hydronics) Merchant Wholesalers
423730 Warm Air Heating and Air-Conditioning Equipment and Supplies Merchant Wholesalers
423740 Refrigeration Equipment and Supplies Merchant Wholesalers
423830 Industrial Machinery and Equipment Merchant Wholesalers

The 2008 Annual Wholesale Trade Report provided information on the gross margins for these wholesalers. Using the gross margins and the change in inventories, we estimate that these wholesalers spend between 70% and 80% of their sales purchasing goods for resale. This indicates how much spending is passed along to the manufacturers of capital equipment. The alternative labor intensive assumption finds that between 36%-37% of expenditures goes to capital. This point underscores the fundamental difference between the two assumptions.

Labor Intensive Assumption

Table 26 converts the potential implementation costs into employment requirements assuming that energy saving recommendations are labor intensive (e.g equipment repairs, modifications, and servicing). Approximately $7.4 million dollars could be spent by Delaware manufacturers on furnace, process heating and boiler related improvements with relatively quick payback periods. Another $13.4 million could be spent on heat recovery processes. Using the sales to employment ratios in Table 24, we estimate that these expenditures could directly employ 110 skilled construction workers and 36 other workers. The $24.8 million attributable to recommendations with longer paybacks would create a need for approximately 132 skilled workers and 43 other workers.

If all $25.4 million in HVAC related expenditures were performed by plumbing, heating, and air conditioning contractors, 410 workers with relevant trade skills and 133 workers without such skills would be needed. Similarly, if all potential electrical expenditures ($38.9 million) were treated as sales to electrical contractors or other wiring installation contractors, then 184 workers with electrically-related skills and 60 other workers would be demanded. Expenditures in other facility improvements ($4.4 million) would require 28 jobs.

Table 26 Estimated Impact on Delaware's Economy from Potential Expenditures

0 < Payback ≤ 1.4

	Assumed Ratios	Potential Expenditures	Construction Workers	Non Construction Workers	Components, Materials, and Supplies
Furnaces, etc.	HVAC	$7,351,922	39.1	12.7	$2,714,779
Heat Recovery		$13,394,196	71.3	23.1	$4,945,955
Steam, hot water, etc.		$1,874,521	10.0	3.2	$692,188
Insulating, Equipment,		$1,208,819	6.4	2.1	$446,370
Space heating, etc.		$1,539,483	8.2	2.7	$568,471
Electrical Power	Electrical	$17,992	0.1	0.0	$6,672
Lights		$1,644,813	7.8	2.5	$609,913
Motors		$1,002,289	4.7	1.5	$371,659
Air Compressors		$292,481	1.4	0.5	$108,455
Other Facility	Other	$4,081,824	20.3	6.4	$1,466,502
Behavior & Admin.	n.a.	$70,108	n.a.	n.a.	n.a.
		$32,478,447	169.2	54.8	$11,930,964

1.4 < Payback ≤ 5

	Assumed Ratios	Potential Expenditures	Construction Workers	Non Construction Workers	Components, Materials, and Supplies
Furnaces, etc.	HVAC	$24,818,153	132.0	42.9	$9,164,378
Heat Recovery		$22,155,989	117.9	38.3	$8,181,345
Steam, hot water, etc.		$1,903,344	10.1	3.3	$702,831
Insulating, Equipment,		$2,312,118	12.3	4.0	$853,775
Space heating, etc.		$524,228	2.8	0.9	$193,577
Electrical Power	Electrical	$7,726,311	36.6	11.9	$2,864,996
Lights		$3,832,672	18.1	5.9	$1,421,194
Motors		$4,599,270	21.8	7.1	$1,705,457
Air Compressors		$19,737,835	93.4	30.4	$7,318,993
Other Facility	Other	$347,354	1.7	0.5	$124,796
Behavior & Admin.	n.a.	$55,500	n.a.	n.a.	n.a.
		$88,012,772	446.7	145.4	$32,531,341

Overall, the labor intensive method finds that Delaware's manufacturers could potentially increase the demand for construction jobs by 616 and for other jobs by 200. Employment will also be stimulated from the ($11.9 + $32.5) $44.5 million spent on components, materials, and supplies, though we only focus on direct employment in this report.

Capital Intensive Assumption

In the alternative scenario, we assume that expenditures are divided between wages and sales to equipment wholesalers. The direct employment effect from labor expenditures is estimated by dividing wage payments by the expected wage per worker plus a 35% benefit premium. The direct employment effect from capital expenditures is estimated using employment to sales ratios for specific wholesale industries.

Table 27 summarizes the estimated costs attributed to wage payments. The six panels are again decomposed by the payback of each recommendation (rows) and firm size (columns). The top three panels indicate that Delaware manufacturers could spend nearly $4.8 million in labor on recommendations that have paybacks less than 1.4 years in length. The largest share of this expenditure would come from heat recovery recommendations ($1.8 million), followed by furnaces, process heating, and boilers ($1.0 million), and other facility recommendations ($0.5 million). Medium sized manufacturers are expected to spend the most on wages.

The bottom three panels of Table 27 indicate that nearly $9.0 million could be spent on labor performing recommendations with paybacks between 1.4 years and 5 years in length. The bulk of this expenditure is due to recommendations in air compressors ($2.5 million), heat recovery ($2.4 million), and furnaces, process heating, and boilers ($1.9 million).

In sum, $13.8 million of potential labor expenditures are estimated to be spent on relevant energy saving improvements in Delaware. Given that size of total expenditures, approximately 11.5% of implementation costs are directly attributable to wage payments. The remaining 88.5% of expenditures are assumed to be wholesale receipts and are presented in Table 28. The magnitudes are obviously much larger, but the results are qualitatively similar to Table 27.

Table 27 Expected Value of Labor's Implementation Costs for Delaware Manufacturing Establishments, by Recommendation Category and Payback Class

0<Employment<20 (N=394)

0≤Payback≤1.4

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$952	$449	1,495	$375,019
Heat Recovery	$1,106	$342	2,422	$435,689
Steam, hot water, etc.	$72	$10	227	$28,247
Insulating, Equipment,	$471	$457	224	$185,733
Space heating, etc.	$350	$227	482	$137,835
Electrical Power	$2	$1	2	$668
Lights	$166	$101	193	$65,310
Motors	$431	$399	184	$169,680
Air Compressors	$108	$99	46	$42,621
Other Facility	$543	$447	348	$213,846
Behavior & Admin.	$25	$21	13	$9,715
			Total	$1,664,364

1.4<Payback≤5

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$1,794	$1,037	2,401	$706,716
Heat Recovery	$1,138	$355	3,138	$448,563
Steam, hot water, etc.	$56	$18	140	$22,208
Insulating, Equipment,	$724	$625	363	$285,114
Space heating, etc.	$127	$77	142	$49,955
Electrical Power	$268	$89	467	$105,776
Lights	$178	$88	281	$70,119
Motors	$517	$493	197	$203,826
Air Compressors	$3,407	$3,273	910	$1,342,341
Other Facility	$92	$85	49	$36,391
Behavior & Admin.	$17	$16	9	$6,858
			Total	$3,277,867

20≤Employment<500 (N=155)

0≤Payback≤1.4

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$3,302	$1,926	3,123	$511,834
Heat Recovery	$7,206	$2,863	9,560	$1,116,901
Steam, hot water, etc.	$966	$208	1,707	$149,799
Insulating, Equipment,	$818	$797	408	$126,814
Space heating, etc.	$852	$693	702	$131,985
Electrical Power	$13	$8	13	$1,984
Lights	$870	$498	886	$134,839
Motors	$1,180	$1,028	534	$182,967
Air Compressors	$307	$273	137	$47,616
Other Facility	$1,453	$1,324	823	$225,170
Behavior & Admin.	$93	$77	49	$14,490
			Total	$2,644,400

1.4<Payback≤5

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$6,532	$3,983	6,035	$1,012,383
Heat Recovery	$10,092	$3,735	14,990	$1,564,319
Steam, hot water, etc.	$457	$211	643	$70,902
Insulating, Equipment,	$1,332	$1,201	687	$206,516
Space heating, etc.	$322	$266	263	$49,985
Electrical Power	$2,556	$770	3,696	$396,216
Lights	$1,539	$808	1,893	$238,604
Motors	$1,023	$1,032	336	$158,577
Air Compressors	$6,655	$6,367	1,999	$1,031,540
Other Facility	$229	$206	123	$35,562
Behavior & Admin.	$28	$25	13	$4,346
			Total	$4,768,950

500≤Employment (N=11)

0≤Payback≤1.4

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$6,984	$4,967	4,616	$76,825
Heat Recovery	$22,180	$15,699	15,559	$243,984
Steam, hot water, etc.	$4,307	$2,759	3,508	$47,377
Insulating, Equipment,	$1,454	$758	967	$15,989
Space heating, etc.	$1,507	$853	1,579	$16,572
Electrical Power	$73	$54	64	$801
Lights	$2,406	$1,832	1,539	$26,465
Motors	$2,410	$2,299	452	$26,510
Air Compressors	$932	$940	183	$10,255
Other Facility	$3,354	$3,231	1,870	$36,895
Behavior & Admin.	$229	$208	75	$2,515
			Total	$504,189

1.4<Payback≤5

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$16,901	$11,183	14,304	$185,911
Heat Recovery	$35,491	$25,902	29,027	$390,399
Steam, hot water, etc.	$3,838	$2,870	4,484	$42,217
Insulating, Equipment,	$2,027	$1,337	1,594	$22,302
Space heating, etc.	$662	$703	286	$7,281
Electrical Power	$8,641	$5,678	7,997	$95,053
Lights	$5,308	$4,077	3,660	$58,390
Motors	$1,254	$1,328	399	$13,798
Air Compressors	$13,412	$13,850	1,912	$147,532
Other Facility	$389	$314	193	$4,276
Behavior & Admin.	$43	$52	14	$468
			Total	$967,627

Table 28 Expected Value of Capital's Implementation Costs for Delaware Manufacturing Establishments, by Recommendation Category and Payback Class

0<Employment<20 (N=394)

0≤Payback≤1.4

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$4,860	$1,488	12,256	$1,914,690
Heat Recovery	$5,281	$907	16,251	$2,080,558
Steam, hot water, etc.	$342	$28	1,269	$134,555
Insulating, Equipment,	$1,141	$1,068	623	$449,703
Space heating, etc.	$1,390	$663	2,674	$547,652
Electrical Power	$4	$2	7	$1,515
Lights	$739	$356	1,121	$291,111
Motors	$551	$476	326	$217,054
Air Compressors	$159	$137	87	$62,645
Other Facility	$3,329	$2,366	2,919	$1,311,656
Behavior & Admin.	$25	$19	20	$9,991
			Total	$7,021,129

1.4<Payback≤5

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$15,130	$5,008	42,080	$5,961,061
Heat Recovery	$6,523	$1,208	25,821	$2,570,100
Steam, hot water, etc.	$443	$91	1,525	$174,422
Insulating, Equipment,	$2,117	$1,718	1,338	$834,088
Space heating, etc.	$458	$243	597	$180,435
Electrical Power	$2,891	$878	5,317	$1,139,115
Lights	$1,259	$504	2,394	$495,884
Motors	$3,909	$2,963	2,908	$1,540,045
Air Compressors	$17,960	$16,647	7,279	$7,076,366
Other Facility	$248	$199	193	$97,703
Behavior & Admin.	$64	$58	34	$25,353
			Total	$20,094,572

20≤Employment<500 (N=155)

0≤Payback≤1.4

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$24,363	$10,160	34,762	$3,776,305
Heat Recovery	$48,781	$12,153	83,719	$7,561,129
Steam, hot water, etc.	$6,987	$997	14,713	$1,083,032
Insulating, Equipment,	$2,405	$2,294	1,392	$372,832
Space heating, etc.	$3,931	$2,648	4,256	$609,245
Electrical Power	$50	$23	68	$7,716
Lights	$5,859	$2,537	7,710	$908,085
Motors	$2,210	$1,724	1,469	$342,537
Air Compressors	$646	$523	412	$100,147
Other Facility	$12,339	$9,689	9,908	$1,912,508
Behavior & Admin.	$172	$123	138	$26,671
			Total	$16,700,207

1.4<Payback≤5

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$84,962	$31,002	137,663	$13,169,129
Heat Recovery	$84,355	$20,146	163,346	$13,074,983
Steam, hot water, etc.	$5,113	$1,692	8,808	$792,568
Insulating, Equipment,	$5,426	$4,512	3,436	$841,106
Space heating, etc.	$1,320	$977	1,245	$204,582
Electrical Power	$30,857	$8,524	46,710	$4,782,874
Lights	$14,958	$6,429	21,718	$2,318,438
Motors	$15,312	$11,978	10,678	$2,373,285
Air Compressors	$54,090	$46,235	26,916	$8,383,954
Other Facility	$968	$786	714	$150,082
Behavior & Admin.	$107	$95	52	$16,623
			Total	$46,107,623

500≤Employment (N=11)

0≤Payback≤1.4

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$63,386	$34,984	61,026	$697,248
Heat Recovery	$177,812	$100,649	161,206	$1,955,934
Steam, hot water, etc.	$39,228	$20,050	41,317	$431,511
Insulating, Equipment,	$5,250	$2,375	3,900	$57,746
Space heating, etc.	$8,745	$3,587	12,460	$96,195
Electrical Power	$483	$269	571	$5,309
Lights	$19,909	$13,198	16,243	$219,003
Motors	$5,776	$5,240	1,675	$63,541
Air Compressors	$2,654	$2,577	759	$29,196
Other Facility	$34,704	$29,179	25,034	$381,749
Behavior & Admin.	$612	$557	237	$6,727
			Total	$3,944,160

1.4<Payback≤5

	Mean	Median	Std. Dev.	Sum
Furnaces, etc.	$343,905	$139,140	528,246	$3,782,952
Heat Recovery	$373,420	$224,639	394,476	$4,107,625
Steam, hot water, etc.	$72,821	$39,879	120,674	$801,027
Insulating, Equipment,	$11,181	$6,475	10,073	$122,993
Space heating, etc.	$2,908	$2,996	1,354	$31,990
Electrical Power	$109,752	$69,877	106,056	$1,207,276
Lights	$59,203	$40,918	48,224	$651,236
Motors	$28,158	$25,217	18,670	$309,739
Air Compressors	$159,646	$163,786	36,539	$1,756,101
Other Facility	$2,122	$1,558	1,402	$23,342
Behavior & Admin.	$168	$205	56	$1,852
			Total	$12,796,134

Table 29 Estimated Employment from Direct Labor Expenditures

	0 < Payback ≤ 1.4			1.4 < Payback ≤ 5			
	Small	Medium	Large	Small	Medium	Large	Total
Furnaces, etc.	5.6	7.6	1.1	10.5	15.0	2.8	42.5
Heat Recovery	6.5	16.5	3.6	6.6	23.2	5.8	62.2
Steam, hot water, etc.	0.4	2.2	0.7	0.3	1.1	0.6	5.3
Insulating, Equipment,	2.8	1.9	0.2	4.2	3.1	0.3	12.5
Space heating, etc.	2.0	2.0	0.2	0.7	0.7	0.1	5.8
Electrical Power	0.0	0.0	0.0	1.5	5.7	1.4	8.7
Lights	0.9	2.0	0.4	1.0	3.5	0.8	8.6
Motors	2.5	2.7	0.4	3.0	2.3	0.2	11.0
Air Compressors	0.6	0.7	0.1	19.5	15.0	2.1	38.0
Other Facility	3.6	3.8	0.6	1.0	1.0	0.1	9.3
Behavior & Admin.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total	24.9	39.3	7.5	48.0	70.1	14.2	203.9

Table 29 shows the potential employment that would be generated by the $13.8 million of wage costs. Investments that could be performed by medium sized manufacturers are estimated to use approximately (39.3+70.1) 109.4 workers. Small manufacturers are estimated to need up to (24.9+48.0) 72.9 workers. Most of this labor would arise due to expenditures on heat recovery, combustive processes, and air compressors.

Table 30 Estimated Employment from Direct Capital Expenditures

		0 < Payback ≤ 1.4		1.4 < Payback ≤ 5	
	Employment Ratio	Employment	Capital Purchased	Employment	Capital Purchased
Furnaces, etc.	2.63	16.8	$4,546,187	60.2	$16,306,117
Heat Recovery	2.63	30.5	$8,253,437	51.9	$14,056,997
Steam, hot water, etc.	1.45	2.4	$1,157,789	2.6	$1,241,279
Insulating, Equipment,	2.63	2.3	$626,452	4.7	$1,279,678
Space heating, etc.	2.02	2.5	$871,872	0.8	$290,143
Electrical Power	1.33	0.0	$11,130	9.5	$5,457,500
Lights	1.33	1.9	$1,085,641	4.6	$2,652,908
Motors	1.33	0.8	$477,012	5.6	$3,232,788
Air Compressors	2.63	0.5	$136,628	45.2	$12,252,051
Other Facility	1.38	5.0	$2,803,969	0.4	$210,828
		62.7	$19,970,116	185.6	$56,980,289

Table 30 shows the employment effect of spending the remaining $106.7 million of capital expenditures. The majority of jobs are expected to come from expenditures in furnaces, heat recovery, and air compressors. Overall, 248 jobs in the wholesale sector could be attributable to such spending. Combined with the estimates from Table 29, the capital intensive approach yields a direct employment effect of 452 workers. This is approximately 45% fewer jobs than the estimates in the labor intensive assumption.

Table 30 also shows that wholesalers would likely "recycle" $77 million purchasing the necessary capital and equipment from other manufacturers. This is in contrast to the labor intensive method, that assumed all necessary components, materials, and supplies would cost $45 million.

Discussion

This report identified specific technological areas in manufacturing where energy inefficiencies are common. A series of models and algorithms were developed in order to predict the possible implementation costs of different technologies for Delaware manufacturers. The costs were then converted into employment. That final conversion assumed that the energy-efficient investments are either mostly labor intensive or mostly capital intensive. The labor intensive assumption is most appropriate when the recommendations involve modifications repairs, maintenance, or other services. The capital intensive assumption is more appropriate when the recommendations require installing new equipment.

Table 31 compares the employment estimates of each assumption. The labor intensive assumption finds that 224 jobs could be generated by energy saving recommendations with relatively short payback lengths, while the capital intensive assumption finds that 134 jobs could be created. Recommendations with longer payback periods were found to require 593 jobs under the labor intensive assumption and 318 jobs under the capital intensive assumption. If a policy was effective enough to make all such recommendations become implemented, roughly 450 to 815 jobs would be needed. Therefore, a simple average would predict that 635 jobs could be required.

Table 31 Estimated Potential Employment Impact under Labor Intensive and Capital Intensive Assumptions

Labor Intensive Projections

0 < Payback ≤ 1.4

	Small	Medium	Large	Total
Furnaces, etc.	16.1	30.2	5.5	51.8
Heat Recovery	17.7	61.2	15.5	94.4
Steam, hot water, etc.	1.1	8.7	3.4	13.2
Insulating, Equipment,	4.5	3.5	0.5	8.5
Space heating, etc.	4.8	5.2	0.8	10.8
Electrical Power	0.0	0.1	0.0	0.1
Lights	2.2	6.5	1.6	10.4
Motors	2.4	3.3	0.6	6.3
Air Compressors	0.7	0.9	0.3	1.8
Other Facility	10.0	14.0	2.7	26.7
Behavior & Admin.	n.a.	n.a.	n.a.	n.a.
Total	59.6	133.6	30.9	224.1

1.4 < Payback ≤ 5

	Small	Medium	Large	Total
Furnaces, etc.	47.0	99.9	28.0	174.9
Heat Recovery	21.3	103.2	31.7	156.1
Steam, hot water, etc.	1.4	6.1	5.9	13.4
Insulating, Equipment,	7.9	7.4	1.0	16.3
Space heating, etc.	1.6	1.8	0.3	3.7
Electrical Power	7.8	32.5	8.5	48.8
Lights	3.6	16.1	4.6	24.2
Motors	10.9	15.9	2.1	29.0
Air Compressors	52.9	59.1	12.4	124.4
Other Facility	0.9	1.2	0.2	2.3
Behavior & Admin.	n.a.	n.a.	n.a.	n.a.
Total	155.2	343.2	94.8	593.2

Capital Intensive Projections

0 < Payback ≤ 1.4

	Small	Medium	Large	Total
Furnaces, etc.	10.6	17.5	3.0	31.1
Heat Recovery	11.9	36.4	8.8	57.1
Steam, hot water, etc.	0.6	3.8	1.3	5.7
Insulating, Equipment,	3.9	2.9	0.4	7.2
Space heating, etc.	3.1	3.2	0.4	6.8
Electrical Power	0.0	0.0	0.0	0.1
Lights	1.3	3.2	0.7	5.2
Motors	2.7	3.1	0.5	6.3
Air Compressors	0.8	1.0	0.2	2.0
Other Facility	5.4	6.4	1.1	13.0
Behavior & Admin.	n.a.	n.a.	n.a.	n.a.
Total	40.5	77.5	16.4	134.4

1.4 < Payback ≤ 5

	Small	Medium	Large	Total
Furnaces, etc.	26.1	49.6	12.7	88.4
Heat Recovery	13.4	57.5	16.6	87.5
Steam, hot water, etc.	0.6	2.2	1.8	4.6
Insulating, Equipment,	6.4	5.3	0.7	12.3
Space heating, etc.	1.1	1.2	0.2	2.4
Electrical Power	3.0	12.1	3.0	18.1
Lights	1.7	6.5	1.7	9.9
Motors	5.0	5.5	0.6	11.1
Air Compressors	38.1	37.0	6.8	81.8
Other Facility	0.7	0.8	0.1	1.7
Behavior & Admin.	n.a.	n.a.	n.a.	n.a.
Total	96.2	177.6	44.1	317.9

Our model predicts that the greatest potential for employment by making energy efficient investments will require skills in combustive processes, like furnaces, ovens, boilers, and heat recovery. Proper design and maintenance of air compressors were another area that would require skilled workforce. Not many jobs are expected to come from energy-efficient repairs to the building envelopes.

The process also implied that less profitable recommendations (i.e. those with longer payback periods) would use more labor than more profitable recommendations. More specifically, three out of every four potential jobs could come from recommendations with paybacks between 1.4 and 5 years in length.

The results also imply that most of the potential employment gains would come from servicing medium-sized manufacturers in Delaware. Approximately 60% of potential employment would be the direct result of manufacturers that employ more than 20 but less than 500 employees. Small and medium sized manufacturers would require nearly 85% of the potential employment if all recommendations were implemented. Of course, these jobs will only be realized if manufacturers actually implement the recommended investments in energy efficiency.

The employment discussed in this report refers only to those jobs that would be directly affected by expenditures on energy efficiency. However, jobs would also be created indirectly due to indirect effects on the supply chain and induced effects from household wealth and improved productivity. Companies in the Fabricated Metal Product Manufacturing (NAICS 332) and the Machinery Manufacturing (NAICS 333) sectors would likely see an increased demand. However, much of that multiplier effect may migrate to another state, since so few industrial equipment manufacturers are located in Delaware.

The analysis has also ignored the potential employment and training skills necessary to perform the energy audits for all 560 manufacturing establishments in Delaware. Quantifying the number of auditors to do these audits ultimately depends on the type of audit, the characteristics of the manufacturing establishment, and the quality of the energy auditors. If we assumed that each plant requires 1.5 weeks of labor from an experienced auditor, approximately 16 energy auditors would be needed to perform the all of the assessments in one year.

Finally, many of these recommendations require one-time investments, so a policy that encourages that investment will create temporary employment. Employment calculations were derived using full time employee equivalents, so policies of differing scales can be devised. For example, a policy that generates nearly 160 jobs could find work for 4 years, while a policy that generates 320 jobs could have work that would last for 2 years. Of course, capital depreciation would give way for new energy efficient investments, so there would be some amount of labor necessary to sustain future investments. That amount of permanent employment is not addressed in this report.

Limitations and Recommendations for Future Research

This paper relied on a variety of data sources, models, and assumptions to generate estimates of the labor needed to make a more energy efficient manufacturing sector in Delaware. That process required a number of important assumptions and considerations. In this section, we highlight which considerations we feel were most important and highlight areas where future research could improve upon the process.

First, a nonrandom selection of medium sized manufacturers was used to generate a predictive model for all manufacturing establishments. If there are meaningful differences in the kind of energy improvements that are possible, then important errors could result from such extrapolation.

Second, we assumed all energy assessments would be conducted by the IAC team from the University of Delaware. Any idiosyncrasies of those audits were controlled for via econometric specification. Other auditors might make different recommendations. Policy incentives could also affect the profitability of particular recommendations.

The third limitation is that we had to estimate each firm's energy use. The estimates were derived primarily from ratios constructed for regional data as of 2006. Accuracy would have improved if more recent, establishment level data were available. Sharing data between the Department of Energy, the Census Bureau, and the Department of Labor could bear fruit in future extensions of this process.

Also, the estimation of labor expenditures could be improved if the IAC database refined how it tracks labor and capital expenditures. Currently, most recommendations appear classified as either labor-only or capital-only recommendations. A more useful question for the purposes of this project would have been how many hours of labor each recommendation would require.

The final, and perhaps most important, consideration is that the report estimates the *potential* demand for jobs. However, the literature suggests that the implementation decision is influenced by a number of factors. Although longer term investments require more labor, such investments are less likely to be implemented. According to Anderson and Newell (2004), 4 out of 10 recommendations with a 5 year payback are expected to be implemented. This suggests that smart and effective policies need to address the implementation-gap if policy makers want to stimulate energy efficient investments in manufacturing.

Conclusions

Much of the green jobs literature attempts to label jobs as green and then find them in the economy. While useful for descriptive purposes, these tend not to adequately inform policy makers of what kind and how many skills the future workforce needs to possess. Reports that analyze specific green policies often do so with cost-benefit analysis. Unfortunately, that kind of aggregate employment does not provide policy makers with sufficient details to implement any particular policy. This report was designed in explicit recognition of these limitations.

The purpose of this report is to develop a process that can answer questions more relevant to workforce development; namely what training and how many jobs for a particular policy. More specifically, we estimate the type of energy-saving opportunities that exist among Delaware's manufacturers, and how many jobs could be created if those opportunities were realized.

This report found that improving the manufacturing sector in Delaware would directly require about 635 employees. Most of these jobs would be needed due to investments in heat recovery, furnaces, process heating, and boiler systems. Profitable investments in air compressor systems would require a substantial number of jobs. Vocational and training programs that teach these types of industrial processes will likely be more relevant to the green economy than programs that teach motor repair, building envelope improvements, or equipment insulation.

The predicted impact on employment depends on a number of important assumptions. If the recommendations are particularly labor intensive, then more jobs would be needed. As recommendations become more capital intensive, the direct number of jobs would decline. That consideration will also impact whether the supply of energy efficient services will come from building equipment contractors or equipment wholesalers. States that have manufacturers of industrial equipment would likely reap significant benefits.

The estimated 635 jobs refer to jobs that are *directly* needed to fulfill a particular policy. Jobs created indirectly through the multiplier effect are ignored. In addition, these jobs reflect the *potential* employment that such energy-saving improvements could draw from the labor force. Previous research suggests that manufacturers are hesitant to implement seemingly profitable investments. Consequently, there is the real possibility that fewer than 635 green jobs will actually be created from energy efficient improvements in the manufacturing sector. For example, if the investments have a 40% (70%) chance of implementation, the manufacturing sector is expected to stimulate 254 (445) green jobs.

In order for these green jobs to be realized, effective policies must not only ensure that sufficient skills exist in the labor force, but also address the reasons behind the implementation-gap. Others report that the most common reason was the financial hurdle of large up-front costs. If true, effective policies may require heavy financing costs. On a more positive note, manufacturers are generally more open to energy-efficient investments compared to other businesses.

In conclusion, this report should give policy makers an idea of what is and what is not possible with energy efficient investments in manufacturing. While 650 jobs is certainly commendable in a small state such as ours, it would have to be considered a relatively small part of a policy goal intending to reduce the unemployment rate by adding green jobs.

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Appendix

Table A1 ARC Codes Representing Furnaces, Boilers and Process Heating

Class 2 Description	Class 3 Description	Class 4 Description	ARC	Class 5 Description
Combustion Systems	Furnaces, Ovens And Directly Fired Operations	Operations	2.1111	Control Pressure On Steamer Operations
			2.1112	Heat Oil To Proper Temperature For Good Atomization
			2.1113	Reduce Combustion Air Flow To Optimum
			2.1114	Limit And Control Secondary Combustion Air In Furnace
			2.1115	Eliminate Combustible Gas In Flue Gas
			2.1116	Improve Combustion Control Capability
			2.1117	Relocate Oven / Furnace To More Efficient Location
		Hardware	2.1122	Re-size Charging Openings Or Add A Movable Door On Equipment
			2.1123	Install Automatic Stack Damper
			2.1124	Replace Direct Fired With Steam Heat
			2.1125	Convert To Oxyfuel Burners
		Maintenance	2.1132	Repair Faulty Louvers And Dampers
			2.1133	Adjust Burners For Efficient Operation
			2.1134	Eliminate Leaks In Combustible Gas Lines
			2.1135	Repair Furnaces And Oven Doors So That They Seal Efficiently
	Boilers	Operation	2.1211	Move Boiler To More Efficient Location
			2.1212	Operate Boilers On High Fire Setting
			2.1213	Direct Warmest Air To Combustion Intake
		Hardware	2.1221	Replace Obsolete Burners With More Efficient Ones
			2.1222	Install Turbulators
			2.1223	Install Smaller Boiler (increase High Fire Duty Cycle)
			2.1224	Replace Boiler
		Maintenance	2.1231	Establish Burner Maintenance Schedule For Boilers
			2.1232	Keep Boiler Tubes Clean
			2.1233	Analyze Flue Gas For Proper Air/fuel Ratio
		Blowdown	2.1241	Reduce Excessive Boiler Blowdown
			2.1242	Minimize Boiler Blowdown With Better Feedwater Treatment
			2.1243	Use Heat From Boiler Blowdown To Preheat Boiler Feed Water
	Fuel Switching	Electric To Fossil Fuel	2.1311	Replace Electrically-operated Equipment With Fossil Fuel Equipment
		Fossil Fuel To Electric	2.1321	Replace Fossil Fuel Equipment With Electrical Equipment
			2.1322	Use Electric Heat In Place Of Fossil Fuel Heating System
			2.1323	Replace Gas-fired Absorption Air Conditioners With Electric Units

Table A1 ARC Codes Representing Furnaces, Boilers and Process Heating (continued)

Class 2 Description	Class 3 Description	Class 4 Description	ARC	Class 5 Description
Combustion Systems	Fuel Switching	Alternate Fuel	2.1331	Burn A Less Expensive Grade Of Fuel
			2.1332	Convert Combustion Equipment To Burn Natural Gas
			2.1333	Convert Combustion Equipment To Burn Oil
			2.1334	Convert Oil Or Gas Burners To Combustion Of Coal
			2.1335	Replace Gasoline With Diesel, Lpg, Or Natural Gas
			2.1336	Install Equipment To Utilize Waste Fuel
		Miscellaneous	2.1391	Replace Purchased Steam With Electric Heating
			2.1392	Replace Purchased Steam With Other Energy Source
			2.1393	Use Steam Sparging Or Injections In Place Of Indirect Heating
			2.1394	Replace Steam Jets On Vacuum System With Electric Motor Driven Vacuum Pumps
Thermal Systems	Heating	Operation	2.2211	Use Optimum Temperature
			2.2212	Use Minimum Safe Oven Ventilation
		Hardware	2.2221	Use Immersion Heating In Tanks, Melting Pots, Etc
			2.2222	Convert Liquid Heaters From Underfiring To Immersion Or Submersion Heating
			2.2223	Enhance Sensitivity Of Temperature Control And Cutoff
	Heat Treating	General	2.2311	Heat Treat Parts Only To Required Specifications Or Standards
			2.2312	Minimize Non-essential Material In Heat Treatment Process
			2.2313	Use Batch Firing With Kiln "furniture" Specifically Designed
			2.2314	Replace Heat Treating Oven With More Efficient Unit
	Heat Containment	Infiltration	2.2531	Re-size Charging Openings Or Add Movable Cover Or Door
			2.2532	Use Only Amount Of Air Necessary To Prevent Explosion Hazard
			2.2533	Replace Air Curtain Doors With Solid Doors
Industrial Design	Systems	Thermal	2.5111	Convert From Indirect To Direct Fired Systems
			2.5112	Use Continuous Equipment Which Retains Process Heating Conveyors Within The Heated Chamber
			2.5113	Use Direct Flame Impingement Or Infrared Processing For Chamber Type Heating
			2.5114	Use Shaft Type Furnaces For Preheating Incoming Material
			2.5115	Reposition Oven Walls To Reduce Heated Space
			2.5117	Convert To Indirect Temperature Control System

Table A2 ARC Codes Representing Heat Recovery

Class 2 Description	Class 3 Description	Class 4 Description	ARC	Class 5 Description
Thermal Systems	Heat Recovery	Flue Gas Recuperation	2.2411	Use Waste Heat From Hot Flue Gases To Preheat Combustion Air
			2.2412	Use Flue Gas Heat To Preheat Boiler Feedwater
			2.2413	Use Hot Flue Gases To Preheat Wastes For Incinerator Boiler
		Flue Gas - Other Uses	2.2421	Install Waste Heat Boiler To Provide Direct Power
			2.2422	Use Waste Heat From Hot Flue Gases To Generate Steam
			2.2423	Install Waste Heat Boiler To Produce Steam
			2.2424	Use Heat In Flue Gases To Preheat Products Or Materials
			2.2425	Use Flue Gases To Heat Process Or Service Water
			2.2426	Use Waste Heat From Flue Gases To Heat Space Conditioning Air
			2.2427	Use Waste Heat From Hot Flue Gases To Preheat Incoming Fluids
			2.2428	Use Flue Gases In Radiant Heater For Space Heating, Ovens, Etc
		Heat Recovery From Specific Equipment	2.2431	Recover Heat From Transformers
			2.2432	Recover Heat From Oven Exhaust / Kilns
			2.2433	Recover Heat From Engine Exhausts
			2.2434	Recover Heat From Air Compressor
			2.2435	Recover Heat From Compressed Air Dryers
			2.2436	Recover Heat From Refrigeration Condensers
			2.2437	Recover Waste Heat From Equipment
		Other Process Waste Heat	2.2441	Preheat Boiler Makeup Water With Waste Process Heat
			2.2442	Preheat Combustion Air With Waste Heat
			2.2443	Re-use Or Recycle Hot Or Cold Process Exhaust Air
			2.2444	Use Hot Process Fluids To Preheat Incoming Process Fluids
			2.2445	Recover Heat From Exhausted Steam
			2.2446	Recover Heat From Hot Waste Water
			2.2447	Heat Water With Exhaust Heat
		Miscellaneous	2.2491	Use Cooling Air Which Cools Hot Work Pieces For Space Heating
			2.2492	Use "heat Wheel" Or Other Heat Exchanger To Cross-exchange Building Exhaust Air With Make-up Air
			2.2493	Use Recovered Heat From Lighting Fixtures For Useful Purpose
			2.2494	Recover Heat In Domestic Hot Water Going To Drain
			2.2495	Use Exhaust Heat From Building For Snow And Ice Removal
			2.2496	Heat Service Hot Water With Air Conditioning Equipment

Table A3 ARC Codes Representing Steam, Hot Water, Process Piping, Refrigeration, and Cooling

Class 2 Description	Class 3 Description	Class 4 Description	ARC	Class 5 Description
Thermal Systems	Steam	Traps	2.2111	Install Steam Trap
			2.2112	Use Correct Size Steam Traps
			2.2113	Repair Or Replace Steam Traps
			2.2114	Shut Off Steam Traps On Super Heated Steam Lines When Not In Use
		Condensate	2.2121	Increase Amount Of Condensate Returned
			2.2124	Install De-aerator In Place Of Condensate Tank
			2.2125	Replace Barometric Condensers With Surface Condensers
			2.2126	Lower Operating Pressure Of Condenser (steam)
			2.2127	Flash Condensate To Produce Lower Pressure Steam
			2.2128	Use Steam Condensate For Hot Water Supply (non-potable)
		Leaks And Insulation	2.2133	Repair Leaks In Lines And Valves
			2.2134	Eliminate Leaks In High Pressure Reducing Stations
			2.2135	Repair And Eliminate Steam Leaks
		Distillation	2.2141	Operate Distillation Columns Efficiently
			2.2142	Upgrade Distillation Hardware
		Maintenance	2.2151	Clean Steam Coils In Processing Tanks
			2.2152	Maintain Steam Jets Used For Vacuum System
			2.2153	Close Off Unneeded Steam Lines
		Operations	2.2161	Optimize Operation Of Multi-stage Vacuum Steam Jets
			2.2162	Reduce Excess Steam Bleeding
			2.2163	Use Minimum Steam Operating Pressure
			2.2164	Turn Off Steam Tracing During Mild Weather
			2.2165	Substitute Air For Steam To Atomize Oil
		Miscellaneous	2.2191	Substitute Hot Process Fluids For Steam
			2.2192	Use Heat Exchange Fluids Instead Of Steam In Pipeline Tracing Systems

Table A3 ARC Codes Representing Steam, Hot Water, Process Piping, Refrigeration, and Cooling (continued)

Class 2 Description	Class 3 Description	Class 4 Description	ARC	Class 5 Description
Thermal Systems	Heat Containment	Isolation	2.2521	Isolate Steam Lines To Avoid Heating Air Conditioned Areas
			2.2522	Isolate Hot or Cold Equipment
			2.2523	Reduce Infiltration To Refrigerated Areas; Isolate Hot Equipment From Refrigerated Areas
			2.2524	Avoid Cooling Of Process Streams Or Materials That Must Subsequently Be Heated
			2.2525	Eliminate Cooling Of Process Streams Which Subsequently Must Be Heated And Vice Versa
	Cooling	Cooling Towers	2.2611	Moderate Cooling Tower Outlet Temperature
			2.2612	Use Cooling Tower Water Instead Of Refrigeration
			2.2613	Use Antifreeze In Cooling Towers To Allow Winter Use
			2.2614	Use Cooling Tower Or Economizer To Replace Chiller Cooling
			2.2615	Clean Condenser Tubes
		Chillers And Refrigeration	2.2621	Modify Refrigeration System To Operate At A Lower Pressure
			2.2622	Replace Existing Chiller With High Efficiency Model
			2.2623	Minimize Condenser Cooling Water Temperature
			2.2624	Use Cold Waste Water To Cool Chiller Feed Water
			2.2625	Chill Water To The Highest Temperature Possible
			2.2626	Avoid Frost Formation On Evaporators
			2.2627	Use Multiple-effect Evaporators
			2.2628	Utilize A Less Expensive Cooling Method
		Miscellaneous	2.2692	Use Outside Cold Water Source As A Supply Of Cooling Water
			2.2693	Use Waste Heat Steam For Absorption Refrigeration
			2.2694	Use Highest Temperature For Chilling Or Cold Storage
			2.2695	Use Cascade System Of Recirculating During Cold Weather To Avoid Sub-cooling
			2.2696	Use Excess Cold Process Fluid For Industrial Cooling Needs
Electrical Power	Demand Management	Thermal Energy Storage	2.3111	Heat Water During Off-peak Periods And Store For Later Use
			2.3112	Store Heated/ Cooled Water For Use During Peak Demand Periods
			2.3113	Make Ice During Off Peak Hours For Cooling
Industrial Design	Systems	Thermal	2.5116	Use Excess Cold Process Fluid For Industrial Cooling Needs
		Mechanical	2.5121	Redesign Flow To Minimize Mass Transfer Length
			2.5123	Reduce Fluid Flow Rates
Operations	Maintenance	General	2.6121	Reduce Hot Water Temperature To The Minimum Required
Building And Grounds	Space Conditioning	Maintenance	2.7211	Clean And Maintain Refrigerant Condensers And Towers
Alternative Energy Usage	General	Solar	2.9112	Use Solar Heat to Heat Water

Table A4 ARC Codes Representing Space Conditioning

Class 2 Description	Class 3 Description	Class 4 Description	ARC	Class 5 Description
Thermal Systems	Drying	Use Of Air	2.2711	Utilize Outside Air Instead Of Conditioned Air For Drying
Operations	Maintenance	General	2.6122	Adjust Vents To Minimize Energy Use
Building And Grounds	Space Conditioning	Operation	2.7222	Air Condition Only Space In Use
			2.7223	Condition Smallest Space Necessary
			2.7226	Use Computer Programs To Optimize Hvac Performance
			2.7227	Use Water On Air Conditioning Exchanger To Improve Heat Transfer And Increase AC Efficiency
			2.7228	Avoid Introducing Hot, Humid, Or Dirty Air Into Hvac System
		Hardware - Heating / Cooling	2.7231	Use Radiant Heater For Spot Heating
			2.7232	Replace Existing Hvac Unit With High Efficiency Model
			2.7233	Use Properly Designed And Sized Hvac Equipment
			2.7234	Use Heat Pump For Space Conditioning
			2.7235	Install Fossil Fuel Make-up Air Unit
		Hardware - Air Circulation	2.7241	Install Outside Air Damper / Economizer On Hvac Unit
			2.7242	Change Zone Reheat Coils To Variable Air Volume Boxes
			2.7243	Improve Air Circulation With Destratification Fans / Other Methods
			2.7244	Revise Smoke Cleanup From Operations
			2.7245	Use Direct Air Supply To Exhaust Hoods
		Evaporation	2.7251	Reduce Air Conditioning Load By Evaporating Water From Roof
			2.7252	Utilize An Evaporative Air Pre-cooler Or Other Heat Exchanger In Ac System
		Controls	2.7261	Install Timers And/or Thermostats
			2.7262	Separate Controls Of Air Handlers From Ac/ Heating Systems
			2.7263	Lower Compressor Pressure Through A/c System Modification
			2.7264	Interlock Heating And Air Conditioning Systems To Prevent Simultaneous Operation
		Humidity Control	2.7271	Replace Electric Reheat With Heat Pipes
			2.7272	Install Heat Pipes / Raise Cooling Setpoint
			2.7273	Install Desiccant Humidity Control System
		Miscellaneous	2.7291	Reschedule And Rearrange Multiple-source Heating Systems
			2.7293	Install Dry Sprinkler System Or Other Method To Reduce Heating Requirements
	Ventilation	General	2.7311	Ventilation System To Shut Off When Room Is Not In Use
			2.7312	Minimize Use Of Outside Make-up Air For Ventilation Except When Used For Economizer Cycle
			2.7313	Recycle Air For Heating, Ventilation And Air Conditioning
			2.7314	Reduce Ventilation Air
			2.7315	Reduce Building Ventilation Air To Minimum Safe Levels
			2.7316	Centralize Control Of Exhaust Fans To Ensure Their Shutdown / Establish Program for Manual Shutdown
Alternative Energy Usage	General	Solar	2.9111	Use Solar Heat To Heat Make-up Air

Table A5 ARC Codes Representing Insulating Machines, Equipment, and Pipes

Level 2 Description	Level 3 Description	Level 4 Description	ARC	Level 5 Description
Combustion Systems	Furnaces, Ovens And Directly Fired Operations	Hardware	2.1121	Use Insulation in Furnaces to Facilitate Heating / Cooling
		Maintenance	2.1131	Repair Faulty Insulation in Furnaces, Boilers, Etc.
Thermal Systems	Steam	Condensate	2.2122	Install / Repair Insulation On Condensate Lines
			2.2123	Insulate Feedwater Tank
		Leaks And Insulation	2.2131	Insulate Steam / Hot Water Lines
			2.2132	Repair Faulty Insulation On Steam Lines
	Heat Containment	Insulation	2.2511	Insulate Bare Equipment
			2.2512	Increase Insulation Thickness
			2.2513	Cover Open Tanks With Floating Insulation
			2.2514	Cover Open Tanks
			2.2515	Use Optimum Thickness Insulation
			2.2516	Use Economic Thickness Of Insulation For Low Temperatures
Industrial Design	Systems	Mechanical	2.5122	Replace High Resistance Ducts, Pipes, And Fittings
Building And Grounds	Space Conditioning	Maintenance	2.7212	Install Or Upgrade Insulation On Hvac Distribution Systems

Table A6 ARC Codes Representing Electrical Power

Electrical Power	Demand Management	Miscellaneous	2.3191	Use Demand Controller Or Load Shedder
			2.3192	Use Fossil Fuel Powered Generator During Peak Demand Periods
	Power Factor	General	2.3211	Use Power Factor Controllers
			2.3212	Optimize Plant Power Factor
	Generation Of Power	Dc	2.3311	Replace Dc Equipment With Ac Equipment
			2.3312	Install Efficient Rectifiers
		Ac	2.3321	Use Steam Pressure Reduction To Generate Power
			2.3322	Use Existing Dam To Generate Electricity
			2.3323	Install Emissions Controls To Increase Capacity
	Cogeneration	General	2.3411	Replace Electric Motors With Back Pressure Steam Turbines And Use Exhaust Steam For Process Heat
			2.3412	Use Waste Heat To Produce Steam To Drive A Steam Turbine-generator
			2.3413	Burn Fossil Fuel To Produce Steam To Drive A Steam Turbine-generator And Use Steam Exhaust For Heat
			2.3414	Burn Waste To Produce Steam To Drive A Steam Turbine Generator Set And Use Steam Exhaust For Heat
			2.3415	Use A Fossil Fuel Engine To Cogenerate Electricity Or Motive Power; And Utilize Heat
			2.3416	Use Combined Cycle Gas Turbine Generator Sets With Waste Heat Boilers Connected To Turbine Exhaust
			2.3417	Use Waste Heat With A Closed-cycle Gas Turbine-generator Set To Cogenerate Electricity And Heat
	Transmission	Transformers	2.3511	Use Plant Owned Transformers Or Lease Transformers
			2.3512	De-energize Excess Transformer Capacity
			2.3513	Consider Power Loss As Well As Initial Loads And Load Growth In Down-sizing Transformers
		Conductor Size	2.3521	Reduce Load On Electrical Conductor To Reduce Heating Losses
			2.3522	Increase Electrical Conductor Size To Reduce Distribution Losses
Alternative Energy Usage	General	Solar	2.9114	Use Solar Heat To Make Electricity
		Wind Power	2.9121	Install Wind Powered Electric Generator
		Hydrogen	2.9131	Install Hydrogen Fuel Cell
		Biofuels	2.9141	Install Anaerobic Digester

Table A7 ARC Codes Representing Motors and Other Electrical Equipment

Motor Systems	Motors	Operation	2.4111	Utilize Energy-efficient Belts And Other Improved Mechanisms
			2.4112	Install Soft-start To Eliminate Nuisance Trips
			2.4113	Install Motor Voltage Controller On Lightly Loaded Motors
		Hardware	2.4131	Replace Over-size Motors And Pumps With Optimum Size
			2.4132	Size Electric Motors For Peak Operating Efficiency
			2.4133	Use Most Efficient Type Of Electric Motors
			2.4134	Replace Electric Motor With Fossil Fuel Engine
		Motor System Drives	2.4141	Use Multiple Speed Motors Or Afd For Variable Pump, Blower And Compressor Loads
			2.4142	Use Adjustable Frequency Drive To Replace Motor-generator Set
			2.4143	Use Adjustable Frequency Drive To Replace Throttling System
			2.4144	Use Adjustable Frequency Drive To Replace Mechanical Drive
			2.4145	Install Isolation Transformer On Adjustable Frequency Drive
		Motor Maintenance/repair	2.4153	Avoid Emergency Rewind Of Motors
			2.4154	Avoid Rewinding Motors More Than Twice
			2.4156	Establish A Preventative Maintenance Program
			2.4157	Establish A Predictive Maintenance Program
	Other Equipment	Operations	2.4311	Recover Mechanical Energy
			2.4312	Improve Lubrication Practices
			2.4313	Provide Proper Maintenance / Of Motor Driven Equipment
			2.4314	Use Synthetic Lubricant
		Hardware	2.4321	Upgrade Obsolete Equipment
			2.4322	Use Or Replace With Energy Efficient Substitutes
			2.4323	Use Optimum Size And Capacity Equipment
			2.4324	Replace Hydraulic / Pneumatic Equipment With Electric Equipment
			2.4325	Upgrade Conveyors
Industrial Design	Systems	Mechanical	2.5124	Use Gravity Feeds Wherever Possible
			2.5125	Size Air Handling Grills/ Duct/s Coils To Minimize Air Resistance
		Miscellaneous	2.5192	Modify Textile Dryers
Operations	Equipment Control	Equipment Automation	2.6231	Utilize Controls To Operate Equipment Only When Needed
			2.6232	Install Set-back Timers
Alternative Energy Usage	General	Solar	2.9113	Use Solar Heat For Heat

Table A8 ARC Codes Representing Air Compressors

Motor Systems	Air Compressors	Hardware	2.4221	Install Compressor Air Intakes In Coolest Locations
			2.4222	Install Adequate Dryers On Air Lines To Eliminate Blowdown
			2.4223	Install Direct Acting Units In Place Of Compressed Air Pressure System In Safety System
			2.4224	Upgrade Controls On Compressors
			2.4225	Install Common Header On Compressors
			2.4226	Use / Purchase Optimum Sized Compressor
			2.4227	Use Compressor Air Filters
		Operations	2.4231	Reduce The Pressure Of Compressed Air To The Minimum Required
			2.4232	Eliminate Or Reduce Compressed Air Used For Cooling, Agitating Liquids, Moving Product, Or Drying
			2.4233	Eliminate Permanently The Use Of Compressed Air
			2.4234	Cool Compressor Air Intake With Heat Exchanger
			2.4235	Remove Or Close Off Unneeded Compressed Air Lines
			2.4236	Eliminate Leaks In Inert Gas And Compressed Air Lines/ Valves
			2.4237	Substitute Compressed Air Cooling With Water Or Air Cooling
Operations	Maintenance	General	2.6123	Remove Unneeded Service Lines to Eliminate Potential Leaks

Table A9 ARC Codes Representing Lighting

Building And Grounds	Lighting	Level	2.7111	Reduce Illumination To Minimum Necessary Levels
			2.7112	Reduce Exterior Illumination To Minimum Safe Level
		Operation	2.7122	Disconnect Ballasts
		Controls	2.7131	Add Area Lighting Switches
			2.7132	Install Timers On Light Switches In Little Used Areas
			2.7133	Use Separate Switches On Perimeter Lighting Which May Be Turned Off When Natural Light Is Available
			2.7134	Use Photocell Controls
			2.7135	Install Occupancy Sensors
		Hardware	2.7141	Lower Light Fixtures In High Ceiling Areas
			2.7142	Utilize Higher Efficiency Lamps And/or Ballasts
			2.7143	Use More Efficient Light Source
			2.7144	Install Spectral Reflectors / Delamp

Table A10 ARC Codes Representing Facility Improvements

Building And Grounds	Lighting	Hardware	2.7145	Install Skylights
	Space Conditioning	Miscellaneous	2.7292	Lower Ceiling To Reduce Conditioned Space
	Building Envelope	Solar Loading	2.7421	Reduce Glazed Areas In Buildings
			2.7422	Plant Trees Or Shrubs Near Windows To Shield From Sunlight
			2.7423	Reduce Heat Gain By Window Tinting
			2.7424	Shade Windows From Summer Sun
			2.7425	Clean Or Color Roof To Reduce Solar Load
		Infiltration	2.7441	Replace Broken Windows And/or Window Sash
			2.7443	Air Seals Around Truck Loading Dock Doors
			2.7444	Close Holes And Openings In Building Such As Broken Windows
			2.7445	Install Weather Stripping On Windows And Doors
			2.7446	Utilize Sensors Controlling Roof And Wall Openings
			2.7447	Install Vinyl Strip / High Speed / Air Curtain Doors
		Miscellaneous	2.7491	Insulate Glazing, Walls, Ceilings, And Roofs
			2.7492	Use Proper Thickness Of Insulation On Building Envelope
			2.7493	Use Double Or Triple Glazed Windows To Maintain Higher Relative Humidity And To Reduce Heat Losses
			2.7494	Install Storm Windows And Doors
			2.7495	Install Replacement Doors
			2.7496	Install Partitions To Reduce Size Of Conditioned Space

Table A11 ARC Codes Representing Employee Training or Administrative Tasks

Level 2 Description	Level 3 Description	Level 4 Description	ARC	Level 5 Description
Thermal Systems	Cooling	Miscellaneous	2.2691	Shut Off Cooling If Cold Outside Air Will Cool Process
Electrical Power	Demand Management	Scheduling	2.3131	Reschedule Plant Operations Or Reduce Load To Avoid Peaks
			2.3132	Recharge Batteries On During Off-peak Demand Periods
			2.3133	Consider Three Or Four Days Around-the-clock Operation Rather Than One Or Two Shifts Per Day
			2.3134	Shift From Daytime To Nighttime Operation
			2.3135	Schedule Routine Maintenance During Non-operating Periods
			2.3136	Overlap Custodial Services With Normal Day Hours
			2.3137	Use Power During Off-peak Periods
Motor Systems	Motors	Motor Maintenance/repair	2.4151	Develop A Repair/replace Policy
			2.4152	Use Only Certified Motor Repair Shops
			2.4155	Standardize Motor Inventory
	Air Compressors	Operations	2.4238	Do Not Use Compressed Air For Personal Cooling
Industrial Design	Systems	Miscellaneous	2.5197	Avoid Electrically-powered Animated Displays
Operations	Maintenance	General	2.6124	Establish Equipment Maintenance Schedule
			2.6125	Keep Equipment Clean
			2.6126	Keep Solid Fuels / Raw Materials Dry
			2.6127	Maintain Air Filters By Cleaning Or Replacement
	Equipment Control	Equipment Use Reduction	2.6211	Conserve Energy By Efficient Use Of Vending Machines
			2.6212	Turn Off Equipment During Breaks, Reduce Operating Time
			2.6213	Turn Off Steam / Hot Water Lines Leading To Space Heating Units
			2.6214	Shut Off Pilots In Standby Equipment
			2.6215	Shut Off Air Conditioning In Winter Heating Season
			2.6216	Shut Off Cooling Water When Not Required
			2.6217	Shut Off All Laboratory Fume Hoods When Not In Use
			2.6218	Turn Off Equipment When Not In Use
		Equipment Scheduling	2.6221	Use Most Efficient Equipment At It's Maximum Capacity And Less Efficient Equipment Only When Necessary
			2.6222	Use Drying Oven (batch Type) On Alternate Days Or Other Optimum Schedule To Run Equipment With Full Loads
			2.6223	Schedule Use Of Elevators To Conserve Energy
			2.6224	Schedule Baking Times Of Small And Large Components
			2.6225	Eliminate Third Shift
			2.6226	Optimize Filtration Cleaning / Replacement To Minimize Air Resistance
		Load Reduction	2.6241	Reduce Temperature Of Process Equipment When On Standby
			2.6242	Minimize Operation Of Equipment Maintained In Standby Condition

Table A11 ARC Codes Representing Employee Training or Administrative Tasks (continued)

Level 2 Description	Level 3 Description	Level 4 Description	ARC	Level 5 Description
Building And Grounds	Lighting	Operation	2.7121	Utilize Daylight Whenever Possible In Lieu Of Artificial Light
			2.7123	Keep Lamps And Reflectors Clean
			2.7124	Make A Practice Of Turning Off Lights When Not Needed
	Space Conditioning	Operation	2.7221	Lower Temperature During The Winter Season And Vice-versa
			2.7224	Reduce Space Conditioning During Non-working Hours
			2.7225	Close Outdoor Air Dampers During Warm-up / Cool-down Periods
	Building Envelope	Infiltration	2.7442	Keep Doors And Windows Shut When Not On Use
Ancillary Costs	Administrative	Utility Costs	2.8111	Check For Accuracy Of Utility Meters
			2.8112	Combine Utility Meters
			2.8113	Purchase Gas Directly From A Contract Gas Supplier
			2.8114	Change Rate Schedules Or Other Changes In Utility Service
			2.8115	Base Utility Charges On Usage Rather Than Area Occupied
			2.8116	Check for Accuracy of Power Meter
		Fiscal	2.8121	Apply For Tax-free Status For Energy Purchases
			2.8122	Use Utility Controlled Power Management
			2.8123	Pay Utility Bills On Time
	Shipping, Distribution, And Transportation	Shipping	2.8211	Consolidate Freight Shipments And/or Deliveries
			2.8212	Reduce Delivery Schedules
		Vehicles	2.8221	Consider Intermediate Or Economy Size Autos / Trucks
			2.8222	Size Trucks To Job
			2.8223	Add Air Shields To Trucks To Increase Fuel Mileage
			2.8224	Shut Down Truck Engines While Loading, Unloading, Or Waiting
			2.8225	Schedule Regular Maintenance To Maintain Truck Engines
			2.8226	Increase Efficiency Of Trucks
			2.8227	Adjust / Maintain Fork Lift Trucks For Most Efficient Operation