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Center for Innovation Strategy and Policy

Saving Energy, Building Skills

Industrial Assessment Centers Impact

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Executive Summary

The U.S. Department of Energy's (DOE) Industrial Assessment Centers (IAC) program, which began in 1976, partners with universities across the country to generate energy savings at small- and medium-sized manufacturing facilities. Following faculty and student-led industrial assessments at these facilities, clients are provided with information on their energy usage and a list of recommendations for interventions for energy conservation, waste minimization, productivity increases, and other improvements. Between FY2014 and FY2020, the timeframe considered for this report, 34 IACs conducted approximately 450 assessments annually, for a total of 3,197 assessments.

The primary goals of this program are twofold: (1) to increase the energy efficiency of small- and medium-sized manufacturers to generate energy savings, and (2) to develop valuable skills in students that will prepare them for careers in energy efficiency engineering through hands-on, applied experiences. In 2015 SRI International (SRI) conducted an objective, third-party evaluation of the IAC program that concluded that it is measurably successful in achieving both of those goals. This report discusses SRI's follow-up evaluation, conducted seven years later, to determine the degree to which those goals continue to be met. Similar to the prior evaluation, SRI also explored additional available data—this time around the skilled technical workforce (STW)—to determine whether there might be an opportunity for the IAC program to expand its impact. The following paragraphs summarize our approach, key outcomes, and recommendations for each program goal.

Energy Savings

SRI evaluated the level of impact the IAC program had on energy savings among small- and medium-sized manufacturers from FY2014–FY2020. First, SRI used data maintained by Rutgers University, the Field Management Office for the IAC program, to calculate *gross energy savings*: the sum of the energy savings estimates associated with all IAC recommendations implemented within one year.

Building upon the information gathered from every client during the implementation follow-up calls, SRI also estimated *net energy savings*: savings associated with interventions that clients only implemented due to their IAC's assessment (i.e., they wouldn't have implemented them if the IAC program was not available, or they did not consider them before the IAC team site visit). Supplemental implementation data were collected from IAC clients as to whether/how many interventions resulting from IAC assessments were still being implemented beyond the standard, one-year post-assessment follow-up calls, and how many of them were directly due to the impact of the IAC program. SRI was able to compare findings from the 2015 evaluation to those from the more recent evaluation by maintaining similar methodologies.

Key Outcomes

As in the 2015 report, the IAC program showed significant figures representing its energy saving impact from FY2014–FY2020. The most notable findings were as follows:

- 94.5 million MMBtu gross energy savings across the United States, based on data from the IAC database.
- ~60% of IAC recommendations were implemented or had a concrete plan to be implemented within one year.
    - The 2015 report only analyzed recommendations related to 'energy management.' Considering only that category for FY2014–FY2020, SRI concluded that the rate of

    - implemented recommendations remained the same since the last report (45%), but the rate of recommended MMBtu savings actually implemented increased from 33% to 35%.
- 75% of clients would not have sought an energy assessment if the IAC program had not been available to them the year that they received their assessment.
    - The main reasons for this include a lack of suitable service providers, time, and budget.
- Gross energy savings from wastewater treatment plants (33.3 million MMBtu) is approximately 35% of the total gross energy savings.
- For every $1 in IAC program funding, approximately $5 of private investment was spent to implement the IAC energy saving recommendations.
- The average one-year gross energy savings per IAC program dollar is 1.584 MMBtu/dollar (2020-dollar basis).
- The average one-year gross energy savings per private investment mobilized is 0.312 MMBtu/dollar (2020-dollar basis).

Recommendations

1. During follow-ups with clients, IACs should ask them to quantify partial implementation of recommendations, i.e., if they did not fully implement a recommendation, have them quantify how much of the recommendation they did implement.
2. IACs should standardize follow-ups with clients and pilot increased post-assessment touchpoints. At six months, IACs should check in to ensure clients are well supported to implement any remaining recommendations; at one year, IACs should track how many recommendations were implemented within the year after assessment; and at two years, IACs should track how many recommendations were sustained long term. A pilot is suggested because it may be the case that rapid changeover of personnel at plants leads to diminishing returns.

Student Development

A separate and equally important impact of the IAC program is its effect on the careers and contributions of the graduate and undergraduate students who participate. SRI measured the mix of energy efficiency skills acquired by program alumni and tracked their career paths in energy efficiency jobs, as compared to other engineering students. While SRI made an attempt to analyze data specifically related to females, it was concluded that data for analysis of program impacts on minority students need to be more consistent before statistically significant conclusions can be reached.

SRI's access to text analytics and other methodologies allowed the research team to develop and compare multiple pools of energy professionals, some comprising IAC graduates and some comprising matched pools of non-participants, defined in a variety of ways and drawn from the population as a whole (e.g., selected based on degree, academic institution, and current job). Profiles for the matched pool of non-IAC participants were collected via a database that contains profiles of over 120 million workers in the United States and includes data on individuals' geographic location, job and education history, and skills.

Key Outcomes

The IAC program develops a variety of valuable skills among the students that participate and motivates and prepares them to be the next generation of energy management professionals. SRI was able to conclude this by analyzing employee profile data for IAC alumni and comparing it with control groups of students who did not participate in the IAC program.

SRI identified five major impacts on students of the IAC program:

- **IAC students develop skills beneficial to a career in energy efficiency.** IAC alumni have 72% more energy efficiency-related skills than other students in similar majors at their school who did not participate in the IAC program.
- **Students with more participation in the IAC program have more energy efficiency skills.** Even students who do not participate in the IAC program for long still develop valuable skills, especially related to energy efficiency, but students who participate for longer do have marginal gains in the number of skills developed.
- **IAC alumni possess more valuable energy efficiency skills.** IAC alumni possess more skills than those in their comparison groups, and the energy efficiency skills IAC alumni possess are more valuable, based on the skills' associated values determined by a Brookings Institution study. IAC alumni also have a greater total skill value associated with their overall profile.
- **Male IAC alumni possess more energy efficiency skills than do females.** Male alumni have on average 24% more energy efficiency skills than do their female counterparts. This is a statistically significant difference, despite a non-statistically significant difference in the total number of all skills found on male and female profiles.
- **IAC alumni are more likely to work in energy efficiency jobs than their peers.** The jobs listed on 46% of IAC alumni profiles were in an energy or "green" field, compared to only 18% of the jobs found on the profiles of their academic peers.

Recommendations

1. Collect more complete, standardized student data, i.e., via student exit surveys using a single, shared instrument (collecting gender, race, and ethnicity as allowed and/or at students' will as required).
2. Encourage students to aim for being a lead student on an assessment, which will first require gaining sufficient experience/qualifications, and ensure that Directors maximize the opportunity for all students to serve in this capacity.
3. Support more opportunities for networking and collaboration among IAC Directors to share best practices, discuss lessons learned, etc.

Skilled Technical Workforce

SRI used a Natural Language Processing (NLP) machine learning approach to identify energy efficiency-related skills in recent job postings of IAC clients. These skills were then filtered to represent only those held by recipients of associate degrees or certificates, comprising the STW[1], rather than by those with bachelor's degrees or higher. This resulted in 1,302 relevant job postings for analysis.

By analyzing this set of energy efficiency-related skills, specifically for the STW, as sought by small- and medium-sized manufacturers, SRI aimed to determine whether energy-oriented instructional programs targeted to the STW are in fact developing those desired skills. Available aggregated descriptions of curricula for associate degrees and certificate programs are more limited than anticipated, but SRI was able to identify particular associate degree and certificate programs that are relevant for the STW population.

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[1] Workers in the skilled technical workforce have high technical skill and knowledge levels but do not have a bachelor's degree or higher. With proper training, they can be a valuable component of the energy efficiency workforce.

Key Outcomes

The mapping of the energy efficiency skillset to the curricula of associate degree and certificate programs was challenged by unexpectedly limited curricula descriptions. However, **SRI was able to identify occupational training/instruction programs with the highest likelihood of helping STW workers gain the energy efficiency skills** required by the small- and medium-sized manufacturers that participate in the IAC program. Some of the top programs are listed below:

- Electrician
- Heating, Ventilation, Air Conditioning and Refrigeration Engineering Technology/Technician
- Medium/Heavy Vehicle and Truck Technology/Technician
- Mechanical/Mechanical Engineering Technology/Technician
- Electrical and Power Transmission Installation/Installer, General
- Lineworker
- Plumbing Technology/Plumber
- Aeronautical/Aerospace Engineering Technology/Technician
- Automotive Engineering Technology/Technician
- Petroleum Technology/Technician

Recommendations

1. Partner with institutions (such as community colleges or vocational schools) that offer the identified instructional programs and encourage their students to participate in those programs, preparing more students to work in energy-intensive manufacturing upon graduation.
2. Extend IAC participation to students at partner institutions (such as community colleges or vocational schools) near an existing IAC to better prepare students for the STW.

Introduction

Since 1976, the federally funded Industrial Assessment Centers (IAC) program has provided small- and medium-sized manufacturers with site-specific recommendations for improving energy efficiency, reducing waste, and increasing productivity through changes in processes and equipment. At the time this report was prepared, there were 35 universities across the United States that participate in the IAC program, engaging faculty and students to assess industrial facilities. These assessments lead to recommendations for improvement regarding energy efficiency, waste minimization, and pollution prevention. Nearly 20,000 assessments have been conducted since the program began, with almost 150,000 associated recommendations.

This program contributes to the programmatic priorities of the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) under which it resides, especially those priorities focused on decarbonizing the industrial sector and reducing the carbon footprint of buildings. The extent to which the IAC program moves the needle on these goals is determined, in part, through periodic third-party evaluations, the last of which was conducted by SRI International (SRI) in 2015. SRI not only rigorously evaluated the program's impact on energy efficiency and workforce preparation but also assessed the program's operations and implementation of activities to identify possible areas for process improvement.

This report describes the results of SRI's follow-on evaluation, conducted from November 2021 through May 2022. Energy savings analysis spans data from FY2014 through FY2020, while analysis of student development outcomes spans data from 2014 through 2020. The sections following the introduction convey:

- The methodological approaches involved in evaluating energy savings and student development
- The outcomes and impacts of the IAC program with respect to energy savings and student development
- Programmatic insights from faculty and students who work for IACs
- Exploratory research determining the linkage, if any, between academic programs designed for the skilled technical workforce (STW)—those receiving associate degrees or certificates—and skills desired in the energy efficiency industry
- A conclusion that summarizes major program-related findings and recommendations from SRI
- Appendices providing additional details on evaluation and analysis methodology and results, as well as questionnaires used to interview IAC students and Directors

IAC Program Background

Formerly the Energy Analysis and Diagnostic Center program within the Department of Commerce, the IAC program is now administered through the Advanced Manufacturing Office (AMO) in EERE. Though the IAC program's objectives have changed over time, the following can be considered the overarching goals of the program:

- Increase the energy efficiency, productivity, sustainability, and competitiveness of U.S. manufacturers
- Provide students in engineering and related disciplines with applied experiences not available in the classroom
- Develop the pipeline of energy efficiency engineers in the workforce
- Keep engineering faculty apprised of technological changes and industry needs

IACs conduct in-depth assessments of industrial facilities' major energy-consuming systems; these assessments are led by engineering faculty from participating universities with extensive involvement of graduate and undergraduate students. The IAC program is supported by a Field Manager at the Center for Advanced Energy Systems at Rutgers, the State University of New Jersey. The Field Manager role is a competitively awarded 5-year cooperative agreement. The Field Manager provides coordination and technical facilitation of all Centers participating in the IAC program, including monitoring the technical performance of each Center, coordinating Center activities, improving Center performance, and providing feedback to the Centers and the DOE Project Officer. The Field Manager is also responsible for providing technical training and support to existing and new Centers as needed.

The IAC program awards five-year cooperative agreements through a competitive process to institutions of higher education with an ABET-accredited engineering or technology program. The number of institutions supported by the program fluctuates as a function of available funding and program management priorities. Figure 1 conveys the relevant institutions participating in the IAC program during the 2019–2021 period. The list of all 38 academic institutions with IACs that were active during the analysis period and are included in this evaluation can be found in Appendix D.

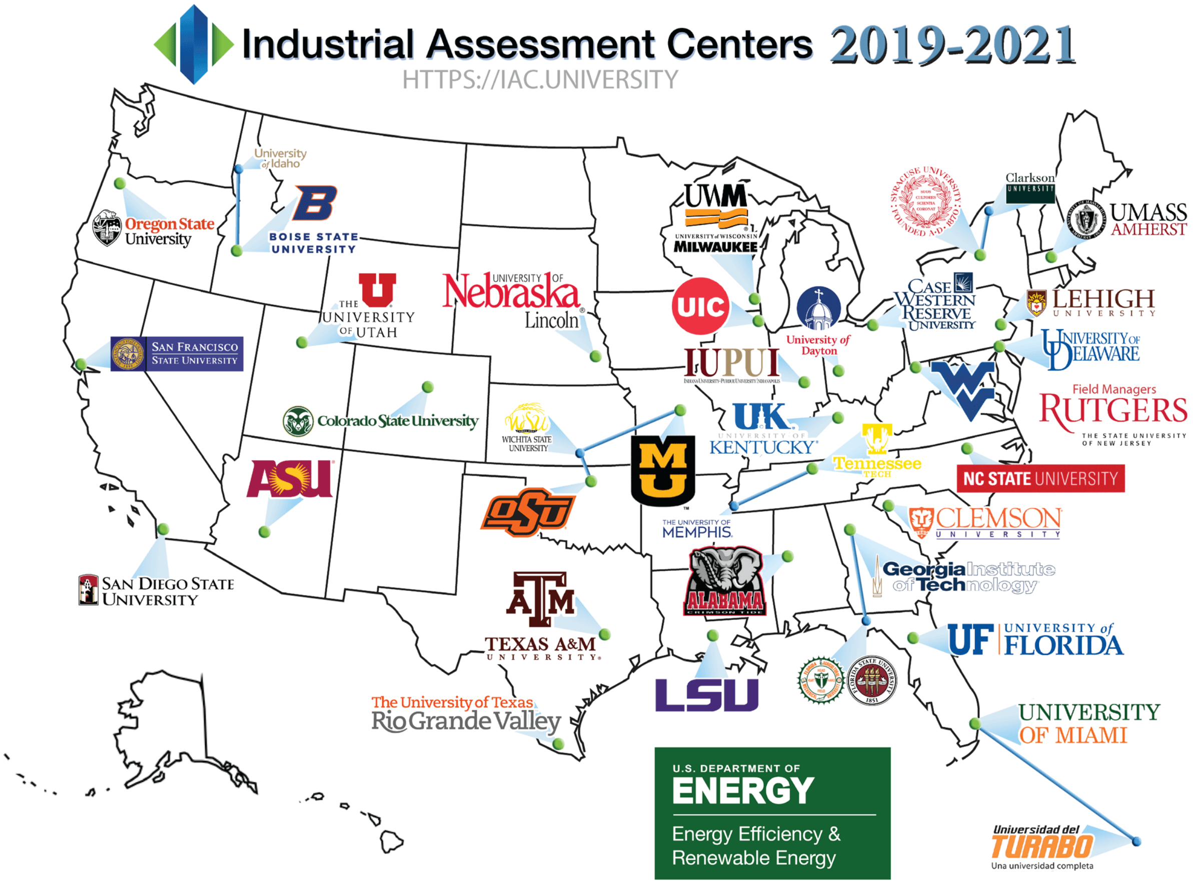

Figure 1. Participating universities with IACs, 2019–2021[2]

Figure 2 displays the distribution of Centers as a function of the number of years they have provided assessments. Among the longest-participating universities are the University of Dayton and

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[2] U.S. Department of Energy Advanced Manufacturing Office, “Industrial Assessment Centers” (2022), https://iac.university/.

Oklahoma State University, each hosting IACs for 40+ years. Though the Field Manager provides training and report oversight, each Center implements its own set of activities to meet the goals of the program.

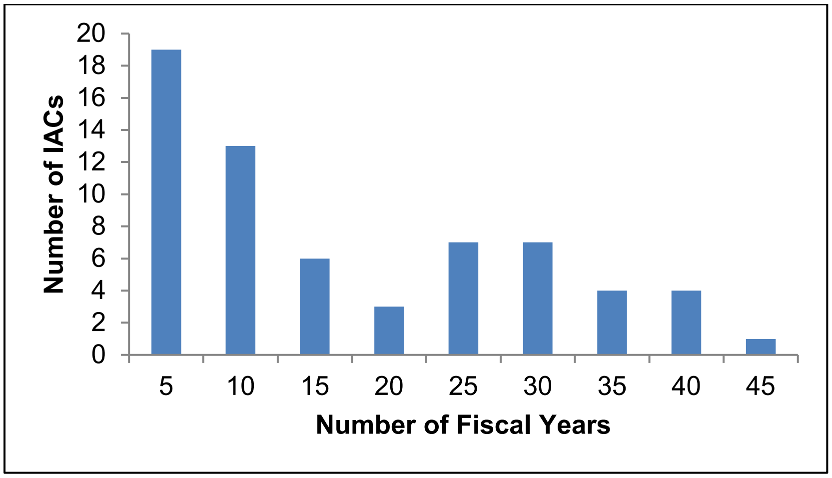

Figure 2. IAC years of participation

Major Activities of the IAC Program

Facility Assessments and Recommendations

Facilities are motivated to be assessed by IACs (at no cost to the facilities) because not only does implementing energy efficient measures help the environment, but it also generally helps to save on operating costs. During the report study period of FY2014 through FY2020, 3,197 assessments were conducted by 34 IACs, with approximately 450 assessments conducted per year.

Facilities eligible for assessment generally meet the following criteria:

- Be part of a ‘manufacturing’ industry, as indicated by a primary business activity classified with a Standard Industrial Classification (SIC) Code between 20 and 39
- Have gross annual sales below $100 million
- Have fewer than 500 employees at the plant site
- Have annual energy bills of more than $100,000 and less than $2.5 million
- Have no professional in-house staff to perform the assessment

Figure 3 conveys the geographic distribution of assessments from FY2014–FY2020.

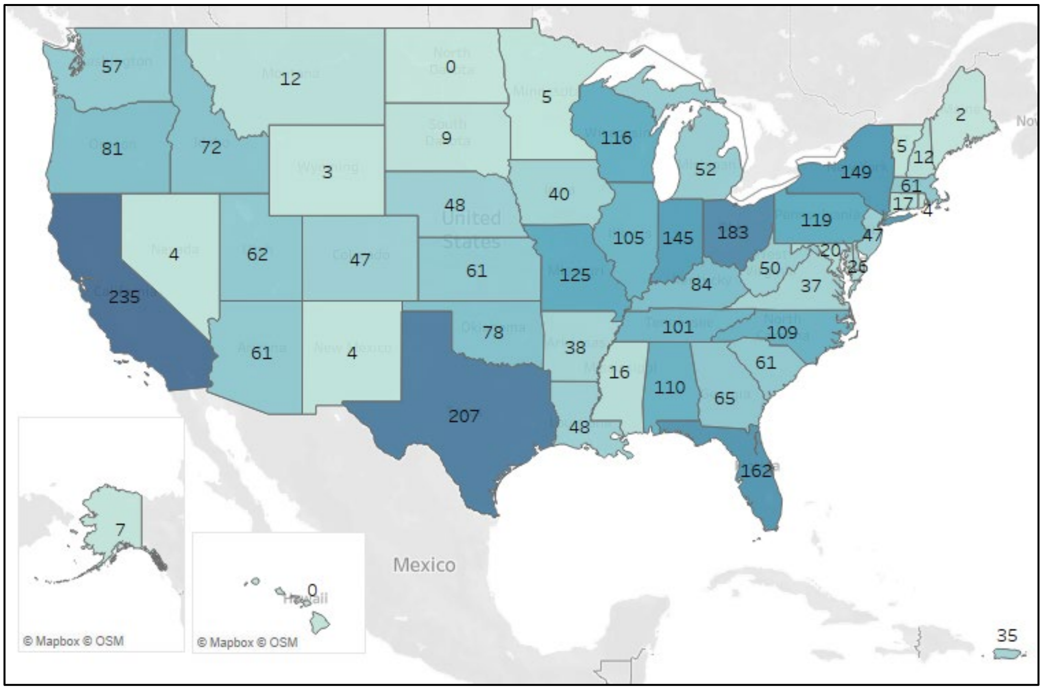

Figure 3. Distribution of IAC assessments, FY2014–FY2020

Assessments of facilities are meant to be standardized, allowing for minor variations across Centers as needed. Centers begin with a baseline assessment of the client's facility, informed by a standard pre-assessment form populated by the client. This form captures the size of the plant and plant layout, industry type (classified by Standard Industrial Classification (SIC) or North American Industry Classification System (NAICS) code), process description, production levels, units and dollars, operating hours, a one-year history of utility bills, and a list of major energy consuming equipment. Centers also assess the manufacturing process, process design, and other technical documentation to inform their team's eventual visit to the site. The site visit by the IAC team, consisting primarily of engineering students, begins with a brief meeting and tour of the plant, during which the team becomes acquainted with the facility, equipment, and priorities of site management. During this tour, the IAC team identifies potential recommendations for energy savings, such as replacing light fixtures, tuning air compressors, and installing new, more energy efficient pumps or furnaces.

The IAC team then systematically measures individual components of the facility's energy systems. Some IAC Directors have developed their own tools and loggers, which they employ during the visit. Frequently, teams get permission to leave their tools in place for a week or more in order to obtain a longer-term measurement of the energy used. These measurements are used to calculate energy expended based on mathematical models developed by university faculty.

Some teams share potential recommendations with the client on the day of the visit and some take the opportunity to gauge their interest in particular recommendations. The measurements taken and the estimates of energy consumed by individual pieces of equipment are the baseline for estimating the impact of the implementation of a particular improvement. That impact and those savings are compared to the cost of the improvement, which is estimated through a variety of means such as by asking the client, by applying previous knowledge of similar installations elsewhere, or by researching third-party sources that provide the specifications and costs of new equipment.

The resulting industrial assessment includes a list of efficiency measures with estimated costs, estimated energy savings, and a return on investment (ROI). Once the report is delivered to the client, the Center follows up with a phone call within two weeks (in practice usually right away so that the findings are still recent in the minds of the recipients). The client is invited to ask questions and seek clarification if necessary. Centers then contact each participating manufacturer six to nine months later to find out which of the recommendations have been implemented.

These self-reports by clients six to nine months after assessment of the measures implemented, planned to be implemented, or in the process of being implemented are the only systematic information the program has about the degree to which program recommendations are implemented. The results of assessments, the number and character of recommendations, the potential energy savings they represent, and the number of recommendations actually adopted by clients are reported and compiled by the Field Manager at the Center for Advanced Energy Systems at Rutgers University. These data are reviewed and aggregated, yielding a complete and consistent record of the activities of the IACs.

Trends in Industry Participation

From FY2014 to FY2020, 98% of IAC assessment clients were in industries categorized as manufacturing according to SIC codes (20-39), as reported in the IAC database: a carefully managed dataset that contains detailed information about the firms and facilities that have received assessments, the recommendations made as a part of those assessments, and the results of follow-up calls that track implementation of the recommendations. During this period, the number of assessments received by clients in various manufacturing industries, by major SIC group, are listed in Figure 4. The industries that received the most assessments are: Food and Kindred Products (SIC 20), Fabricated Metal Products (SIC 34); Rubber and Miscellaneous Plastic Products (SIC 30); and Industrial Machinery and Equipment (SIC 35). The non-manufacturing industries that received the most assessments from FY2014 to FY2020 included Electric, Gas, and Sanitary Services (SIC 49), Mining and Quarrying of Nonmetallic Minerals, Except Fuels (SIC 14), and Wholesale Trade (SIC 50-51).

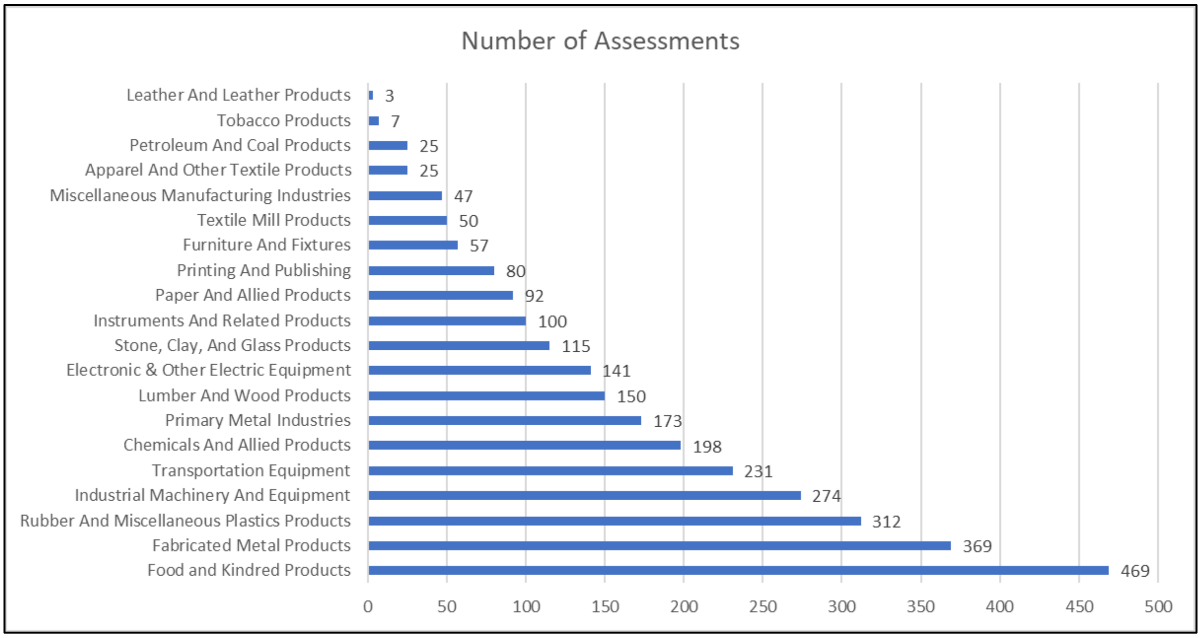

Figure 4. Number of assessments by SIC major group, FY2014–FY2020

The specific SIC industry groups that account for the most total implemented energy savings over the FY2014 to FY2020 period are presented in Table 1. Note that there is high variation in the energy savings per implemented recommendation across these industries, with a range of more than 3,300 MMBtu.

SIC Code	SIC Industry Group	Gross Energy Savings (MMBtu)	# of Recommendations Implemented	Gross Energy Savings (MMBtu) per Recommendation
3714	Motor Vehicle Parts and Accessories	1,004,313	420	2,391
3089	Plastics Products, Not Elsewhere Classified (NEC)	974,966	589	1,655
4941	Water Supply	245,976	120	2,050
2421	Sawmills and Planing Mills, General	230,140	128	1,798
2621	Paper Mills	147,180	41	3,590
2819	Industrial Inorganic Chemicals, NEC	83,421	23	3,627
3679	Electronic Components, NEC	29,596	44	673
2436	Softwood Veneer and Plywood	20,020	8	2,502
3295	Minerals and Earths, Ground or Otherwise Treated	17,223	11	1,566
2911	Petroleum Refining	616	2	308

Table 1. Estimated gross energy savings implemented by SIC industry group, FY2014–FY2020

Trends in Recommendations

SRI used the IAC database to investigate and identify patterns among clients and their associated IAC recommendations. Note that all results in this section are based on the IAC database energy savings estimates and implementation records.

All recommendations entered into the IAC database are categorized according to a detailed, multi-level taxonomy. From this, we are able to identify what categories of recommendations are most frequently recommended and implemented. In Table 2, we present the frequency of recommendations implemented, as well as the rate of implementation for each of the high-level energy management recommendation categories, Table 3 shows the same information for waste minimization and pollution prevention strategy categories, and Table 4 shows the same information for direct productivity enhancements. Table 5 conveys the energy savings per energy management recommendation category, Table 6 conveys the energy savings per waste minimization and pollution prevention strategy category, and Table 7 conveys the energy savings per direct productivity enhancement strategy category.

ARC Number	Recommendation Category	Number of Implementations	Number of Recommendations	Percentage Implemented
2.1	Combustion Systems	365	964	38%
2.2	Thermal Systems	938	2,810	33%
2.3	Electrical Power	293	1,018	29%
2.4	Motor Systems	4,042	8,548	47%
2.5	Industrial Design	26	82	32%
2.6	Operations	540	1,102	49%
2.7	Building and Grounds	3,793	7,617	50%
2.8	Ancillary Costs	287	575	50%
2.9	Alternative Energy Usage	43	235	18%
2	Total Energy Management	10,327	22,951	45%

Table 2. Number of energy management strategies recommended and implemented by IACs, FY2014–FY2020

Table 2 shows that on average, 45% of the energy management recommendations were implemented. The lowest implementation rates are observed in the alternative energy usage, electrical power, industrial design, and thermal systems categories. The highest implementation rates are in the building and grounds and ancillary costs categories.

ARC Number	Recommendation Category	Number of Implementations	Number of Recommendations	Percentage Implemented
3.1	Operations	57	182	31%
3.2	Equipment	9	29	31%
3.3	Post Generation Treatment / Minimization	5	37	14%
3.4	Water Use	117	342	34%
3.5	Recycling	47	130	36%
3.6	Waste Disposal	27	97	28%
3.7	Maintenance	48	81	59%
3.8	Raw Materials	6	15	40%
3	Total Waste Minimization / Pollution Prevention	316	913	35%

Table 3. Number of waste minimization and pollution prevention strategies recommended and implemented by IACs, FY2014–FY2020

Table 3 shows that on average, 35% of the waste minimization and pollution prevention strategy recommendations were implemented. The lowest implementation rate is observed in the post generation treatment/minimization category. The highest implementation rate is in the maintenance category.

ARC Number	Recommendation Category	Number of Implementations	Number of Recommendations	Percentage Implemented
4.1	Manufacturing Enhancements	15	65	23%
4.2	Purchasing	5	23	22%
4.3	Inventory	3	11	27%
4.4	Labor Optimization	21	60	35%
4.5	Space Utilization	13	26	50%
4.6	Reduction of Downtime	24	59	41%
4.7	Management Practices	0	1	0%
4.8	Other Administrative Savings	64	99	65%
4	Total Direct Productivity Enhancements	145	344	42%

Table 4. Number of direct productivity enhancement strategies recommended and implemented by IACs, FY2014–FY2020

Table 4 shows that on average, 42% of the direct productivity enhancement strategy recommendations were implemented. The lowest implementation rates are observed in the management practices, purchasing, and manufacturing enhancements categories. The highest implementation rate is in the other administrative savings category.

ARC Number	Recommendation Category	MMBtu Savings Implemented	MMBtu Savings Recommended	% of MMBtu Implemented	MMBtu Savings / Implementation	MMBtu Savings / Recommendation
2.1	Combustion Systems	1,690,097	6,546,476	26%	4,630	6,791
2.2	Thermal Systems	3,605,120	16,028,143	22%	3,843	5,704
2.3	Electrical Power	918,959	4,375,512	21%	3,136	4,298
2.4	Motor Systems	6,501,690	13,789,603	47%	1,609	1,613
2.5	Industrial Design	97,394	430,235	23%	3,746	5,247
2.6	Operations	883,999	2,309,218	38%	1,637	2,095
2.7	Building and Grounds	5,318,329	10,349,843	51%	1,402	1,359
2.8	Ancillary Costs	14,361	114,489	13%	50	199
2.9	Alternative Energy Usage	415,666	1,446,937	29%	9,667	6,157
2	Total Energy Management	19,445,614	55,390,457	35%	1,883	2,413

Table 5. Gross energy savings implemented and recommended by IAC energy management strategy, FY2014–FY2020

As indicated by Table 5, the average energy savings per implemented energy management recommendation for FY2014–FY2020 is 1,883 MMBtu, and the average energy savings is 2,413 MMBtu for all recommendations (FY2014–FY2020). The most likely explanation for this outcome is that recommendations which lead to higher energy savings take more effort and capital costs to implement, while the recommendations that are more easily implemented may have lower energy savings.

One interesting observation is that the alternative energy usage category has the lowest implementation rate (18%), but also the highest amount of energy saved per implementation (9,667 MMBtu/implementation). Switching to an alternative energy source might be a difficult recommendation to implement, but it may significantly reduce the consumption of the original energy source. This finding underscores the potential for additional incentives to reduce the actual payback period or to increase the willingness of manufacturers to extend their acceptable payback period, either of which could generate substantial long-term energy efficiency/decarbonization benefits.

ARC Number	Recommendation Category	MMBtu Savings Implemented	MMBtu Savings Recommended	% of MMBtu Implemented	MMBtu Savings / Implementation	MMBtu Savings / Recommendation
3.1	Operations	144,963	295,151	49%	2,543	1,622
3.2	Equipment	1,848	1,572	118%	205	54
3.3	Post Generation Treatment / Minimization	20,026	78,683	25%	4,005	2,127
3.4	Water Use	66,150,007	94,944,159	70%	565,385	277,614
3.5	Recycling	8,719,527	17,548,589	50%	185,522	134,989
3.6	Waste Disposal	(16,852)	(28,850)	58%	(624)	(297)
3.7	Maintenance	22,582	67,728	33%	470	836
3.8	Raw Materials	986	142,454	1%	164	9,497
3	Total Waste Minimization / Pollution Prevention	75,043,087	113,049,486	66%	237,478	123,822

Table 6. Gross energy savings implemented and recommended by IAC waste minimization/pollution prevention strategy, FY2014–FY2020

As indicated by Table 6, the average energy savings per implemented waste minimization/pollution prevention recommendation for FY2014–FY2020 is 237,478 MMBtu, and the average energy savings is 123,822 MMBtu for all recommendations (FY2014–FY2020). Energy savings in the water use and recycling categories show the highest energy savings per implementation with 565,385 MMBtu saved per water use implementation and 185,522 MMBtu saved per recycling implementation. These values are higher than the average energy savings per energy management implementation (1,883 MMBtu/implementation).

ARC Number	Recommendation Category	MMBtu Savings Implemented	MMBtu Savings Recommended	% of MMBtu Implemented	MMBtu Savings / Implementation	MMBtu Savings / Recommendation
4.1	Manufacturing Enhancements	(191)	122,058	0%	(13)	1,878
4.2	Purchasing	(780)	(33,401)	2%	(156)	(1,452)
4.3	Inventory	0	169	0%	0	15
4.4	Labor Optimization	13,773	11,652	118%	656	194
4.5	Space Utilization	(9,200)	2,940	(313%)	(708)	113
4.6	Reduction of Downtime	12,750	302,565	4%	531	5,128
4.7	Management Practices	0	0	N/A	N/A	0
4.8	Other Administrative Savings	381	381	100%	6	4
4	Total Direct Productivity Enhancements	16,731	406,363	4%	115	1,181

Table 7. Gross energy savings implemented and recommended by IAC direct productivity enhancement strategy, FY2014–FY2020

As indicated by Table 7, the average energy savings per implemented direct productivity enhancement recommendation for FY2014–FY2020 is 115 MMBtu, and the average energy savings is 1,181 MMBtu for all recommendations (FY2014–FY2020). This is lower than the average energy savings per energy management implementation (1,883 MMBtu/implementation) and the average energy savings per waste minimization/pollution prevention strategy (237,478 MMBtu/implementation), but still contributes to overall energy savings. Energy savings in the labor optimization and reduction of downtime categories show the highest energy savings per implementation with 656 MMBtu saved per labor optimization implementation and 531 MMBtu saved per reduction of downtime implementation.

Table 8 presents the specific recommendations that account for the highest levels of implemented gross energy savings. The recommendations related to the usage of water have the highest energy savings.

ARC Code	ARC Code Message	Gross Energy Savings (MMBtu)
3.4111	Use Closed Cycle Process to Minimize Wastewater Production	29,498,921
3.4115	Recover and Reuse Cooling Water	22,433,732
3.5132	Reuse Rich White Water in Other Applications	8,687,855
3.4151	Minimize Water Usage	7,385,067
3.4156	Use Flow Control Valves on Equipment to Optimize Water Use	6,377,813
2.7142	Utilize Higher Efficiency Lamps and/or Ballasts	3,041,962
2.4236	Eliminate Leaks in Inert Gas and Compressed Air Lines/Valves	1,328,502

2.4146	Use Adjustable Frequency Drive or Multiple Speed Motors on Existing System	1,225,905
2.4131	Replace Over-Size Motors and Pumps with Optimum Size	1,038,903
2.2113	Repair or Replace Steam Traps	950,903
2.3415	Use a Fossil Fuel Engine to Cogenerate Electricity or Motive Power; and Utilize Heat	786,757
2.4239	Eliminate or Reduce Compressed Air Usage	553,475
2.1233	Analyze Flue Gas for Proper Air/Fuel Ratio	542,661
2.6218	Turn Off Equipment When Not in Use	408,806
2.4322	Use or Replace with Energy Efficient Substitutes	392,818
2.4226	Use/Purchase Optimum Sized Compressor	343,634
2.2511	Insulate Bare Equipment	341,883
2.2414	Use Waste Heat from Hot Flue Gases to Preheat	328,078
2.4133	Use Most Efficient Type of Electric Motors	323,625
2.4224	Upgrade Controls on Compressors	314,866

Table 8. IAC recommendations that account for the highest total gross energy savings, FY2014–2020

Student Development

A second major focus of the IAC program is to educate and train engineering students in assessing industrial energy efficiency practices and performance. Students usually come to participate in the program through applying, but infrequently students take a course in which they participate in assessments as part of an academic program. Students are key contributors to IAC energy assessments and IAC operations. They participate fully in site visits, analyze plant-level data, and generate recommendations and reports, although the IAC Director has ultimate responsibility for the overall quality of each assessment. While assessment methods are relatively consistent among Centers, specific activities used to train students vary. These activities include:

- Formalized training (such as workshops)
- Academic courses
- Student-to-student knowledge transfer
- “On the assessment” training

Some Centers rely heavily on students enrolled in an academic course; in this model enrolled students typically do a few assessments each and are “supervised” by graduate students supported by the IAC. Other Centers rely on students with experience working for the IAC to teach new hires. Many Centers use a mixture of approaches. More details about effective student training methods can be found in the Insights from Interviews with IAC Stakeholders section.

Students who participated in the IAC program at some point between 2014 and 2020 are a diverse group. For those with data on student characteristics, 55% participated as undergraduate students while 45% were graduate students, which consists of both master’s and PhD students. 68% of students were studying mechanical engineering, 19% were studying industrial engineering, and 9% were studying chemical engineering, with other fields having lower participation rates. 81% of participants were identified as male, reflecting the disproportionate rates by which men study engineering fields.

For IAC students who participated in the program during the time period studied, the average number of assessments completed is 5.4, while the median number is 2. The breakdown of assessment participation is presented in Figure 5. For these students, the average estimated number of months they participated in the program is 9, and the median number of months is 5. Table 9 shows how these numbers compare for all IAC alumni in the period studied for which we have data to only those for which we collected additional profile data.

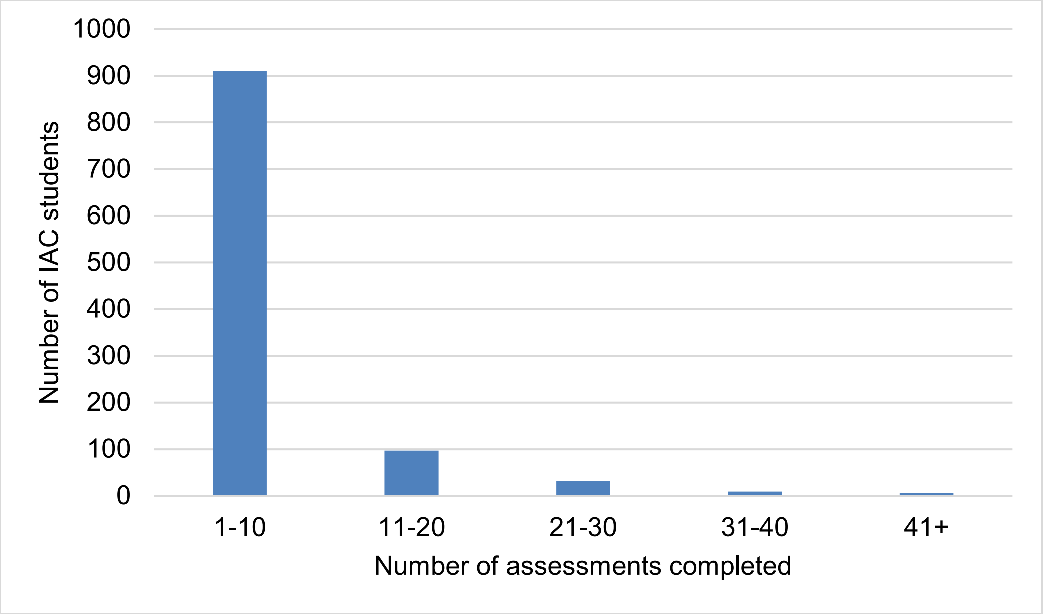

Figure 5. Number of assessments completed by IAC alumni who participated in the program between 2014 and 2020

Metric	All 2014-2020 Alumni	2014-2020 Alumni with Profile Data
Average Number of Assessments	5.363	6.537
Median Number of Assessments	2	2
Average Length of Participation	8.997 months	14.788
Median Length of Participation	5	12.5

Table 9. Characteristics of IAC alumni

SRI's Impact Evaluation Goals

SRI's evaluation of the IAC program focused on the following research questions:

- **Energy savings:** To what extent has the program improved energy efficiency at small- and medium-sized manufacturers?
    - To what extent has the IAC program and the recommendations produced resulted in actual energy savings by the target population?
    - How much energy was saved immediately after recommendations were made and at least nine months later?
    - What are the cost implications of the energy saved due to the IACs?

- **Student development:** What is the program's contribution to training the next generation of engineers with experience in energy efficiency?
    - To what extent has the IAC program increased the number of energy efficiency-related skills in engineering graduates?
    - To what extent has the IAC program increased in the number of engineering graduates going into energy efficiency?

SRI sought answers to these questions by (1) calculating the gross and net energy saved by manufacturers from implemented energy assessment recommendations, (2) assessing program impact on IAC alumni and current student skills.

SRI also conducted exploratory analysis aimed at determining how the IAC program could support or engage the STW, those who have attained less than a bachelor's degree, in entering the energy engineering workforce. The focus of this work was to understand the current state of academic programs' preparation of STW workers for the energy engineering sector, and to consider how the IAC program could potentially coordinate with such programs to bolster skill development.

Energy Savings Impact

The IAC database provides information about the location, size, and industrial sector of the firms involved; energy savings and waste reduction achieved as a result of IAC recommendations; and cost per recommendation. SRI was thus able to calculate *gross energy savings*: the sum of the energy savings estimates associated with all implemented recommendations for the study years.

To calculate *net energy savings*—the sum of energy estimates associated with implemented recommendations sustained beyond nine months—SRI engaged with IAC clients through a targeted activity following up on the implementation inquiry conducted for every IAC assessment. This helped SRI understand the degree to which client interventions resulting from IAC assessments were retained over time. It was important to try to distinguish between interventions that were implemented due to Center recommendations and those interventions that would have been implemented regardless of IAC involvement.

SRI's approach to evaluating energy savings impact replicates the approach used in the 2015 evaluation. As a result, SRI is able to compare the findings, controlling for broader changes in the economy (e.g., business cycle and cost of energy) and to uncover changes in program impact over time.

Student Development Impact

A separate and important impact of the IAC program is its effect on the careers and contributions of the graduate and undergraduate students who participate. SRI measured the mix of energy efficiency skills acquired by program alumni and tracked their career paths in energy efficiency jobs, as compared to other engineering students. While SRI made an attempt to analyze data specifically related to females, it was concluded that data for analysis of program impacts on minority students needs to be more consistent before statistically significant conclusions can be reached.

SRI's access to text-analytics and other methodologies allowed the research team to develop and compare multiple pools of energy professionals, some comprising IAC graduates and some comprising matched pools of non-participants, defined in a variety of ways and drawn from the population as a whole (e.g., selected based on degree, academic institution, and current job). Profiles for the matched pool of non-IAC participants were collected via a database that contains profiles of over 120 million workers in the United States and includes data on individuals' geographic location, job and education history, and skills.

Similar to the evaluation of energy savings impact, SRI's approach to evaluating student development impact is sufficiently comparable to the approach used in 2015 so that results from the time-separated evaluations could be compared. One notable difference is that the previous research team was able to collect data on energy professionals directly from employee networking sites such as Indeed and LinkedIn, which allowed for examination and comparison of individuals' time spent in the workforce. These sites have since tightened access to this data, so in the more recent evaluation, SRI was unable to establish comparison groups using graduation date and career length as metrics. Consequently, SRI cannot rule out that differences in metrics between IAC alumni and comparison groups is not due to different career lengths, though SRI believes this to be an unlikely explanation for the results presented later.

Potential Support for the STW

The small- and medium-sized manufacturers served by the IAC program depend to a great extent on the STW. Workers in this population have high technical skill and knowledge levels but do not have a bachelor's degree or higher. SRI sought to understand how well academic programs that result in an associate degree or certificate are actually developing their students' skills and preparing them for meaningful contribution to the energy efficiency sector.

Drawing on a national dataset housed at the National Association of State Workforce Agencies (NASWA), SRI scraped desired skills embedded in job postings by manufacturers associated with the IAC program. SRI then mapped the most frequently appearing energy-oriented skills against STW curriculum available via the Integrated Postsecondary Education Data System (IPEDS), a national federally mandated dataset. This allowed SRI to gauge whether the education received by the STW is indeed helping to develop skills sought by manufacturers and to further think about how the IAC program could potentially support the STW as it increases engagement with institutions (e.g., community colleges, technical schools, and union training programs) that train the STW, as well as engagement with the students themselves.

Methodology

SRI's evaluation of the IAC program focused on the two principal objectives of the program: generate energy savings at small- and medium-sized manufacturers and develop valuable energy efficiency skills in the students who participate. This section details the methods used to collect and analyze data for those two components of the evaluation. Methodologies for the exploration of the STW can be found in Appendix A.

In most cases, SRI employed the same evaluation techniques that were used in SRI's 2015 evaluation of the IAC program. SRI's evaluation this time focused on outcomes associated with the program between 2014 and 2020. In addition to the quantitative data collected for this evaluation, described below, SRI also conducted interviews with 18 program stakeholders to gather qualitative data on program impacts and best practices. Main themes from these interviews are described in the Insights from Interviews with IAC Stakeholders section.

Energy Savings Evaluation Methodology

To measure the energy savings obtained at small- and medium-sized manufacturers that participated in the IAC program, SRI reviewed the records of IAC recommendations and prepared calculations of energy savings based on these records. The calculations are prepared using the same methodology as SRI's 2015 evaluation; please refer to Appendix B for more background on how SRI's 2015 evaluation methodology was developed.

Data Sources and Collection

The primary source for SRI's estimates of energy savings is the IAC database. The IAC database is based on detailed measurement of all energy-consuming equipment and systems in the population of small- and medium-sized manufacturers that participated in the IAC program. The IAC database also contains records of implementation of IAC recommendations, collected six to nine months after the energy audit during a follow-up interview. Energy savings can be estimated based on the IAC recommendations that are implemented.

However, there are some challenges regarding the energy savings estimates from the IAC database. First, the IAC client may change implementation plans after the six to nine-month follow-up call. Second, the data do not include information about persistence (how long are measures retained and how quickly do they degrade). Finally, the IAC data do not indicate what portion of the implemented energy savings is attributable to the IAC program; the IAC clients may have already considered implementing these energy savings even if they had not participated in the IAC program. To address these concerns, SRI designed and implemented a supplemental implementation survey of IAC clients that received assessments from FY2014 to FY2020. The questions used in this survey instrument can be found in Appendix C. Of the 3,197 assessments that were completed during FY2014–FY2020, SRI received responses from 95 clients. This included 78 responses that were fully completed and 17 incomplete responses.

Data Analysis

To understand the impacts of implementing IAC recommendations, SRI prepared calculations related to *gross energy savings*, *gross carbon emissions avoided*, and *net energy savings*.

Gross energy savings are the changes in energy consumption that resulted from implementing the energy efficiency recommendations made by the IAC. This can be calculated by summing the energy saving estimates from the IAC database for recommendations that were marked as implemented during the six to nine-month follow-up call. This value does not consider whether the implementation of the energy efficiency action was due to the IAC recommendation or whether the client had been considering implementing such an action before contacting the IAC. To consider the possibility that some of the recommendations were only partially implemented, SRI conducted a follow-up implementation survey of IAC clients and asked clients if the recommendations were implemented in full or partially implemented, and the *gross energy savings* were updated accordingly based on the survey responses. The *gross energy savings* are based on the assumption that the energy savings persist for one year following implementation.

Gross carbon dioxide emissions avoided are the carbon dioxide emissions that are avoided based on the reduction of energy consumption after implementing the IAC recommendation. This is calculated by multiplying the *gross energy savings* for each energy stream conserved (i.e., electricity consumption, natural gas, fuel oils, coal, etc.) by the corresponding U.S. Energy Information Agency carbon coefficient[3] to obtain a baseline estimate of the overall carbon dioxide emissions avoided. Similar to the *gross energy savings*, the *gross carbon dioxide emissions avoided* are based on the assumption that the energy savings persist for one year following implementation.

Net energy savings are the changes in energy consumption that are attributable to the IAC program. The objective of the net energy savings calculations is to separate energy savings that are attributable to the IAC program from energy savings that are not attributable to the IAC program. For instance, an IAC client may have been considering the energy efficiency measures before receiving an IAC energy audit. An IAC client may have also considered implementing an energy saving measure after consulting with an external group other than IAC. The IAC database records only include information about *gross energy savings* and not *net energy savings*. Therefore, to calculate the *net energy savings* that are attributable to the IAC program, SRI asked IAC clients in the follow-up implementation survey whether they would have engaged alternative energy audit providers or if they had any plans to implement energy saving measures before conducting the IAC energy audit. Based on the findings, SRI removed from the *gross energy savings* the energy savings associated with any energy efficiency measure if the implementing IAC client indicated that they would have pursued energy audits from another provider in the absence of the IAC program, or if the IAC client had plans to implement the energy efficiency measures prior to the IAC assessment. If the IAC client did not know if plans were in place to implement energy efficiency measures prior to the IAC assessment, these energy savings were also removed from the *gross energy savings* in order to calculate the *net energy savings*.

Student Development Evaluation Methodology

To evaluate how effective the IAC program is at developing valuable skills in participating students, SRI collected employee profile data on students who participated in the program at some point between 2014 and 2020 and who are no longer participating in the program. This included alumni at 39 higher education institutions. (The list of institute IACs included in the analysis can be found in Appendix D.)

Additionally, SRI collected employee profile data on individuals from two comparison groups. The first comparison group, referred to as the *cohort* group, consists of non-IAC participating individuals who graduated from one of the 39 institutions included in the alumni group with similar majors. The second comparison group, referred to as the *energy* group, consists of individuals who did not

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[3] U.S. Energy Information Administration, “Carbon Dioxide Emissions Coefficients,” (February 2022), https://www.eia.gov/environment/emissions/co2_vol_mass.php.

graduate from one of the 39 institutions included in the alumni group and have similar job titles. How these two comparison groups were matched is detailed below.

Because SRI is unable to analyze the skillset of IAC alumni before they participated in the program, the use of the two comparison groups allows us to better evaluate the impact of the IAC program and eliminate alternative explanations for the skills they possess. Specifically, the *cohort* comparison group allows us to control for the possibility that IAC alumni developed their skillset from the courses in their degree program. Furthermore, there is a risk of selection bias, as students who participate in the IAC program are likely more interested in energy efficiency careers pre-participation. The *energy* comparison group allows us to reduce that bias and control for the possibility that alumni developed their skillset post-participation through energy efficiency jobs.

Data Sources and Collection

For the IAC alumni group, SRI gathered profile data using two methods. First, a member of the IAC field management team at Rutgers emailed all IAC alumni for whom they have an email address in their database. This email explained the nature of SRI's evaluation of the IAC program and requested that alumni send their most current resumes to SRI for us to use in our skills analysis work. From this request, SRI received 93 alumni resumes, 47 of which were for individuals who participated in the IAC program at any point between 2014 and 2020.

To collect data on more IAC alumni, SRI then gathered employee profile data using a database called Emsi Burning Glass. This database contains individual profiles of over 120 million workers in the United States, providing data on individuals' geographic location, job and education history, and skills. While Emsi does not publish a list of their sources for proprietary and confidentiality reasons, these profile data likely come primarily from websites such as Glassdoor and Indeed by which individuals upload their own resume and job qualification data.

SRI searched Emsi's profile database using two parameters: Profiles were filtered to only include individuals who attended one of the 39 IAC academic institutions and who have the key phrase "industrial assessment" somewhere in their profile data. For the resulting profiles, SRI matched the names on the Emsi profiles with those on the list of IAC alumni provided to SRI by the Rutgers field management team to filter out any individuals who coincidentally had "industrial assessment" in their profile data but were not identified alumni of the IAC program. This resulted in profile data for an additional 308 IAC alumni, 190 of whom participated in the program at some point between 2014 and 2020.

To estimate IAC participation dates for alumni, SRI used the dates recorded in Rutgers' alumni database for first and last IAC assessment. Though it is almost certain that each alumnus was involved in the IAC program before the recorded date of their first assessment and after the recorded date of their last assessment, this statistic has the most data for approximating alumni participation dates. For alumni for whom employee profile data were collected, either through the emailed resume request or through Emsi, if there were no recorded dates for first and last assessment, SRI filled in participation dates based on what was recorded on that individual's resume or LinkedIn profile. If dates of participation could not be found, that individual's profile data were excluded from the dataset SRI used for analysis.

In total, SRI collected employee profile data for 401 IAC alumni, of whom 236 participated in the IAC program during the time frame SRI examined. This represents 20.3% of all alumni who participated in the IAC program during the time frame examined.[4]

For the two comparison groups that SRI analyzed, SRI relied on data retrieved from the Emsi database. For the *cohort* comparison group, SRI searched the Emsi profile database along four parameters. First, individuals must have attended one of the 39 academic institutions examined in this report. Second, they must have obtained a bachelor's degree or higher. Third, they must have obtained a degree in mechanical engineering, industrial engineering, or chemical engineering. These three degree fields were examined as they comprised 96% of the majors of IAC alumni in the time frame examined for which we have data. Fourth and finally, individuals must not have the key phrase "industrial assessment center" in their profile data. After removing duplicate profiles, this query resulted in employee profile data for 868 individuals.

One important note is that in SRI's 2015 evaluation, comparison group data were collected using a different method through which we were able to narrow the profile search to individuals who graduated within two years of the date range examined. For this evaluation, we were not able to limit our query by graduation date, so individuals in the cohort comparison group could have spent a different amount of time in the workforce. Because less than two years passed since individuals in our focus group participated in the program and by necessity were still students, it is unlikely many individuals in our *cohort* comparison group have fewer years of work experience than individuals in our alumni focus group. As a result, in our analysis, we assume that differences in skillsets of the two groups are not attributable to the *cohort* comparison group having less work experience, though this potential cannot be eliminated.

For the *energy* comparison group, SRI searched the Emsi profile database along three parameters. First, individuals must not have attended one of the 39 academic institutions examined in this report. Second, the standardized job title of the position provided must be energy analyst, energy auditor, energy efficiency engineer, energy engineer, or energy manager. These five jobs were examined as they correspond to either job titles used in the previous SRI evaluation and/or the most common job titles found in IAC alumni profile data.[5] Third and finally, individuals must not have the key phrase "industrial assessment center" in their profile data. After removing duplicate profiles, this query resulted in employee profile data for 6,099 individuals.

In SRI's first evaluation of the IAC program, the *energy* comparison group was weighted by career length to correspond with that of the alumni group. Again because of the way data were collected for this evaluation as compared to the prior one, we were unable to measure the time in the workforce for the alumni or comparison groups, so this weighting was not done. However, for the same reasons discussed previously regarding the *cohort* comparison group, it's unlikely that the individuals in the *energy* comparison group have on average spent a greater amount of time in the workforce than have IAC alumni.

Data Analysis

SRI's analysis of the impact of the IAC program on student participants focused on two aspects: the skills developed and the careers entered. For most cases, SRI used the same tools to measure these aspects as were developed and employed for SRI's prior evaluation.

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[4] Ratio is based only on IAC alumni for whom we have data that can be used to approximate dates of participation.

[5] Overly generic job titles that appeared frequently in alumni profile data, such as "project manager" and "engineer," were excluded from the search query.

To evaluate the skillsets of IAC alumni and members in both comparison groups, the entire content of an individual's resume or Emsi profile was searched for skills. SRI used the dictionary of nearly 9,000 skills identified by the Brookings Institution in their 2014 study of the STEM workforce involving an analysis of millions of job postings.[6] The Brookings skill dictionary also includes the average salary of job postings associated with each skill. From that list of 9,000 skills, SRI previously identified approximately 550 skills that are associated with energy efficiency activities. These two lists—of energy efficiency skills and general skills—are the same lists as were employed in the skills analysis for SRI's prior IAC evaluation.

To evaluate the career paths of IAC alumni and individuals in the *cohort* comparison group, SRI used the automated text classifier built for our previous evaluation to assign an O*NET code[7] to each profile based on job title and description. When this classifier was developed in 2015, it achieved a 96% accuracy when tested against a randomly selected sample of 200 job descriptions classified manually by a human analyst. Because not all profiles included a job description, this classification was limited to 70 alumni profiles and 306 *cohort* group profiles.

Unlike the process used for the previous evaluation, this time SRI did not use the previous classifier to subsequently determine whether a job was associated with energy efficiency. Instead, SRI developed a list of O*NET codes that we determined to be associated with energy efficiency and compared that list to the assigned O*NET code for each individual. This list of O*NET codes and their descriptors for IAC alumni and members of the *cohort* comparison group can be found in Table 29.

New with this evaluation is the analysis of skill development broken down by gender. Of the 4,656 individuals in Rutgers' alumni database, only 873 of them had a gender recorded. Thus, to more thoroughly analyze the impact of IAC participation by gender, SRI classified the gender of the remaining IAC alumni using a publicly available R package called *gender* that uses historical datasets to infer gender based on first name.[8] When the gender predicted by this package was compared to the gender recorded for the 873 alumni with existing data, it achieved a 72% accuracy. More complete reporting of IAC participants' gender would be a welcome step toward better understanding of the impacts of the IAC program and the program's ability to recruit more women, who are traditionally underrepresented in engineering fields.

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[6] Jonathan Rothwell, "Still Searching: Job Vacancies and STEM Skills," Brookings Institution (July 2014), https://www.brookings.edu/interactives/still-searching-job-vacancies-and-stem-skills/.

[7] The Occupational Information Network (O*NET) is a database sponsored by the U.S. Department of Labor containing hundreds of standardized descriptors of almost 1,000 occupations covering the entire U.S. economy.

[8] Cameron Blevins and Lincoln Mullen, "Jane, John … Leslie? A Historical Method for Algorithmic Gender Prediction," *Digital Humanities Quarterly* 9:3(2015), http://www.digitalhumanities.org/dhq/vol/9/3/000223/000223.html.

IAC Program Impact on Energy Savings

This section reports on the primary goal of the IAC program, which is the energy efficiency impact on small- and medium- sized manufacturers, including energy savings and reduction of carbon emissions. The findings are based on the IAC Assessment Database as well as SRI's supplemental implementation survey of client firms. SRI's assessment shows the following key findings:

- 94.5 million MMBtu gross energy savings across the United States during FY2014–FY2020, based on data from the IAC database.
- ~60% of IAC recommendations were implemented or had a concrete plan to be implemented within one year.
- 75% of clients would not have sought an energy assessment if the IAC program had not been available to them the year that they received their assessment.
    - The main reasons for this include a lack of suitable service provider (35%), time not available (19%), and budget not available (17%)
- Gross energy savings from wastewater treatment plants (33.3 million MMBtu) is approximately 35% of the total gross energy savings during FY2014–FY2020.
- Table 10 shows summary statistics of the IAC program impact on energy savings for the current report period (FY2014–FY2020) and the 2015 report (FY2009–FY2013):
    - Compared to FY2009–FY2013, there is a substantial increase in the gross energy savings estimated from the IAC database in FY2014–FY2020, which can be attributed in large part to recommendations involving water management.
    - The total IAC program budget for FY2014–FY2020 ($59.7 million, 2020-dollar basis) is approximately twice the total IAC program budget during FY2009–FY2013 ($28.3 million, 2020-dollar basis).
    - The average one-year gross energy savings per IAC program dollar spent in FY2014–FY2020 (1.584 MMBtu/Dollar) is 3.1 times higher than during the FY2009–FY2013 report period (0.510 MMBtu/Dollar).
    - The average one-year gross energy savings per private investment dollar mobilized in FY2014–FY2020 (0.312 MMBtu/Dollar) is 3.8 times higher than during the FY2009–FY2013 report period (0.083 MMBtu/Dollar).

	FY2014–FY2020	FY2009–FY2013
Number of IAC Assessments	3,197	2,158
Number of Recommendations made to firms	24,208	17,329
% of Recommendations Implemented	45%	44%
Share of Recommended Energy Management Savings Implemented (MMBtu)	35%	33%
Gross Energy Savings estimated from IAC database (MMBtu)	94.5 million	14.4 million
Total Program Budget (2020 US $)	59.7 million[9]	28.3 million[10]
Total Private Investment Mobilized (2020 US $)	303.4 million	174.2 million[11]
Average 1-Year Gross Energy Savings (MMBtu) per Program Dollar (2020 US $)	1.584	0.510
Average 1-Year Gross Energy Savings (MMBtu) per Private Investment Mobilized (2020 US $)	0.312	0.083
Average 1-Year Gross Energy Savings (MMBtu) per Dollar Invested* (2020 US $) ***Included program dollars and private investment mobilized**	0.260	0.071

Table 10. Summary statistics of IAC program impact on energy savings

Key Terms and Definitions

Evaluations of energy conservation and efficiency programs focus primarily on two impacts: (1) Estimates of **gross energy savings** and (2) estimates of **net energy savings.** Depending on the type of program(s) under review, evaluations may also look at other non-energy benefits and outcomes, such as avoided emissions, increased/decreased maintenance costs, or job creation. Evaluations may also include estimates of the **persistence** of energy savings, but typically they do not because of the high costs and complexity of measurement. Please refer to Appendix B for a discussion of how the study methodology was developed.

Gross energy savings are the change in energy consumption (or demand) from program-promoted actions taken by participants, regardless of the extent to which the program influenced their actions. Estimates of gross energy impacts involve a comparison of changes in energy use over time among participants who installed measures against some baseline level of usage.

Net energy savings are the portion of the change in energy consumption attributable to the program. Estimating net energy impact typically involves assessing free-ridership and spillover. “Free-ridership” refers to the portion of energy savings that participants would have achieved

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[9] Program budget estimated based on $7 million annual spend in FY2014-FY2016, $9 million annual spend in FY2017-FY2020, and adjusting for inflation. Inflation adjustments in this report are based on the US Bureau of Economic Analysis’ Implicit Price Deflators for GDP (https://apps.bea.gov/iTable/iTableHtml.cfm?reqid=19&step=3&isuri=1&1921=survey&1903=13)

[10] Value adjusted for inflation; was previously reported as $25.3 million in the 2015 SRI Report using 2013 US dollar basis.

[11] Value adjusted for inflation; was previously reported as $156 million in the 2015 SRI Report using 2013 US dollar basis.

through their own initiatives and expenditures without participating in the program. Participant "spillover" refers to the situation in which a participant installed equipment prompted by the program and then installed additional equipment due to program influences, but without direct program support. The comparison between net and gross savings is called the net-to-gross ratio (NTGR).

Gross savings and net savings estimates focus on first-year savings, so evaluations looking for energy savings beyond the first year of installation require an analysis of **persistence**. Definitions for persistence are not nationally consistent, but the concept generally encompasses both the retention and performance degradation of energy efficiency measures.

Client Impact Estimates

The IAC database is the primary data source for the estimates of energy savings, implementation patterns, and other key outcomes presented in this section. Since the IAC recommendations provided detailed energy saving estimates in terms of Metric Million British Thermal Units (MMBtu), the gross energy savings can be calculated by summing the energy savings estimates associated with all implemented recommendations for FY2014 through FY2020.

However, the data are subject to three key limitations: (1) the implementation status of IAC recommendations is recorded based on a follow-up phone call, which typically occurs six to nine months after the assessment, (2) the data do not provide insight into what might have happened in the absence of the IAC program, and (3) the data provide no information about persistence: how quickly do energy efficiency measures degrade, and how long are they retained? To address these questions, the SRI team designed and implemented a short web-based survey of a sample of firms that received IAC assessments from FY2014 to FY2020.

The results from the SRI client supplemental implementation survey are utilized to (1) better understand the sensitivity of gross energy savings estimates to different assumptions about implementation, (2) provide insight into what a manufacturer would have done in the absence of the IAC program (affecting the net energy savings rates), and (3) better understand the persistence of implemented measures.

However, results should not be interpreted as representative of the entire IAC client population but instead as illustrative of how the program works for some firms. Additional details about the instrument and protocol can be found in Appendix C.

Gross Energy Savings

The gross energy savings estimates are based on the IAC database, summed for all **implemented recommendations**. An *implemented* recommendation is defined as in place at the time of the follow-up call or with definite plans in place for completion within 12 months of the call (and not more than 24 months from the assessment date). The IAC database does not distinguish between a measure that is partially versus fully implemented and does not account for changes in implementation plans after the follow-up call.

To better understand how sensitive our gross energy savings estimates might be to these data gaps, we examined the results of the SRI supplemental implementation survey in comparison to the IAC database records. The client supplemental implementation survey response group implemented approximately 59% of recommendations. In the survey, these respondents indicated that they had implemented 37% of recommendations in full and 22% of recommendations in part, as shown in Figure 6. Respondents also reported that while most recommendations were implemented within a year (60%) or two (33%), the remaining 8% of recommendations were implemented more than two years after the assessment, as shown in Figure 7.

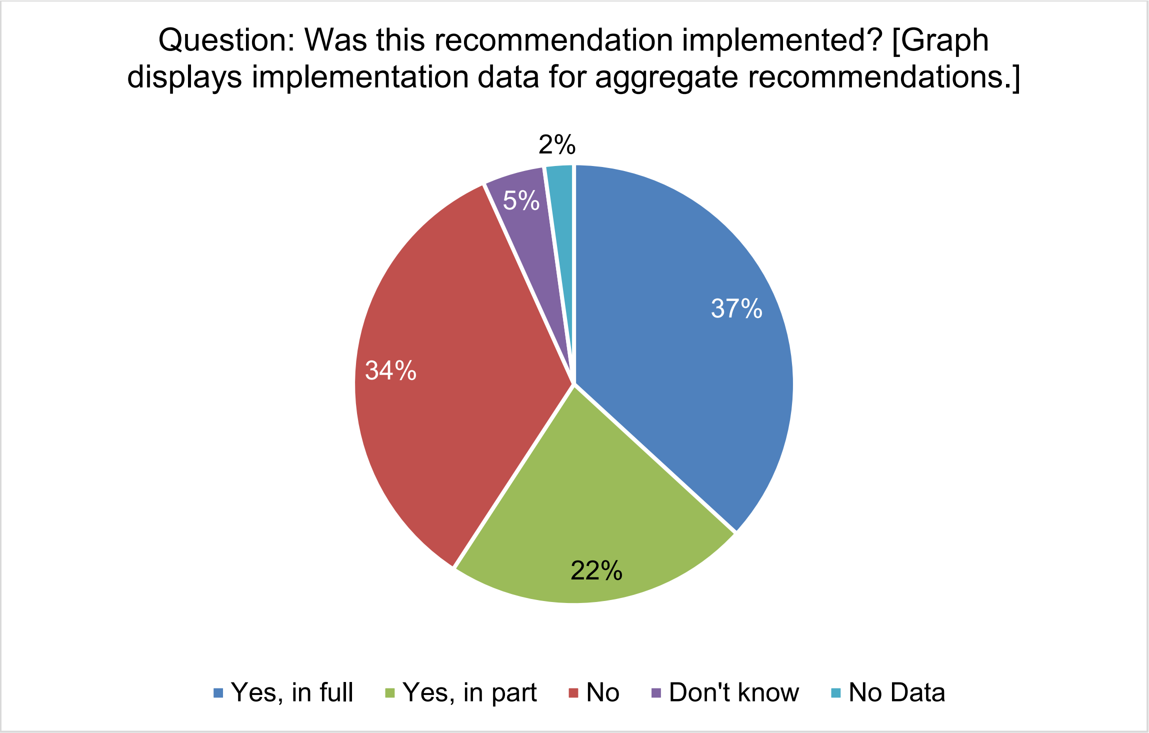

Figure 6. Percentage of recommendations implemented

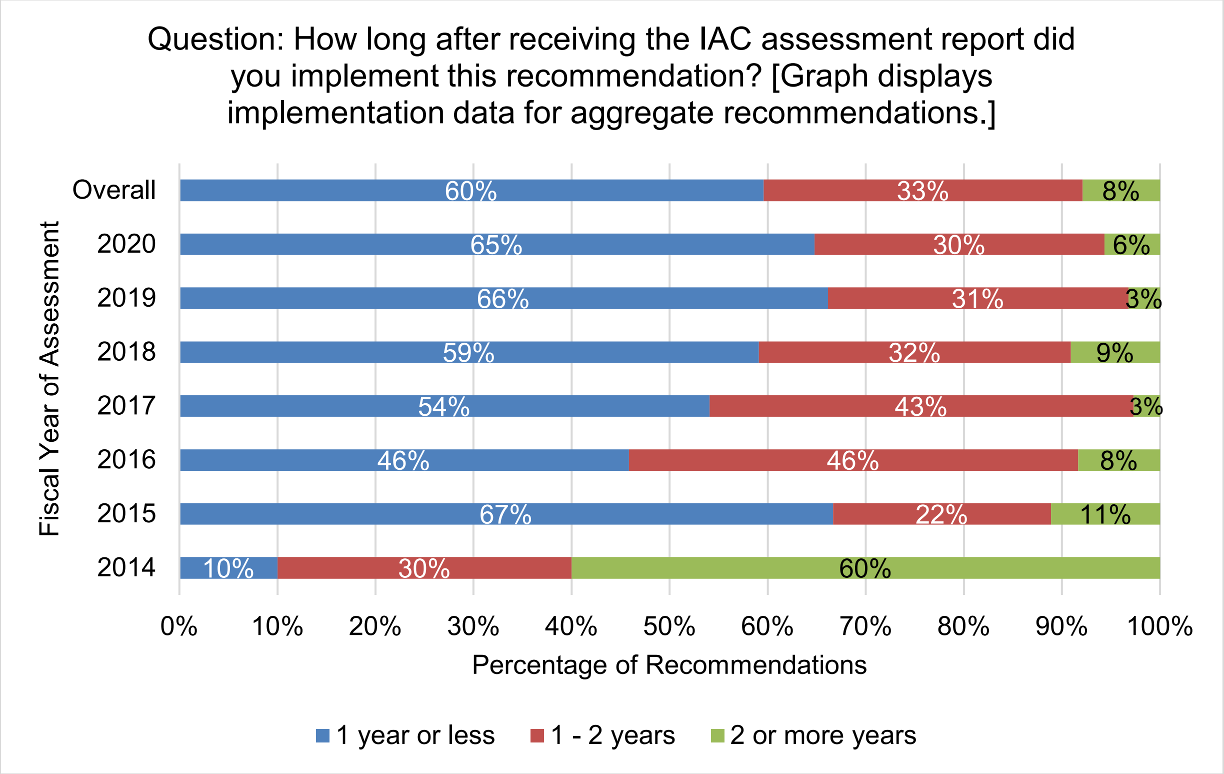

Figure 7. Length of time to implement recommendations[12]

There is a risk of overestimating the gross energy savings if we simply sum the energy savings from all implemented recommendations (as this assumes that all implemented recommendations were fully implemented, while the supplemental implementation survey results show that 22% of all recommendations were implemented partially). In the survey response group, the IAC database estimates a gross energy savings of 0.699 million MMBtu (this is a one-year estimate and does not take into consideration possible persistence of savings in future years).

Scenarios	**Gross Energy Savings Implemented by Survey Respondents (MMBtu)**	**Percentage of Baseline Estimate**
IAC Database	0.699 million	Baseline
IAC Client Supplemental Implementation Survey		
0% Partial Implementation (lower bound)	0.342 million	49%
25% Partial Implementation	0.424 million	61%
50% Partial Implementation	0.507 million	73%
75% Partial Implementation	0.590 million	84%
100% Partial Implementation (upper bound)	0.672 million	96%

Table 11. Gross energy savings implemented by supplemental survey respondents

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[12] Percentages may not total 100% due to rounding. FY2014 responses are anomalistic due to the relatively low number of respondents representing that year.

Different scenarios of gross energy savings are prepared by assuming that the partial implementation energy savings were 0%, 25%, 50%, 75%, and 100% of the fully implemented energy savings. The estimated gross energy savings for these cases, as well as how they compare to the baseline estimate from the IAC database, are listed in Table 11. Based on the different rates of partial implementation, the gross energy savings from the survey response group range from 0.342 to 0.672 MMBtu (49% to 96% of the baseline gross energy savings determined from the IAC database). This variation in the gross energy savings estimate demonstrates that the gross energy savings is sensitive to the level of partial implementation.

Although the survey response group is only a small subset of the entire IAC client population, we can use the findings from the survey to assess how partial implementation of recommendations affects the gross energy savings estimate for the overall IAC client population. In Table 12, we see that the baseline gross energy savings of the IAC client population from FY2014–FY2020 is 94.5 million MMBtu. After taking into consideration the rates of partial implementation from Table 11, the gross energy estimates for the overall IAC population are between 46.3 to 90.7 million MMBtu.

Gross Carbon Dioxide Emissions Avoided

In addition to estimating gross energy savings, the carbon dioxide emissions avoided by implementing the IAC recommendations can also be estimated. For each recommendation, the IAC database tracks the associated change in energy consumption separately for different energy streams (i.e., electricity consumption, natural gas, different fuel oils, coal, etc.). Using implementation records from the IAC database, we can then multiply the gross energy savings for each energy stream by the appropriate carbon coefficient to get our baseline estimate of overall carbon dioxide emissions avoided.[13]

Table 12 shows that the baseline estimate of overall carbon dioxide emissions avoided by implementing the IAC recommendations is 2.37 million metric tons. When considering the impact of the different rates of partial implementation of IAC recommendations, the overall carbon dioxide emissions avoided ranges from 1.16 to 2.27 million metric tons.

Gross Implementation Costs

One of the objectives of the evaluation is to estimate the private industry implementation costs to attain the reported energy savings. To accomplish this, the first step is to calculate the implementation costs associated with the baseline gross energy savings. Based on the implementation costs reported in the IAC database, the baseline implementation cost for the overall IAC client population from FY2014–FY2020 is $303.4 million in 2020 dollars, as shown in Table 12. With a total gross energy savings of 94.5 million MMBtu, the private industry implementation cost is approximately $3.21 per MMBtu of gross energy savings. When considering the impact of different rates of partial implementation, the implementation costs range from $148.6 to $291.2 million (2020-dollar basis) (the implementation costs are still based on $3.21 per MMBtu of gross energy savings). An estimate of the implementation costs that can be attributed to the IAC program is located in Net Implementation Costs.

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[13] We use U.S. average emission coefficients for electricity generation (http://www.eia.gov/electricity/state/unitedstates/) and fuels (http://www.eia.gov/environment/emissions/co2_vol_mass.cfm).

	Gross Energy Savings FY2014 to FY2020 (MMBtu)	CO_2 Avoided FY2014 to FY2020 (metric tons)	Implementation Costs (2020 US $)
IAC Database (baseline)	94.5 million	2.37 million	303.4 million
Range Estimates			
49% of baseline (0% Partial Implementation)	46.3 million	1.16 million	148.6 million
61% of baseline (25% Partial Implementation)	57.6 million	1.44 million	185.0 million
73% of baseline (50% Partial Implementation)	69.0 million	1.73 million	221.5 million
84% of baseline (75% Partial Implementation)	79.4 million	1.99 million	254.8 million
96% of baseline (100% Partial Implementation)	90.7 million	2.27 million	291.2 million

Table 12. Gross energy savings, CO_2 avoided, and implementation costs, FY2014–FY2020

	Gross Energy Savings FY2009 to FY2013 (MMBtu)	CO_2 Avoided FY2009 to FY2013 (metric tons)
IAC Database (baseline)	14.4 million	1.7 million
Range Estimates		
51% of baseline	7.4 million	0.87 million
70% of baseline	10.1 million	1.19 million
90% of baseline	13.0 million	1.53 million
109% of baseline	15.7 million	1.85 million
129% of baseline	18.6 million	2.19 million

Table 13. Gross energy savings and CO_2 avoided, FY2009–FY2013

Table 13 shows the gross energy savings and carbon dioxide avoided in the 2015 SRI evaluation from FY2009–FY2013. Although the study report period is longer in this evaluation (seven years) compared to the previous evaluation (five years), the reported baseline gross energy savings are considerably higher in FY2014–FY2020 (94.5 million MMBtu) as compared to FY2009–FY2013 (14.4 million) and cannot be explained by dividing both values by the length of evaluation period to form a common basis (FY2014–FY2020 had 13.5 million MMBtu/fiscal year of baseline gross energy savings, and FY2009–FY2013 had 2.9 million MMBtu/fiscal year of baseline gross energy savings). Some of the major differences in the gross energy savings might be attributed to the implementation of water management recommendations as identified in Table 8 in FY2014–FY2020; these water management recommendations show the highest level of energy savings out of all recommendations.

When comparing the carbon dioxide emissions avoided between the two evaluation periods, the carbon dioxide emissions avoided in FY2014–FY2020 are higher than in FY2009–FY2013, but not to the same order of magnitude as the differences in gross energy savings. This could be due to differences in energy sources being conserved and the different carbon emissions profiles of those energy sources.

Net Energy Savings

As previously mentioned, the IAC database records only include information for gross energy savings and not for net energy savings that are directly attributable to the IAC program. To calculate the net energy savings, SRI needed to know whether manufacturers would have obtained a similar energy savings assessment in the absence of the IAC program and if they would have implemented some of the energy efficiency measures even if they had not received an energy savings assessment.

These questions were included in the SRI supplemental implementation survey of clients, and the responses are shown in Figure 8. The vast majority of the survey response group (75%) would not have sought an energy assessment that year if the IAC program had not been available to them, and the reasons are listed in Figure 9. The main reasons why IAC clients would not have sought an alternative energy assessment are a lack of a suitable service provider (35%), time not available (19%), and budget not available (17%). The responses show the importance of the IAC program and how IAC clients depend on the IAC to perform energy assessments at no cost.

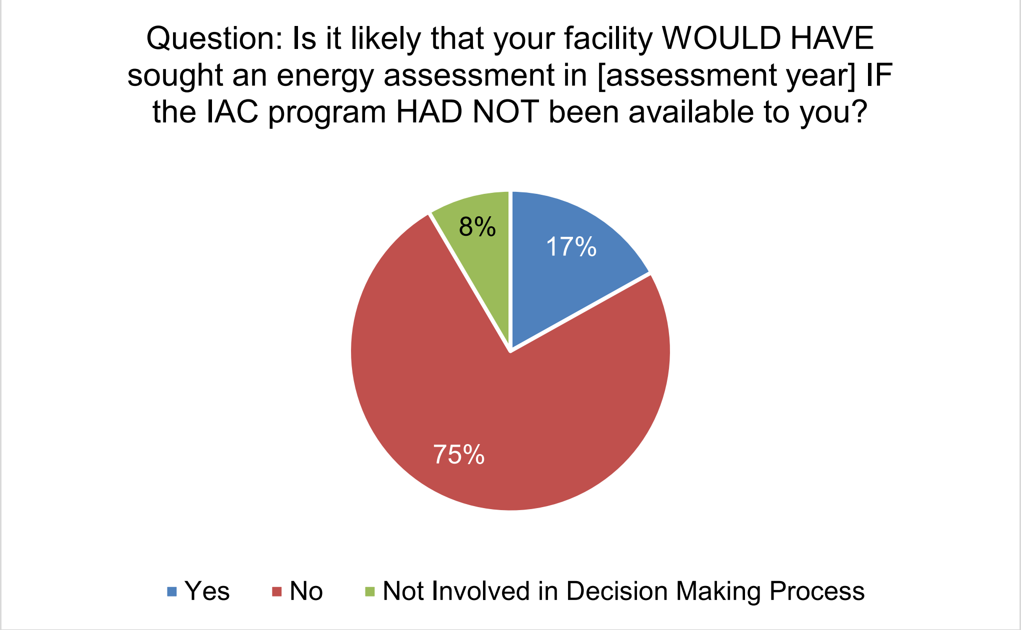

Figure 8. IAC clients who would have sought energy assessment from alternative provider

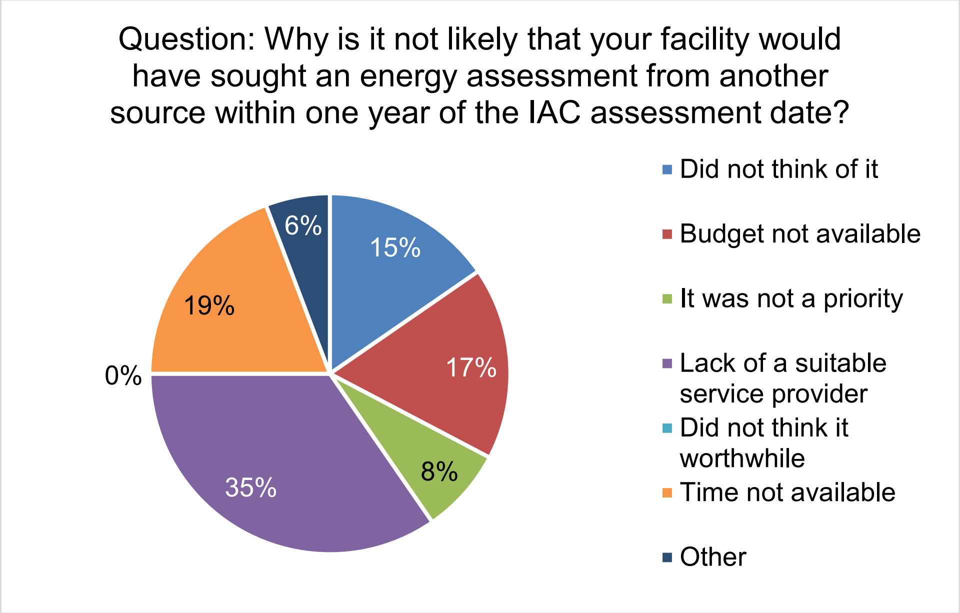

Figure 9. Reasons for not considering alternative energy assessment

In the SRI client supplemental implementation survey, respondents were asked if they had plans to take the recommended actions prior to the IAC team site visit. Figure 10 shows that 87% of the recommendations did not have plans for implementation before the IAC team's site visit, but in over half of these cases, the idea was under consideration (45%). Of the recommendations, 9% were already planned for implementation before the IAC team site visit.

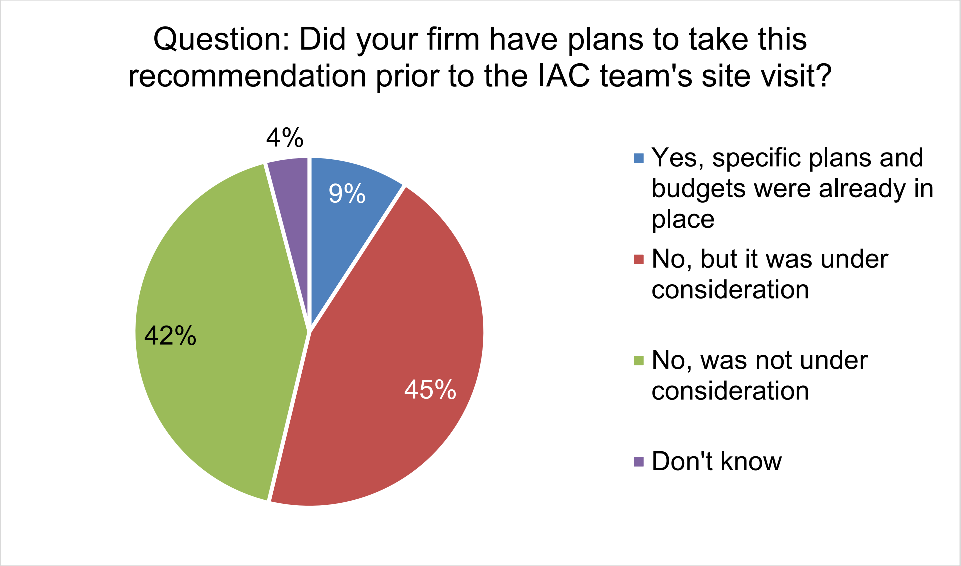

Figure 10. Recommendations under consideration before IAC energy assessment

Based on these results from the supplemental implementation survey, we are able to estimate the approximate net savings and net-to-gross savings ratio for the respondent firms. To produce these estimates, we develop two different cases of net energy savings based on different assumptions. In the first case of net energy savings (Case 1), we remove savings from all recommendations to IAC clients that indicated they would have sought an assessment from another source. We also remove savings from any recommendations that respondents indicated were already planned at the time of the assessment. In Case 1, we find that the one-year net energy savings are about 67%-68% of the gross energy savings estimate for the survey response group, as seen in Table 14.

In the second case of net energy savings (Case 2), we remove the energy savings that are described in Case 1. However, we also remove the recommendations that were not already planned but were considered before the IAC team's site visit. In Case 2, we find that the one-year net energy savings are about 32%-41% of the gross energy savings estimate for the survey response group, as seen in Table 14.

Scenarios of Partial Implementation in Survey Respondents Group	Gross Energy Savings Implemented by Survey Respondents (MMBtu)	Net Energy Savings Case 1 Implemented by Survey Respondents (MMBtu)	Net-to-Gross Ratio Case 1 (%)	Net Energy Savings Case 2 Implemented by Survey Respondents (MMBtu)	Net-to-Gross Ratio Case 2 (%)
0% Partial Implementation (lower bound)	0.342 million	0.232 million	68%	0.142 million	41%
25% Partial Implementation	0.424 million	0.287 million	68%	0.159 million	38%
50% Partial Implementation	0.507 million	0.341 million	67%	0.177 million	35%
75% Partial Implementation	0.590 million	0.396 million	67%	0.194 million	33%
100% Partial Implementation (upper bound)	0.672 million	0.450 million	67%	0.212 million	32%

Table 14. Net energy savings and net-to-gross ratios for net energy savings Cases 1 and 2

The net-to-gross ratios that we developed in Table 14 are based on the recommendation implementation as reported in the SRI Client Supplemental Implementation Survey, dividing the net energy savings from the survey results from the gross energy savings from the survey respondent group. To estimate the net energy savings of the greater IAC population, we can approximate the net-to-gross ratios from the survey respondent group and apply them to the baseline gross energy savings calculated from the IAC database. Caution should be applied when interpreting the net energy saving estimates for the overall population, since the survey response rate is low. In Table 15, the net energy savings are shown for three cases: 70% (representing NTGR Case 1), 40% (representing the higher end of NTGR Case 2), and 30% (representing the lower end of NTGR Case 2).

Gross Energy Savings Baseline from IAC database	94.5 million MMBtu				
Partial Implementation Rate	**0%**	**25%**	**50%**	**75%**	**100%**
Gross Energy Savings (MMBtu) Estimated from Client Survey	46.3 million	57.6 million	69.0 million	79.4 million	90.7 million
Net Energy Savings (MMBtu)					
70% (NTGR Case 1)	32.4 million	40.4 million	48.3 million	55.6 million	63.5 million
40% (NTGR Case 2 High)	18.5 million	23.1 million	27.6 million	31.8 million	36.3 million
30% (NTGR Case 2 Low)	13.9 million	17.3 million	20.7 million	23.8 million	27.2 million

Table 15. Net energy savings scenarios

There is a wide range in the net energy savings that is attributed to the IAC program. Using NTGR Case 1, the one-year net energy savings range is from approximately 32.4 to 63.5 million MMBtu, depending on the rate of partial implementation. Using NTGR Case 2, in which we use the same assumptions as NTGR Case 1 but also remove the energy savings from recommendations that were not already planned but were considered before the IAC team's site visit, the lower end of the one-year net energy estimates ranges from 13.9 to 27.2 million MMBtu and the higher end of the one-year net energy estimates range from 18.5 to 36.3 million MMBtu.

Net Carbon Dioxide Emissions Avoided

The net carbon dioxide emissions avoided can be estimated using the same net-to-gross ratios as used to calculate the net energy savings and are shown in Table 16. Using NTGR Case 1, the one-year net carbon dioxide emissions avoided ranges from approximately 0.8 to 1.6 million metric tons, depending on the rate of partial implementation. Using NTGR Case 2, the lower end of the one-year net carbon dioxide emissions avoided ranges from 0.3 to 0.7 million metric tons and the higher end of the one-year carbon dioxide emissions avoided ranges from 0.5 to 0.9 million metric tons.

CO_2 Avoided Baseline from IAC database	2.4 million metric tons				
Partial Implementation Rate	**0%**	**25%**	**50%**	**75%**	**100%**
Gross CO_2 Avoided (metric tons) Estimated from Client Survey	1.2 million	1.4 million	1.7 million	2.0 million	2.3 million
Net CO_2 Avoided (metric tons)					
70% (NTGR Case 1)	0.8 million	1.0 million	1.2 million	1.4 million	1.6 million
40% (NTGR Case 2 High)	0.5 million	0.6 million	0.7 million	0.8 million	0.9 million
30% (NTGR Case 2 Low)	0.3 million	0.4 million	0.5 million	0.6 million	0.7 million

Table 16. Net carbon dioxide emissions avoided

Net Implementation Costs

The net implementation costs represent the costs that manufacturers spent to implement the recommendations that are attributable to the IAC program. These costs are estimated using the same net-to-gross ratios as used to calculate the net energy savings and are shown in Table 17. Using NGTR Case 1, the net implementation cost ranges from approximately $104.1 to $203.9 million (2020-dollar basis), depending on the rate of partial implementation. Using NGTR Case 2, the lower end of the net implementation cost ranges from $44.6 to $87.4 million and the higher end of the net implementation cost ranges from $59.5 million to $116.5 million.

Implementation Costs Baseline from IAC database (2020 US $)	$303.4 million				
Partial Implementation Rate	**0%**	**25%**	**50%**	**75%**	**100%**
Gross Implementation Cost (2020 US $) Estimated from Client Survey	148.6 million	185.0 million	221.5 million	254.8 million	291.2 million
Net Implementation Cost (2020 US $)					
70% (NTGR Case 1)	104.1 million	129.5 million	155.0 million	178.4 million	203.9 million
40% (NTGR Case 2 High)	59.5 million	74.0 million	88.6 million	101.9 million	116.5 million
30% (NTGR Case 2 Low)	44.6 million	55.5 million	66.4 million	76.4 million	87.4 million

Table 17. Net implementation cost scenarios

Persistence

Due to the costly and time-consuming nature of persistence calculations, rigorous estimates of the persistence of energy savings are not typically included in most energy impact evaluations. The information gathered in this analysis is not sufficient to accurately estimate the persistence of energy savings from the IAC program. However, SRI was able to capture some anecdotal data from its client survey. Of implemented recommendations, 77% had no change in the implementation status from the time of implementation to the time of survey response. Less than 1.5% of recommendations a client had implemented were reported to be no longer in place. Of the recommendations, 16% were initially listed as partially implemented and are currently listed as fully implemented; 3% of recommendations were initially listed as fully in place and are currently listed as partially implemented; and the remaining 2.5% of implementations did not provide the current status of implementation. The client survey responses show that the significant majority of implemented recommendations remain in place, with less than 5% of implemented recommendations showing a reduction or elimination of implementation.

Impact of Water Treatment Facilities on Gross Energy Savings

In this section, the implementation of IAC recommendations for water treatment facilities is explored. For the purpose of this evaluation, water treatment facilities are defined with a SIC code of 4952 (Wastewater Treatment Plants) or a SIC code of 4941 (Water Supply Plants).

	Wastewater Treatment	Water Supply	Combined Water Treatment
Number of IAC Assessments	200	71	271
Number of Recommendations Made to Firms	868	290	1,158
% of Recommendations Implemented	51%	41%	49%
% of Energy Savings Implemented	95%	45%	94%
Gross Energy Savings Estimated from IAC Database (MMBtu)	33.3 million	0.246 million	33.6 million

Table 18. Water treatment facilities statistics and gross energy savings

Table 18 shows that the vast majority of gross energy savings can be attributed to wastewater treatment plants instead of water supply plants. The gross energy savings from wastewater treatment plants (33.3 million MMBtu) is approximately 35% of the total gross energy savings observed in the IAC database during FY2014–FY2020.

ARC Code	ARC Code Message	Gross Energy Savings (MMBtu)
3.4115	Recover and Reuse Cooling Water	22,433,102
3.5132	Reuse Rich White Water in Other Applications	8,687,855
2.3415	Use a Fossil Fuel Engine to Cogenerate Electricity or Motive Power; and Utilize Heat	554,230
3.4159	Replace Treated Water with Well/Surface Water	310,125
2.1336	Install Equipment to Utilize Waste Fuel	231,384
2.4322	Use or Replace with Energy Efficient Substitutes	224,092
2.4146	Use Adjustable Frequency Drive or Multiple Speed Motors on Existing System	136,050
2.4133	Use Most Efficient Type of Electric Motors	117,492
2.4226	Use/Purchase Optimum Sized Compressor	94,990
2.7142	Utilize Higher Efficiency Lamps and/or Ballasts	93,270

Table 19. IAC recommendations that account for the highest total gross energy savings in wastewater treatment plants, FY2014–2020

The top recommendations that contributed to the 33.3 million MMBtu gross energy savings in wastewater treatment plants are shown in Table 19. The largest contributors to the gross energy savings are ARC Code 3.4115 (recover and reuse cooling water) and ARC Code 3.5132 (reuse rich white water in other applications), with these two implemented recommendation categories saving over 31.2 million MMBtu of energy.

IAC Program Impact on Student Development

The second main goal of the IAC program is to equip students with the experience and skills they will need for a career in energy efficiency. In fact, many of the IAC Directors that SRI interviewed stated that they see the role of preparing students for the workforce as more important than generating energy savings for manufacturing firms. Through training in the classroom and on the job, IAC students are prepared to recruit facilities, conduct energy audits, and develop recommendations and final reports to present to clients, all in a real-world setting.

From interviews with students and Directors, it is evident that this experience develops a variety of valuable skills in the students that participate, fostering the next generation of energy management professionals. SRI's analysis of the employee profile data of IAC alumni proved this to be the case. Specifically, SRI's analysis yields evidence of five major impacts on students of the IAC program.

- IAC students develop skills beneficial to a career in energy efficiency.
- Students with more participation in the IAC program have more energy efficiency skills.
- IAC alumni possess more valuable energy efficiency skills.
- Male IAC alumni possess more energy efficiency skills than do females.
- IAC alumni are more likely to work in energy efficiency jobs than their peers.

These results are detailed below. Where relevant, results are compared to those from SRI's 2015 IAC evaluation, which examined individuals who participated in the IAC program between 1990 and 2014. Results of statistical testing for outcomes presented below are found in Table 28.

IAC students develop skills beneficial to a career in energy efficiency.

Every current IAC student that SRI interviewed spoke of the value of receiving hands-on training. This experience provides students the chance to conduct energy audits, understand different manufacturing systems, utilize measuring tools, and perform complex calculations, all of which are valuable to a career in energy efficiency. Furthermore, students gain experience marketing the audit opportunity to manufacturing firms, interfacing directly with clients, and writing technical reports. These activities go beyond energy efficiency to develop skills in students that are valued in most fields.

In a comparison of the skills possessed by IAC alumni to non-IAC alumni of the same universities with similar degrees and other energy professionals, IAC alumni possess more energy efficiency skills and more skills in general, as shown in Figure 11. Specifically, IAC alumni possess 72% more energy efficiency skills than do members of their academic cohort, and alumni possess 138% more energy efficiency skills than do other energy professionals.

As discussed in the methodology section, SRI was unable to match members of the two comparison groups by graduation year or time spent in the workforce. Therefore, SRI cannot rule out that the difference in skill counts between these two groups is due to differences in career length. Still, because SRI looked at very recent graduates of the IAC program, we believe it is unlikely that the average member of the comparison group graduated more recently than 2020 and has spent less time in the workforce developing the skills examined.

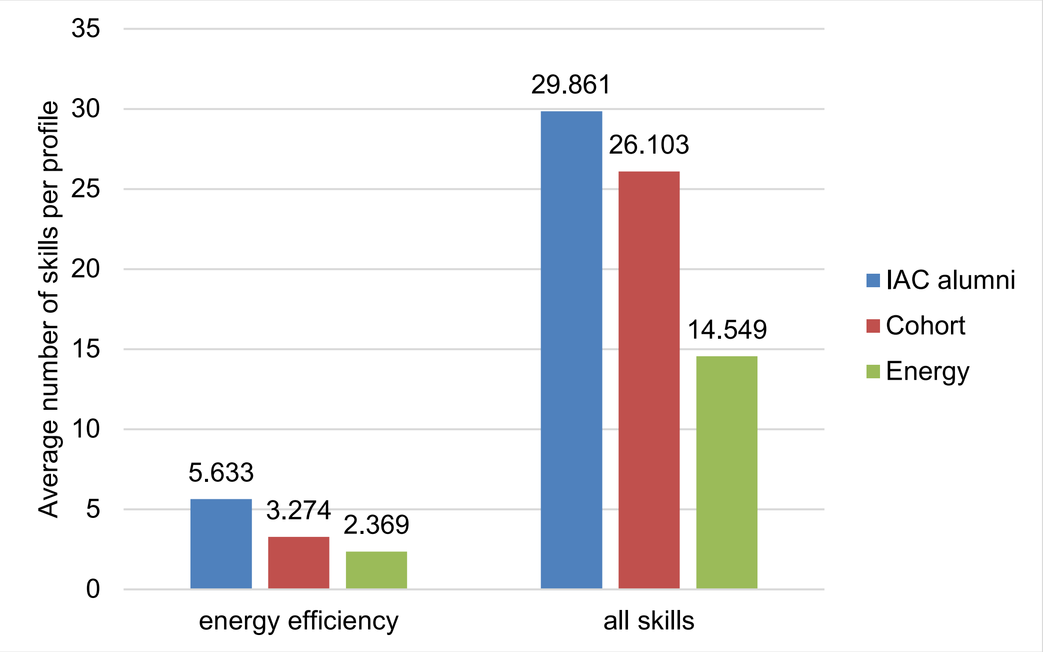

Figure 11. Average number of skills per profile by group

The most common energy efficiency skills found in the employee profile data of all three groups are listed in Table 20. The most common general skills found in the employee profile data of the three groups are listed in Table 21.

IAC Alumni		***Cohort* Comparison Group**		***Energy* Comparison Group**	
Energy Audits	41.4%	Process Improvement	29.8%	Energy Management	18.0%
AutoCAD	39.2%	Lean Manufacturing	28.6%	Energy Audits	17.7%
Data Analysis	31.6%	Six Sigma	27.2%	Energy Conservation	14.9%
Energy Efficiency	22.4%	Process Engineering	22.7%	Energy Efficiency	12.2%
Optimization	18.6%	Data Analysis	19.1%	Data Analysis	11.7%
Boilers	18.6%	AutoCAD	14.7%	AutoCAD	9.7%
Six Sigma	17.7%	Industrial Engineering	10.9%	Renewable Energy	7.8%
Calculation	14.3%	Optimization	10.9%	Green Building	7.7%
Industrial Engineering	13.9%	Process Control	10.9%	Natural Gas	7.5%
Energy Consumption	13.5%	Statistica	8.8%	Process Improvement	6.8%

Table 20. Most common energy efficiency skills appearing in employee profiles and their frequency

IAC Alumni		***Cohort* Comparison Group**		***Energy* Comparison Group**	
Research	73.8%	Management	83.9%	Management	51.9%
Management	68.4%	Leadership	57.6%	Planning	26.1%
Microsoft Office	56.1%	Planning	47.5%	Microsoft Office	24.0%
MATLAB	48.9%	Sales	42.9%	Research	23.8%
Microsoft Excel	48.1%	Research	37.9%	Leadership	23.2%
Leadership	45.1%	Microsoft Office	32.8%	Microsoft Excel	20.5%
Energy Audits	41.4%	Process Improvement	29.8%	Sales	18.8%
Mechanical Engineering	40.5%	Project Management	29.0%	Energy Management	18.0%
AutoCAD	39.2%	Lean Manufacturing	28.6%	Customer Service	18.0%
Microsoft Word	32.9%	Microsoft Excel	28.3%	Energy Audits	17.7%

Table 21. Most common skills appearing in employee profiles and their frequency

In SRI's 2015 evaluation, we also found that IAC alumni possessed more energy efficiency skills than did members of the two comparison groups. In fact, on the previous evaluation, SRI found an average of 8.9 energy efficiency skills per resume, compared to the 5.6 energy efficiency skills found with this evaluation. Energy efficiency skills in the top ten most commonly found on alumni profiles for SRI's 2015 evaluation that are no longer in the top ten are energy assessment, installation, inspection, data collection, and renewable energy.

Students with more participation in the IAC program have more energy efficiency skills.

For the first time with this evaluation, SRI explored the correlation between the number of assessments completed, an estimation of how long a student participated in the IAC program, and the number of skills they possess.

After estimating dates of participation for all 236 IAC alumni in our dataset, SRI found there to be a weak positive correlation between the duration of a student's participation with the IAC program and the number of energy efficiency skills found on their resume. There was a weaker but still positive correlation between the IAC participation duration and the number of general skills found on their resume.

The number of assessments completed by IAC alumni was only recorded for 134 members of the alumni dataset studied, and SRI was unable to estimate this metric for the remainder of individuals. Using the data we had, SRI found results similar to the relationship between duration of participation and skill development: There is a weak positive relationship between the number of assessments alumni completed and the number of energy efficiency skills found on their resumes. Additionally, there is a weaker but still positive relationship between the number of assessments completed and the number of general skills found on their resumes. This indicates that even students who do not participate in the IAC program for long still develop valuable skills, but students who participate for longer do have marginal gains in the skills developed. Table 22 shows the correlation coefficients for these metrics.

Metric	Number of Energy Efficiency Skills per Profile	Number of Skills per Profile
Number of Assessments Completed	0.187	0.111
Duration of IAC Program Participation	0.197	0.141

Table 22. Correlation coefficient ρ for IAC alumni

IAC alumni possess more valuable energy efficiency skills.

In addition to finding that IAC alumni possess more skills than do members of the *cohort* and *energy* comparison groups, our analysis found that the energy efficiency skills that IAC alumni possess are also more valuable, based on the Brookings Institution's skill dictionary that records the average salary of job postings associated with each skill. The combination of these two factors also leads IAC alumni to have a greater skill value associated with their overall profile. However, when examining skills in general, the average value of a skill associated with alumni profiles is less than it is for members of the comparison groups. These results are summarized below in Table 23.

Profile Group	Total EE Skill Value of a Profile	Average Value of a EE Profile Skill	Total Skill Value of a Profile	Average Value of a Profile Skill
IAC Alumni	$414,904	$67,077	$2,135,026	$70,935
Cohort Comparison Group	$251,938	$63,035	$1,956,891	$75,376
Energy Comparison Group	$172,159	$44,208	$1,034,566	$75,029

Table 23. Average skill values per profile

Of the top ten energy efficiency skills found in the profiles of IAC alumni, the most valuable are optimization ($93,543), six sigma ($86,167), and energy consumption ($77,233). Optimization and energy consumption both appear more frequently in the profiles of IAC alumni than they do in the profiles of the *cohort* and *energy* comparison groups.

These results are comparable to those of SRI's 2015 program evaluation, which found that IAC alumni have a higher average energy efficiency skill value than do members of the comparison groups. The 2015 evaluation found that the average value of an energy efficiency skill found on IAC alumni profiles was $72,965, which is higher than the same statistic found for the current evaluation ($67,077). A potential explanation for this difference is that the 2015 evaluation looked at IAC alumni who graduated from the program as much as 25 years before the evaluation was conducted. Thus, these alumni would have spent much longer in the workforce, giving them the chance to acquire more advanced and more valuable skills than the alumni considered in this evaluation.

Male IAC alumni possess more energy efficiency skills than do females.

For this evaluation, SRI employed a name-based gender classification tool to estimate the differences, if any, in skill development between male and female participants. This classification method found that 81% of alumni in the date range explored are men while 19% are women. When looking at IAC alumni in the specified date range for whom we were able to collect employee profile data, 76% were classified as men and 24% as women. Whether examining all IAC alumni or a smaller subset, the wide gaps between male and female participants reflect the longstanding inequities in the participation rates of women in engineering degree fields and careers.

SRI's analysis of the skills developed in male and female IAC alumni found that there is a statistically significant difference in the number of energy efficiency skills found in their profiles. Specifically, male alumni have on average 5.9 energy efficiency skills in their profiles, while female alumni only have 4.8 on average. Furthermore, male alumni have more skills in general on their profile, although this difference is not statistically significant. These results are summarized below in Table 24.

Gender	Number of Alumni in Dataset	Number of Energy Efficiency Skills per Profile	Number of Skills per Profile[14]
Male	176	5.906	30.514
Female	56	4.750	27.750

Table 24. Average number of skills per profile, by gender

IAC alumni are more likely to work in energy efficiency jobs than their peers.

A primary goal of the IAC program is to prepare the next generation of energy efficiency professionals. SRI's interviews with current IAC students affirmed that program participation does lead to increased interest in energy efficiency careers, and SRI's analysis of the career paths of alumni confirmed this anecdata. For this analysis, SRI compared the job titles found on the employee profile data of IAC alumni to those of members of the *cohort* comparison group (individuals matched based on university attended and degree field). Members of the *energy* comparison group were not considered here since those individuals were already identified based on job title.

After classifying the job titles and descriptions found on these profiles as O*NET codes, SRI then determined the number of these jobs considered to be in an energy or "green" field. SRI found that the jobs listed on 46% of IAC alumni profiles were in an energy or "green" field, compared to only 18% of the jobs found on the profiles of their academic peers. These energy efficiency jobs and the number of profiles identified for each can be found in Table 29.

SRI's 2015 evaluation used a slightly different methodology to assess the career trajectories of IAC alumni compared to their non-IAC peers, so the metrics in this section cannot be directly compared (see Student Development Evaluation Methodology for details). Still, the previous evaluation confirmed through both alumni surveys and resume analysis that IAC involvement increased interest and participation in energy efficiency careers.

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[14] Difference is not statistically significant. See Appendix E for z-test p-value.

Insights from Interviews with IAC Stakeholders

In order to substantiate findings from our data analysis discussed in the previous two sections, SRI conducted interviews with 10 IAC Directors and 8 current IAC students across 18 IACs. A project leader at DOE selected the Center Directors to be interviewed.

The eight students interviewed were randomly selected based on gender, field of study, and whether they were an undergraduate or graduate student; the goal was to have a representation of characteristics that was proportional to that of all IAC alumni in our date range. For students who did not initially respond to the request for an interview, Center Directors assisted in identifying current students who met the same degree level and field criteria as the student initially contacted. A ninth student was identified for an interview but never responded to our request.

The 10 IAC Directors interviewed were selected to represent a variety of characteristics regarding IAC tenure, geographic location, and size (in terms of number of staff).

SRI's interviews with these stakeholders focused on understanding what Center Directors and students see as the impacts, challenges, and best practices of the IAC program. Interview scripts used with Directors and current students are in Appendix C. The following are the main takeaways and themes identified from SRI's 18 interviews.

Main Takeaways

Clients and Center Directors believe the IAC program has a big impact.

In general, Directors have found clients to be more and more interested in renewable energy and waste reduction, and Centers are excited to play a role in that. One Director noted that they are starting to add information to their reports about how recommendations will impact the facility's greenhouse gas emissions, even though this isn't required. Another Director noted:

> *"I love this program. From the national point of view, especially from the Biden administration, the energy efficiency aspect matches the national goal very well."*

Clients are typically excited about the opportunity to be assessed and are pleased with the results. One Director noted:

> *"… people are really grateful for the work we do. One guy we did an audit for calls me every few years asking if we can come back because he says 'We learned so much.'"*

Students and Directors alike see the IAC program as a unique opportunity to make a significant impact on the energy usage of mid-sized facilities that otherwise would not be able to conduct an energy assessment. Additionally, the IAC program is a one-of-a-kind chance to provide students with on-the-job training. One Director mentioned having a high success rate of students working in energy, often with former clients, when they graduate. Another Director illustrated this point further:

> *"During the audit day itself, I've seen many times the client has low expectations at the beginning because they think it's just a student team, but by the end of the day, they're totally blown away."*

Students find participating in the IAC program to be extremely valuable.

Every student that SRI interviewed expressed gratitude for the program and believed it developed valuable skills. Specifically, students commonly noted technical writing, leadership, and client communication as skills that were greatly strengthened through their participation in the IAC program. A few students also noted that the IAC program taught them how to approach a real-life calculation and provided the opportunity to apply what they had learned in class, through presentations and textbooks, to real-world problems. Two students expressed a belief that they learned more by participating in the IAC program than they did in their entire degree program.

Other IAC-honed skills mentioned by students include working with a team, using measurement tools, and understanding how a multitude of energy and manufacturing systems operate. One student described their experience as follows:

> *"You get this real-world engineering environment where people will ask you questions about your calculations. Being able to explain that is something you don't get much experience doing in the classroom…. Before joining IAC, I was struggling to find my voice and organize my thoughts clearly in my interviews. Having that regular communication with my team and with clients has been a major improvement."*

All students interviewed predict that their IAC participation will be relevant to their future career, and almost all students observed that their participation increased their interest in a career in energy efficiency. One student noted that even though he doesn't plan to go into energy efficiency specifically, he sees ways to apply his experience and interest to whatever career path he ends up following. One Director detailed inviting IAC alumni and PhD students to speak with current IAC students to illustrate the potential career opportunities that the IAC program creates.

One student explained that the job she's starting when she graduates is at a company to which she was referred by her IAC Director. She described her experience as follows:

> *"Before starting with IAC, I knew I wanted to get into energy, but I saw myself going more into renewable energy, maybe building a technology that's an alternative to fossil fuel. After being with IAC, I felt really fulfilled doing the work in energy efficiency and found it to be just as impactful in helping the environment."*

Students participate for career development and real-world experience.

Many students participated in the program because of the potential for developing skills they saw as valuable for their future careers, such as report writing and understanding energy systems. Many also had little work experience before and saw this as an opportunity to solve real-world problems in a hands-on setting. One Director mentioned that he requires students to create a schedule at the start of a semester, and he monitors their attendance so that students are taught to be reliable employees.

Several students expressed appreciation for the opportunity to see different kinds of manufacturing facilities and systems in person. A few noted the value of having a job sponsored by DOE on their resumes for future job applications. For most students, the potential for obtaining a certificate was a factor in the decision to participate but not the largest motivator. One student noted:

> *"There are a lot of IAC students that are exchange students, and this opportunity to get a certificate that is sponsored by a federal*

> *agency is a big motivating factor."*

Directors have identified strategies for recruiting and supporting the best students.

When asked what they look for when hiring students, many Directors emphasized the need for communication skills in students, not just technical knowledge—though assessing applicants' knowledge with technical questions in an interview is also important. A few Directors also noted that they focus on recruiting younger students who can stay with the program for multiple years. One Director mentioned that he stresses to applicants the responsibility the program requires, telling them that students are representatives of a program that has real-world consequences.

To support students and get the best work out of them, multiple Directors talked about fostering a culture of openness and camaraderie so students feel comfortable taking chances and asking questions. Several Directors also noted the importance of students feeling responsible for creating a strong assessment report. This is done by assigning students specific roles and setting a goal at the start of their participation to lead an assessment one day. One Director said he empowers students by involving them at every step of the process, from client recruitment to pre-audit strategizing to presenting recommendations to the client.

Students value Director support and training.

Three students mentioned that their IAC Director regularly provides training on a specific energy system or measuring technique, which they found helpful. This was done through either free online videos, Rutgers-provided webinars, or through student-led presentations. Another two students found valuable the rigorous and highly structured training they received at the start of their participation. Other ideas shared by students about Director best practices included granting flexibility with deadlines around finals, requiring students to provide updates twice weekly, and having new students observe more experienced students before conducting an assessment themselves.

Students learn about the IAC program through different methods.

Six of the eight students that SRI interviewed said they learned about the IAC program through either an established relationship with the Center Director or through an affiliated professor. Only two students said they learned about it through a fellow student who was already participating in the program.

Directors mentioned that they recruit primarily through posting on department listservs and student job boards, introducing the program in relevant classes, and presenting to student organizations. Almost all Directors interviewed believe only a small number of students learn about the program through word of mouth from current participating students. One Director noted difficulty in recruiting students studying something other than mechanical engineering.

Finding clients continues to be a challenge.

One Director expressed a belief that there is greater interest by manufacturers today in knowing their energy consumption and striving to reduce energy usage and greenhouse gas emissions, which has made recruitment of clients easier. However, every other Director interviewed expressed frustration with the process of finding manufacturers interested in the services of an IAC and expressed a desire for DOE to play a greater role in this step. Client recruitment is typically done through mailing flyers, cold emailing and calling, and word of mouth from participating facilities. Several Directors noted the difficulty of identifying the right person at a facility to contact with the offer, though LinkedIn helps with this step.

Some Centers employ a designated person to help with recruitment; in some instances, this is a business or marketing student, and at others it is a university staff member. Many Centers have students assist with identifying and contacting facilities, and one student interviewed noted it would be helpful for DOE to assist more with client recruitment. Still, a few Directors believe that having students contact facilities is less effective for two reasons: facilities do not believe the offer is credible, and typically a facility is contacted by multiple students, resulting in confusion and hurting the prestige of the program.

Many Centers have partnerships with regional manufacturing associations, Manufacturing Extension Partnership centers, utilities and regulatory authorities, state and local energy offices, and economic development agencies. Directors noted that these partnerships are often a source of many referrals. Stakeholders from two Centers mentioned attending related conferences and expos as an effective strategy for client recruitment.

One Director noted the importance of marketing the opportunity as an educational program conducted by students in training since plant managers are deterred by a professor telling them how to operate. Additionally, this Director suggested marketing it as a recruiting opportunity for the facilities who get to work with skilled students.

The way recommendations are presented affects implementation rates.

Directors with whom SRI spoke have several strategies for presenting recommendations in a way that will lead to higher implementation rates. The biggest barrier to implementation is always the facility’s budget. Several Centers have utility partners present during the audit; these partners are then able to go over any rebate and incentive programs available to help fund implementations. Many other Centers present information about state and DOE grants available alongside recommendations. However, one Director noted that his Center lacks the capacity to stay aware of those funding opportunities; it would help if DOE took a more proactive approach to sharing that information with Centers so it can be passed along to clients.

Other strategies mentioned for helping facilities overcome financial barriers include emphasizing the payback period of recommendations and organizing recommendations into small, medium, and large capital investments. One Director noted:

> *“I think it’s about the way you communicate [the recommendations]. You have to emphasize the way [they] will save their utility bill.”*

Because recommendations that require a large investment typically involve budget adjustments, which can be slow, several Directors believe implementation rates would be higher if they followed up with clients after two years.

One Director stated that having facilities wait 60 days between an audit and a report hurts momentum, so his Center always provides a preliminary report within a week of the audit. Two Directors noted that following up with facilities within a month after presenting the report is helpful for understanding what is needed for implementation. Another Director noted that his Center uses a lot of data loggers, which allows for recommendations to be backed up by actual data, adding credibility. He suggested:

> *“Try to find the most passionate person [about energy savings] in the company… and make sure they see [the report].”*

Directors value new initiatives but need more guidance.

Many Directors expressed appreciation for new initiatives pushed by DOE, such as cybersecurity and smart manufacturing, recognizing they are important topics for maintaining the IAC program's reputation for innovation and forward thinking. Still, most Directors noted that they don't have expertise in these fields, so they have relied on sharing DOE's cybersecurity assessment tool and other publicly available resources they find. One Director noted that even if they are able to come up with recommendations around cybersecurity, those actions don't generate energy savings, so they are hard to convince clients to implement.

Regarding the pilot assessment of commercial buildings, Directors are excited about the potential pool of new clients. They also noted it would encourage Centers to innovate new ways of marketing the opportunity and develop recommendations unique to commercial facilities.

Centers want funding for more advanced tools.

Both students and Directors expressed an interest in having DOE sponsor equipment that would allow for more advanced measurement and testing. One student noted that newer manufacturers they audit typically have already implemented most of the recommendations in the IAC database, so they can only present a small number of recommendations. More advanced measurement tools that are widely available at all Centers would allow for new, more advanced recommendations to better support these facilities. One Director specifically noted that having access to power loggers would allow them to create "better reports, make more recommendations, and increase implementation rates."

Directors are seeking more opportunities for research.

Several Directors spoke of the difficulty in getting research conducted at an IAC published in a professional journal, even though Centers typically collect large amounts of data about energy usage at facilities. This is because the data is typically collected in an applied setting. One Director did note that he has had greater success in having Center research accepted by academic conferences than in professional publications.

Some Centers are able to use information gleaned from facility assessments to inform students' theses or inspire research conducted at a different lab on campus where they can simulate the interventions. Still, the need for graduate students and tenured faculty, which the IAC Director must be, to conduct and publish research remains a top focus for many Directors. One Director expressed it as follows:

> *"Especially for grad students, it's important for them to know that what they're doing is helpful for their thesis. I have to constantly think about how to find ideas related to their theses so that this benefits them."*

One Director suggested that DOE sponsor a symposium or conduct outreach to journals to help IAC staff find outlets for sharing their research. It was also suggested that Directors be given the chance to present their work and share new ideas at the annual Director's meeting.

Directors enjoy cross-Center collaboration.

One Director expressed great appreciation for the annual Director's meeting and the chance it provides to find mentors and academic collaborators. He elaborated:

> *"I see [other IAC Directors] as a support system that I can collaborate with. They make sure that I'm successful. … This program is so supportive and welcoming at the national level."*

Other Directors noted that collaboration among Centers allows them to establish policies for how to handle clients from states without an IAC and provides the chance to discuss new potential recommendations and the way payback periods can vary across regions. Additionally, one Director noted that cross-Center collaboration, especially if facilitated by DOE, could help Directors determine ways to assess cybersecurity and smart technology opportunities at facilities. Two Directors noted that having an experienced Center Director walk them through their first few audits when they began the job would have helped them get up to speed much faster.

Exploration: Skilled Technical Workforce in the Energy Efficiency Sector

In IAC Program Impact on Student Development, SRI reviewed the mix of energy efficiency skills acquired by IAC program alumni to understand how the IAC program prepares its students for working in energy-intensive manufacturing facilities. In this exploratory study, SRI seeks to understand how workers who have high technical knowledge levels but don't have a bachelor's degree contribute to energy-intensive small- and medium-sized manufacturing facilities. These workers are considered part of the STW. In order for the STW to support small- and medium-sized manufacturing facilities, it is important to understand what energy efficiency skillsets are required by these firms. This will allow for more relevant skills training in 2-year associate degree and other certificate programs.

Identifying Energy Efficiency Skills in Job Postings

As mentioned in Appendix A, job postings from companies participating in the IAC program were parsed to identify energy efficiency skills. This was accomplished using two NLP machine learning approaches: topic extraction model using Non-Negative Matrix Factorization (NMF) and identification of energy efficiency skill keywords using regular expressions. Please refer to Appendix A for a discussion of the data sources and steps taken to prepare the data for use in the NLP models.

Topic Extraction Model

Topic modeling is a machine learning technique that scans a set of documents, detects words and phrases, and automatically generates clusters of word groups (topics) that describe the set of documents. In our evaluation, the documents are a set of job descriptions from the National Labor Exchange database filtered for STW positions with IAC clients. Using the list of energy efficiency skills identified in Student Development Evaluation Methodology as input features, a topic extraction model was built. It identified the following topics for consideration, as shown in Table 25.

Topic Number	Topic
1	inspection, systems monitoring, technical drawings, equipment calibration, environmental compliance
2	machinery, analytical skills, installation, mechanical drawings, data collection
3	process control, systems monitoring, calibration, electrical systems, installation
4	equipment effectiveness, equipment improvement, data collection, preventive maintenance, machinery
5	equipment maintenance, environmental monitoring, validation, inspection, technical assistance
6	test equipment, calibration, technical drawings, equipment calibration, transformers
7	preventive maintenance, equipment repair, equipment operation, cooling towers, electrical schematics
8	process equipment, water treatment, inspection, environmental regulations, validation
9	blueprints, installation, machine operation, milling, optimization
10	manufacturing processes, mechanical drawings, blueprint reading, energy efficiency, costing

Table 25. Energy efficiency topics in STW job postings identified from topic extraction model

When reviewing the topics identified from Table 25, it is important to note that the topics identified from the topic extraction model are a collection of words that are closely associated with each other and bring out a common theme or concept. For instance, Topic 1 suggests that one group of skills required by IAC clients includes skills related to the inspection, monitoring, and calibration of equipment while ensuring environmental compliance and being able to understand technical drawings. These skillsets could be attributed to a job description of an operations or maintenance supervisor. Topic 7 relates to skillsets that are required for maintenance-related job positions, with skills such as knowing preventive maintenance, equipment repair, equipment operation, cooling towers, and electrical schematics. While there may be some overlap in the identified skills between different topics, each topic has a different collection of skills and the topic extraction model allows us to understand how these different skills relate to each other.

Regular Expressions

The second NLP approach to identifying energy efficiency skills from the job descriptions uses regular expressions (regex), which is a powerful pattern matching tool. Using the same text of STW job descriptions for IAC clients, a regex query is set up to search for the list of energy efficiency skills identified in Student Development Evaluation Methodology. The frequency of each energy efficiency skill is calculated, and the thirty most frequent energy efficiency skills are listed in Table 26.

Energy Efficiency Skill	Frequency
inspection	404
machinery	236
preventive maintenance	140
process control	133
equipment maintenance	101
blueprints	96
environmental monitoring	89
test equipment	85
installation	83
process improvement	79
process equipment	77
equipment effectiveness	65
Statistica	58
data collection	53
validation	50
manufacturing processes	49
calibration	48
calculation	45
six sigma	35
electrical systems	33
lean manufacturing	30
machine operation	30
equipment repair	29
energy efficiency	28
government regulations	27

analytical skills	23
current good manufacturing practices (cgmp)	22
insulation	21
technical drawings	21
technical training	20

Table 26. Frequency of top 30 energy efficiency skills identified in STW job postings

The energy efficiency skills that appear the most often in STW job postings appear to be those associated with maintenance equipment. The STW is expected to know how to perform preventative maintenance and inspections of equipment. There are other important skills related to the operation of equipment, such as process control, machine operation, and environmental modeling. Knowledge of how to read blueprints and technical drawings is important. Improving processes and operations is another theme, as shown with the presence of six sigma, lean manufacturing, and process improvement in this list. Finally, the job postings show a demand for analytical skills, calculations, and data collection.

When compared to the energy efficiency skillsets in IAC student alumni, we observe some similarities and several differences. Skills associated with data analysis, including analytical skills, Statistica, and calculation, appear frequently in both IAC alumni skillsets and STW job postings. Similarly, skills associated with improving processes, such as six sigma, optimization, and process improvement, are common in both groups. However, IAC alumni are more likely to have skills that would be learned through a bachelor's engineering program or the IAC program, such as industrial engineering, mechanical design, and energy conservation. On the other hand, STW job postings are more likely to be looking for more specific technical knowledge, such as blueprints, technical drawings and training, and equipment repair.

Mapping Energy Efficiency Skillsets to Curriculum

With the list of the top 30 STW energy efficiency skills identified in Table 26, the next step of the exploratory study is to understand how they relate to the curriculum of instructional programs in non-bachelor's degree programs (i.e., associate degree and certificate programs). As detailed in Appendix A, the Classification of Instructional Programs (CIP) lists all instructional programs offered by postsecondary institutions in the United States and a brief summary of the content in the instructional programs.

A regex query was set up to parse through the 2,848 CIP code descriptions and identify the presence of the top 30 energy efficiency skills. (The top 30 energy efficiency skills are used in this analysis instead of the entire list of approximately 550 skills to ensure that only the energy efficiency skills that are most relevant to the STW population are considered.) The CIP codes with two or more energy efficiency skills listed in their descriptions are presented in Table 27.

CIP Code	CIP Title	Number of Energy Efficiency Skills	Associate Degrees Awarded in 2019	Certificates Awarded in 2019	Combined Credentials Awarded in 2019
46.0302	Electrician.	2	2226	14521	16747
15.0501	Heating, Ventilation, Air Conditioning and Refrigeration Engineering Technology/Technician.	2	632	5758	6390
47.0613	Medium/Heavy Vehicle and Truck Technology/Technician.	3	452	1957	2409
15.0805	Mechanical/Mechanical Engineering Technology/Technician.	2	1492	841	2333
46.0301	Electrical and Power Transmission Installation/Installer, General.	2	590	1452	2042
46.0303	Lineworker.	2	262	1412	1674
46.0503	Plumbing Technology/Plumber.	2	57	1482	1539
15.0401	Biomedical Technology/Technician.	2	658	606	1264
15.0801	Aeronautical/Aerospace Engineering Technology/Technician.	3	195	678	873
15.0803	Automotive Engineering Technology/Technician.	3	401	371	772
15.0903	Petroleum Technology/Technician.	3	234	324	558
48.0511	Metal Fabricator.	4	72	475	547
15.0607	Plastics and Polymer Engineering Technology/Technician.	2	75	280	355
51.0812	Respiratory Therapy Technician/Assistant.	2	264	71	335
15.0507	Environmental/Environmental Engineering Technology/Technician.	2	191	43	234
15.0508	Hazardous Materials Management and Waste Technology/Technician.	2	69	111	180
15.0901	Mining Technology/Technician.	3	3	95	98
15.0611	Metallurgical Technology/Technician.	4	33	27	60
15.1701	Energy Systems Technology/Technician.	2	N/A	N/A	N/A
42.2708	Psychometrics and Quantitative Psychology.	2	N/A	N/A	N/A
46.0000	Construction Trades, General.	2	N/A	N/A	N/A

Table 27. Instructional Programs with Energy Efficiency Skillsets

The CIP program descriptions are very short, so we had minimal content to search. As a result, the number of energy efficiency skills contained in them is limited, even if the curriculum might in reality foster more energy efficiency skills. Therefore, the number of energy efficiency skills listed in Table 27 should not necessarily be interpreted as a quantitative indicator of the most energy efficient instructional programs. Instead, Table 27 provides an initial screening of which of the 2,848 CIP code descriptions could be relevant for energy efficiency careers and requires further refinement by domain experts.

The instructional programs are sorted in Table 27 with the highest total number of awarded credentials (associate degrees and certificates) at the top, with Electrician and Heating, Ventilation, Air Conditioning and Refrigeration Engineering Technology/Technician as the most popular programs. While most of the instructional programs listed can be associated with energy-intensive manufacturing, some of the CIP codes such as respiratory therapy technician/assistant and psychometrics and quantitative psychology are not.

Conclusion

SRI employed several methods to analyze the impact of the IAC program, including:

- Interviews with ten IAC Directors
- Interviews with eight current IAC students
- A survey of client manufacturing facilities
- Analysis of the IAC database tracking the implementation of facility recommendations
- Analysis of IAC alumni employee profile data and data for two comparison groups

Findings

Through this mixed-method approach, SRI concludes that the IAC program had a statistically significant impact on energy saved between FY2014 and FY2020 and on student development between 2014 and 2020.

Energy Savings

SRI's evaluation of the IAC program shows that the recommendations made by the IAC survey from FY2014 to FY2020 yielded a baseline one-year gross energy savings of 94.5 million MMBtu and reduced emissions by 2.37 million metric tons for one year.

The IAC program provides an essential service to manufacturers in making recommendations that increase energy efficiency and reduce emissions. Of those manufacturers surveyed, a majority of the recommendations made by the IAC survey are accepted in full or in part. Of those recommendations accepted, a majority are implemented within a year, and a vast majority are implemented within 1-2 years. Without the IAC program, budgetary, time, and alternative provider constraints would inhibit the vast majority of manufacturers from receiving an energy assessment. As a result, the IAC program is able to fill an important role for manufacturers by conducting the energy assessment.

Given the continued focus on promoting energy efficiency in manufacturing, DOE should consider ways to encourage more manufacturers to participate in the IAC program. Additionally, it should consider incorporating questions that assess why a manufacturer may be unable to implement suggested recommendations.

Student Development

SRI’s analysis of the employee profile data of IAC alumni found that IAC alumni possess more energy efficiency skills and more workforce skills in general than do their non-IAC academic peers and other energy professionals. Furthermore, the average energy efficiency skills possessed by IAC alumni are more valuable than that of the comparison groups. This skill development is confirmed by the current IAC students to whom SRI spoke, all of whom noted that their participation in the program developed many critical skills, such as communication, technical writing, understanding of different types of energy systems, and knowledge of how to use different types of measurement tools.

Skilled Technical Workforce

Using NLP machine learning approaches, SRI has been able to identify key energy efficiency skills in job postings of IAC clients related to the STW. Many of these energy efficiency skills relate to the operation and maintenance of equipment.

Although the mapping of the energy efficiency skillset to the curriculum of associate degree and certificate programs is limited, we can identify certain instructional programs for members of the STW to consider in order to gain energy efficiency skills required by the small- and medium-sized manufacturers that participate in the IAC program. With further study, DOE can identify ways to promote these instructional programs to encourage more students to work in energy efficiency careers.

Recommendations

Following SRI's analysis of energy savings and student development, and after speaking with 18 IAC stakeholders, we have identified five recommendations for consideration.

Increase frequency and depth of IAC follow-up calls.

The IAC follow-up call with the IAC clients is an important tool to understand how the IAC recommendations are being implemented. Currently, there is only one follow-up call that occurs six to nine months after the IAC team site visit to check if the IAC recommendations are being implemented. Without additional follow-up, it is difficult to measure persistence or the longevity of the energy saving implementations.

Therefore, SRI proposes that the follow-up procedure be standardized to include multiple follow-up conversations with the IAC client. During the first follow-up call, the IACs should check that the IAC clients are well supported to implement any remaining recommendations. The second follow-up call should occur one year after the IAC team site visit to check how many recommendations were implemented to date. The third follow-up call should occur two years after the IAC team site visit, and the IACs should ask the IAC clients how many recommendations were sustained long term. SRI believes following up with clients beyond the current 6–9-month period would demonstrate higher implementation rates. Still, we recognize that there is often high turnover in plant management, which can make it more challenging to speak with someone with the necessary context the more time that has passed.

In addition to increasing the frequency of the follow-up calls, the IAC program can also increase the depth of topics asked during the follow-up call. For instance, IACs should ask the IAC clients to quantify partial implementation of recommendations. If the IAC client mentioned that they did not fully implement a recommendation, then the IAC can ask the client to quantify how much of the recommendation they did implement. For cases in which an IAC recommendation was not implemented, the IAC can ask the client why the recommendation was not implemented. Understanding why recommendations are not implemented would allow the IAC to better understand how clients adopt the IAC recommendations and could help the IAC better assist the clients in understanding the benefits of recommendation implementation.

Collect more complete student data.

Though the Rutgers Field Management office requests that all students graduating from the IAC program complete an online exit survey, very few start the survey and even fewer complete it. Consequently, little data are able to be extracted from the survey results. If more students took the survey, DOE and Rutgers would be able to better assess students' motivations for participating, future career plans, and opinions of the program. Additionally, this survey currently asked students to voluntarily provide their gender. More students completing the survey and volunteering this information would facilitate more accurate analysis of the number of female participants, who are underrepresented in the program and in engineering degrees in general, and the impact the IAC program has on preparing women for energy efficiency careers. Furthermore, adding an optional question regarding students' race and ethnicity could be useful, though this should not be required for students to answer.

SRI recommends that IAC Directors more strongly encourage students to complete the exit survey upon leaving the program. In addition, Rutgers could consider making completion of the exit survey a requirement for earning the certificate, though it should be made clear that questions regarding gender and race/ethnicity are optional and students can voluntarily choose to provide that information.

Encourage students to aim for being a lead student on an assessment.

Not only does IAC program participation help students gain technical skills, but it also presents an opportunity for students to develop many valuable soft skills, such as recruiting clients and working as a team. Many IAC students have the chance to be a lead student on an assessment once they have gained sufficient experience in the program. In this role, they are responsible for communicating with the client and overseeing a team to conduct the assessment and write the report. This is an opportunity for students to develop project management and leadership skills, both of which have a high associated salary value ($83,822 and $75,628, respectively), but IAC alumni are less likely to possess these skills than their academic peers in the *cohort* comparison group.

Leading an assessment is a component required for obtaining the IAC certificate, but not every IAC student makes it a goal to receive that certificate. One Director to whom SRI spoke described how he informs every IAC student at the beginning of their tenure that they will one day be expected to lead an assessment. Informing students of this mission from the start could help encourage them to stay with the program longer and work toward that achievement. SRI recommends encouraging IAC Directors to prioritize this goal for all students so that they can develop valuable project management and leadership skills.

Support more opportunities for networking and collaboration among IAC Directors.

IAC Directors with whom SRI spoke frequently expressed a desire for more guidance and strategies for success, including techniques for client recruitment, ideas for recommendations associated with cybersecurity and smart technologies, and training for new Center Directors. Currently, the annual Director's meeting hosted by DOE is the Directors' primary opportunity for working with others and sharing best practices; for many Directors, this is their *only* opportunity for it.

DOE should consider supporting more opportunities for collaboration between Directors. Two potential ideas for strengthening these partnerships are establishing a listserv through which Directors can seek guidance and share innovative ideas and asking for seasoned Directors to assist with training new Center Directors. Additionally, DOE should consider hosting a second annual event at which Directors present their research related to energy efficiency.

Promote instructional programs that teach energy efficiency skills.

Using a series of NLP techniques, SRI prepared a set of instructional programs featuring the energy efficiency-related skills that IAC clients most frequently mention in their job postings. These instructional programs are designed for the STW and do not require bachelor's degrees; they can be offered at an associate degree or certificate program level. To encourage more students to work in energy efficiency careers, DOE should raise awareness of these instructional programs.

One way to accomplish this is for DOE to partner with institutions that train the STW, such as community colleges or vocational schools, to increase student participation in energy efficiency-related instructional programs. Additionally, for partnerships at institutions near existing IACs, DOE should allow their students to participate in the IAC program. This would broaden the range of institutions that work with the IAC program and train more students with different educational backgrounds for careers promoting energy efficiency.

Appendix A: Skilled Technical Workforce Methodology

Identifying Energy Efficiency Skillsets in Job Postings

The first objective of the exploratory study of the STW is to understand the required skillsets relating to energy efficiency for the STW to participate in energy-intensive manufacturing. This is accomplished by reviewing job postings and performing NLP machine learning techniques to identify the most common energy efficiency skills listed in the job postings. The STW is comprised of workers who have high technical skills and knowledge levels but do not have a bachelor's degree.

Data Source and Collection

The job descriptions used in this analysis were obtained from the National Labor Exchange (NLx), which is a public-private partnership between DirectEmployers Association (DirectEmployers) and the National Association of State and Workforce Agencies (NASWA). Job postings from the 50 states and Washington D.C. from March 2021 through February 2022 were obtained from the NLx Data Exchange[15]. The job postings were then filtered to find those for companies that participated in the IAC program; they were also filtered by Occupational Information Network (O*Net) codes that matched the definition of the STW as defined in "Defining Skilled Technical Work" (Rothwell 2015), please see Table 30 for reference.[16] Since the objective of this analysis is to identify skillsets for the STW, job postings that mentioned educational requirements of a bachelor's degree or master's degree were removed. After applying these filters, a total of 1,302 job postings were analyzed.

Data Analysis

To understand the key themes and skillsets required in job postings from IAC clients, two NLP machine learning approaches were conducted. The first NLP approach is a topic extraction model using Non-Negative Matrix Factorization (NMF). This model allows the user to input a list of features, and the model will generate a list of topics that are most frequently found in the text documents (job descriptions). In order to use the NMF model, the job descriptions are prepared for input using a cleaning process. The cleaning process includes the removal of punctuation and extra whitespace, converting text to lowercase, and removing common stop words. The list of features used in the NMF model is the list of approximately 550 energy efficiency skills described in the Student Development Evaluation Methodology section.

The second NLP approach to identifying energy efficiency skillsets is using regular expressions (regex) to identify the presence of the approximately 550 energy efficiency skills in the job description text. A frequency analysis was conducted to identify the most common energy efficiency skills required by IAC clients.

Mapping Energy Efficiency Skillsets to Curriculum

After identifying the top energy efficiency skillsets from the job descriptions of small- and medium-sized energy-intensive manufacturing facilities that participate in the IAC program, the next part of

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[15] The National Labor Exchange (NLx) Data Trust bears no responsibility for the analyses or interpretations of the data presented here. The opinions expressed herein, including any implications for policy, are those of the authors and not of the NLx Data Trust members.

[16] Jonathan Rothwell, "Defining Skilled Technical Work," National Academies (September 2015), https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_167744.pdf.

the exploratory study is to map these skillsets to the curriculum of two-year and associate degree programs.

Data Source and Collection

The Classification of Instructional Programs (CIP) is a taxonomic scheme developed by the U.S. Department of Education's National Center for Education Statistics (NCES). The CIP tracks the fields of study across all educational programs and contains information about each instructional program's name and a brief description of topics covered in the instructional program.[17] In addition, lists of the most common associate degree and certificate programs are prepared in the NCES Integrated Postsecondary Education Data System (IPEDS) Completion Survey. These lists show the number of associate degrees or less-than-two-year certificates awarded to students between July 2018 and June 2019.

Data Analysis

After updating the list of CIP codes with the number of associate degrees or certificates awarded, an NLP approach using regular expressions was used to identify the frequency of energy efficiency skills that appear in the CIP description text. Due to the short length of the CIP description text, the number of energy efficiency skills identified in the text is limited. Nevertheless, we are still able to identify instructional programs that cover multiple energy efficiency skills and identify these programs as potential areas of focus for further exploration.

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[17] National Center for Education Statistics, U.S. Department of Education, "Classification of Instructional Programs" (2020), https://nces.ed.gov/ipeds/cipcode/resources.aspx?y=56.

Appendix B: Background of Energy Savings Evaluation Methodology

Background for Impact Evaluations of Energy Efficiency Programs

The energy efficiency impacts presented in this evaluation of the IAC program are primarily drawn from guidelines laid out by the Environmental Protection Agency (EPA) and the National Action Plan for Energy Efficiency in the 2007 publication, *Model Energy Efficiency Program Impact Evaluation Guide,*[18] and the 2012 update, *Energy Efficiency Program Impact Evaluation Guide*.[19] This EPA guide provides a framework that government agencies, regulatory bodies, and organizations can use to define their "institution-specific" or "program/portfolio-specific" evaluation requirements. The guide defines a standard evaluation planning and implementation process, describes several standard approaches that can be used for calculating energy savings, defines terms, and provides advice on key evaluation issues. This guide was created by distilling the approaches and best practices of numerous guides, protocols, papers, and reports from the last 30 years, including the *International Performance Measurement and Verification Protocol* (IPMVP), California Public Utilities Commission's (CPUC) 2006 publication *California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals,* CPUC's 2004 publication *California Public Utilities Commission Evaluation Framework*, and others.

SRI also reviewed a number of other guides and reports when establishing its methodology, including the National Renewable Energy Laboratory's (NREL) 2013 publication, *Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*,[20] as well as numerous energy efficiency program evaluations.

Evaluations of energy conservation and efficiency programs primarily focus on two impacts related to energy savings: (1) Estimates of **gross savings** and (2) estimates of **net savings.** Depending on the type of program(s) under review, evaluations may also look at other non-energy benefits and outcomes, such as avoided emissions, increased/decreased maintenance costs, or job creation. Evaluations may also include estimates of the **persistence** of energy savings, though rigorous persistence estimates are not normally included in energy efficiency program evaluations.

Calculating Gross Savings

Gross energy savings are the change in energy consumption (or demand) that results directly from program-promoted actions taken by participants, regardless of the extent to which the program influenced their actions. This is the physical change in energy use after considering factors not caused by the efficiency actions, such as weather or operating hours. Estimates of gross energy impacts involve a comparison of changes in energy use over time among participants who installed measures with some baseline level of usage. These baseline levels may be taken from facility energy use prior to program participation, energy use in comparable facilities, codes and standards, or direct observation of conditions in buildings not addressed by the program.

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[18] National Action Plan for Energy Efficiency, *Model Energy Efficiency Program Impact Evaluation Guide* (2007), Prepared for the Environmental Protection Agency and the Department of Energy.

[19] State and Local Energy Efficiency Action Network, *Energy Efficiency Program Impact Evaluation Guide: Evaluation, Measurement, and Verification Working Group* (2012), Prepared for the Environmental Protection Agency and the Department of Energy.

[20] Tina Jayaweera and Hossein Haeri, *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures* (2013), National Renewable Energy Laboratory.

The EPA guide identifies three approaches to calculating gross energy savings:

1. **Deemed savings**. Savings are based on stipulated values, which come from historical savings values of typical projects. In this approach, there are no, or limited, measurement activities, and only the installation and operation of the efficiency measures are verified. This approach involves multiplying the number of installed measures by the estimated (deemed) savings per measure.
2. **Measurement and verification (M&V).** A representative sample of projects in the program is selected, and the savings from those selected projects are determined and applied to the entire population of projects.
3. **Large-scale data analysis**. Statistical analyses are conducted on the energy usage data (typically collected from the meter data on utility bills) for all or most of the participants and possibly non-participants in the program. This approach is primarily used for residential programs with relatively homogenous participants and measures, when project-specific analyses are not required.

Of these three approaches, deemed savings seems to be the predominant method of estimating gross energy savings in large-scale industrial, commercial, and residential energy efficiency program evaluations. The 2013 report, *Evaluation of the Hawaii Energy Conservation and Efficiency Programs,*[21] was an impact evaluation, process evaluation, market assessment, and baseline study of eight business and residential energy efficiency programs in Hawaii. The eight programs use the deemed savings approach based on the historical savings of different efficiency modifications. The program evaluation compared utility meter energy use data to the claimed savings from a sample of program participants to verify the claimed energy savings of the program. The 2011 report, *Evaluation of the Non-Residential Smart $aver Prescriptive Program in North and South Carolina,*[22] was an evaluation of several programs that provide rebate incentives to customers for installing qualifying high-efficiency lighting, cooling, motors or pumps, and these programs also use the deemed savings approach. Projected efficiency measure savings for lighting fixtures were based on fixture wattage data developed by Franklin Energy Services, and HVAC savings were based on the Ohio Technical Reference Manual (TRM). These savings were then multiplied by the facilities' annual operating hours, which were self-reported by the clients, to create the overall estimate for gross savings. The evaluation found the algorithms used by the program tracking database to record energy savings to be in error and recommended a revised set of savings estimates for each efficiency measure in the program database.

The 2010 report, *Process and Impact Evaluation for the Colorado Business Cooling Efficiency Program,*[23] was an evaluation of a program that provides rebates to non-residential customers for a range of qualifying HVAC equipment to lower up-front costs and decrease the payback period of efficient equipment. The program also uses the deemed savings approach, calculating savings based on algorithms from Xcel Energy's Cooling Efficiency Program's Technical Resource Manual (TRM) to estimate the energy savings for end-use cooling measures. The evaluation found the algorithms used by the program to be consistent with algorithms used in similar programs.

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[21] Evergreen Economics, *Evaluation of the Hawaii Energy Conservation and Efficiency Programs* (2013), Prepared for the State of Hawaii Public Utilities Commission.

[22] Nick Hall, Brian Evans, and John Wiedenhoeft, *Evaluation of the Non-Resident Smart $aver Prescriptive Program in North and South Carolina* (2011), Prepared for Duke Energy.

[23] PA Consulting Group, *Process and Impact Evaluation for the Colorado Business Cooling Efficiency Program* (2010), Prepared for Xcel Energy.

The 2011 report, *Evaluation of the 2009 Energy Conscious Blueprint Program*,[24] reviewed a program that provides technical assistance and financial incentives to customers and their contractors to increase the energy efficiency and performance of lighting systems, industrial processes, HVAC systems, motors, and other energy use components of C&I buildings. This evaluation used the M&V approach, visiting a sample of program participants to verify installation of the program-qualifying equipment and conduct spot measurement and data logging of the installed equipment. Evaluators then calculated the difference between company-reported savings and evaluated savings to adjust the gross savings of the program. The 2008 report, *Impact Evaluation of 2005 Custom HVAC Installations*,[25] reviewed a program that provides technical and financial assistance to commercial and industrial customers for equipment and building energy efficiency improvements through the Energy Initiative and Design 2000plus programs. This evaluation also used the M&V approach from a sample of program participants, using the results to adjust the overall gross savings estimates of the program.

Net Energy Savings

The net energy impact is the percentage of the gross energy impact attributable to the program. Estimating net energy impact typically involves assessing free-ridership and spillover. “Free-ridership” refers to the portion of energy savings that participants would have achieved through their own initiatives and expenditures without participating in the program. Participant “spillover” refers to the situation where a participant installed equipment through the program in the past year and then installed additional equipment due to program influences, but without direct program support. The difference between net and gross savings is called the net-to-gross ratio (NTGR).

The EPA guide identifies four primary approaches to calculating the NTGR:

1. **Self-reporting surveys**. Information is reported by participants and non-participants, without independent verification or review.
2. **Enhanced self-reporting surveys**. The self-reporting surveys are combined with interviews and independent documentation review and analysis.
3. **Econometric methods**. Statistical models are used to compare participant and non-participant energy and demand patterns. These models often include survey inputs and other non-program-related factors such as weather and changes to energy costs. When a control group of non-participants is used, the savings indicated are “net” of free riders and participant spillover.
4. **Deemed net-to-gross ratios**. NTGR is estimated using information available from evaluations of similar programs.

In 2003, five northeastern utilities (National Grid, NSTAR Electric, Northeast Utilities, Unitil, Cape Light Compact) sponsored an effort to develop standardized sampling techniques, data collection approaches, survey questions, survey instrument(s), and an analysis methodology to determine free-ridership and spillover factors for C&I programs, resulting in the report, *Standardized Methods for Free-Ridership and Spillover Evaluation*.[26] The report created standardized survey instruments and analysis designed to estimate free-ridership (using a customer survey), spillover (using a

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[24] Global Energy Partners, *Evaluation of the 2009 Energy Conscious Blueprint Program* (2011), Prepared for the Connecticut Energy Efficiency Board.

[25] DMI, *Impact Evaluation of 2005 Custom HVAC Installations* (2008), Prepared for the National Grid USA Service Company.

[26] Pamela Rathburn, Carol Sabo, and Bryan Zent, *Standardized Methods for Free-Ridership and Spillover Evaluation* (2003), Prepared for National Grid, NSTAR Electric, Northeast Utilities, Unitil, and Cape Light Compact.

customer survey), and non-participant spillover (using a survey of participating design professionals and vendors) that the sponsors could use to find free-ridership and spillover impacts.

A 2008 study, *2007 Commercial and Industrial Programs Free-ridership and Spillover Study*,[27] specifically looked at free-ridership and spillover from Connecticut Light & Power's Energy Conscious Blueprint, Energy Opportunities, and Small Business programs using the Standardized Methods methodology. They used a survey of 579 program accounts (one customer could have multiple accounts) and found free-ridership and spillover rates for each type of modification (e.g., lighting, cooling, heating, refrigeration, etc.) offered by the three programs, but did not calculate overall the NTGR of the programs. *Evaluation of the 2009 Energy Conscious Blueprint Program* based free-ridership and spillover rates for each type of modification offered by the programs on the rates reported in the *2007 Commercial and Industrial Programs Free-ridership and Spillover Study*. Evaluators then used those rates to calculate the NTGR for each type of project offered by the program.

Hawaii Energy Conservation & Energy Efficiency Programs Evaluation used the deemed net-to-gross ratio approach. Evaluators assembled a set of values for free ridership and spillover from the available evaluation reports from the four states that conduct the most extensive free-rider and spillover assessments. From those values, they estimated the free-rider rate for each program by averaging the values found from each state. The report found an overall NTGR of 73% for the eight programs under evaluation.

The report, *PacifiCorp Energy FinAnswer 2008 Idaho Program Evaluation*,[28] reviewed a program that promoted energy efficient design, construction, and retrofitting of commercial and industrial processes and buildings. Evaluators used the self-reported survey approach. To find the NTGR, they only quantified free-ridership (not spillovers), which was achieved through telephone surveys with program participants who had completed projects through the program. The evaluation found a NTGR of 75% based on the free-ridership survey results. The 2011 report, *Evaluation of the Non-Residential Smart $aver Prescriptive Program in North and South Carolina*, also used the self-reported survey approach. In a survey of a sample of former program participants, evaluators asked three questions related to free-ridership and two questions on spillover. The report found a NTGR ratio of 70% based on the survey results.

Calculating Persistence

Gross savings and net savings estimates focus on first-year savings, so evaluations looking for energy savings beyond the first year of installation require an analysis of persistence. Definitions for persistence are not nationally consistent, but the concept generally encompasses both the retention and performance degradation of energy efficiency measures, while changes in codes and standards, capital-planning cycles, or the impact of market progression can also reduce net savings. Together, these factors can be used to estimate how the claimed persistence values reported by efficiency programs can be updated based on evaluated savings values.

The National Renewable Energy Laboratory's (NREL) Uniform Methods Project identifies two major components to account for in persistence: (1) effective useful life and (2) savings persistence. Effective useful life (EUL) is the median number of years that a measure is in place and operational

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[27] Pamela Rathburn, Laura Schauer, Jeremy Kraft, and Eric Rambo, *2007 Commercial and Industrial Programs Free-ridership and Spillover Study* (2008), Prepared for Connecticut Light and Power.

[28] The Cadmus Group, *PacifiCorp Energy FinAnswer 2008 Idaho Program Evaluation* (2010), Prepared for PacifiCorp.

after installation. Savings persistence is the percentage of change in expected savings due to changed operating hours, changed process operations, and/or the performance degradation of equipment efficiency relative to the baseline efficiency option.

The Uniform Methods Project outlines two main approaches used by evaluators to find persistence estimates:

1. **Database or Benchmarking Approach**. This approach entails developing and regularly updating a database of information on measure life and performance degradation. This approach is usually based on some combination of engineering judgment, experience with energy efficiency measures, and information on local and regional conditions, which are used to create detailed tables of measure lives. These values are then used as deemed values for persistence and applied to produce estimates of the energy savings over time.
2. **Periodic In-Field Studies**. This approach entails performing in-field studies of program participants from previous years. These studies rely on surveys or on-site visits to determine whether the measure is still in place and operable, or on statistical analyses using regression-based methods to generate retention models that estimate the survival or failure rates of energy efficiency measures.

It should be noted that persistence studies are both costly and time-consuming, and rigorous persistence analyses are not part of the EPA guidelines, nor are they normally included in impact evaluations of energy efficiency programs. Rather, full studies of measure life, retention, or persistence of savings typically focus solely on those measures.

Many energy efficiency program impact evaluations will rely entirely on EUL to calculate persistence (sometimes called lifecycle savings). These EUL values may come from manufacturer data, engineering databases, or other sources. However, EUL often fails to take into account factors beyond an efficiency measure’s estimated operating life, such as periodic capital upgrades, changes to codes and standards, or other factors. It also fails to consider counterfactual situations, in which participants may have eventually made the same efficiency modification(s) without participating in the program.

Evaluation of the Hawaii Energy Conservation and Efficiency Programs based its persistence analysis entirely on the EUL of efficiency measures used in its programs. EUL values were based on manufacturer data and a review of other EUL reports and publications. However, the evaluation did not list the EUL values used by the program. Similarly, *Evaluation of the Non-Residential Smart $aver Prescriptive Program in North and South Carolina* calculated lifecycle savings based on only EUL assumptions. EUL values were provided by Franklin Energy Services, a third-party energy efficiency program management company. These EUL values ranged from eight to ten years for lighting efficiency upgrades.

PacifiCorp Energy FinAnswer 2008 Idaho Program Evaluation calculated lifecycle savings based on EUL derived from a number of sources, including DEER 2008, ACEEE, and the *Measure Life Report* prepared by the consulting firm, GDS Associates. The average EUL for energy efficiency measures used in the program was 14.58 years. *PacifiCorp Energy FinAnswer 2005-2008 Utah Program Evaluation* used the same methodology and found an average EUL of efficiency measures of 13.79 years for efficiency measures used in the program.

Several impact evaluations reviewed by SRI had no analysis of persistence, including *Process and Impact Evaluation for the Colorado Business Cooling Efficiency Program*, *Evaluation of the 2009 Energy Conscious Blueprint Program*, and *Impact Evaluation of 2005 Custom HVAC Installations*. In these evaluations, only first-year savings were calculated with no analysis of savings after the first year.

Appendix C: Interview Scripts and Supplemental Implementation Survey

Client Survey

Design

SRI created a survey to assess former IAC clients on their implementation status and motivations of the recommendations they were given. This survey was designed so that clients would remain anonymous to SRI. Each client was assigned a token that SRI was provided, along with a list of the recommendations given to each client. SRI was then able to create a survey that was personalized with the client's recommendations. The client survey is below.

Instrument

Thank you for agreeing to be surveyed as part of our project. The goal of the project is to study and assess the activities, outputs, outcomes, and impact of the IAC program.

Below is a list of recommendations from the IAC assessment report that you received. For each of the recommendations listed, please indicate both if you implemented the recommendation and, if so, whether or not the recommended measures are still in place.

1. [*Recommendation listed*]: Was this recommendation implemented?
    a. Yes, in full
    b. Yes, in part
    c. No
    d. I don't know
2. [*If answered (a) or (b) to previous question*] For the above recommendation, is the equipment/process still in place?
    a. Yes, in full
    b. Yes, in part
    c. No
    d. I don't know

[*Questions 1 and 2 are repeated for each recommendation a Center was given.*]

For each of the recommendations listed below, please indicate how long it took to implement the recommendation and if you had plans to implement the recommended measures prior to the IAC team's site visit.

3. [*Recommendation listed*]: How long after receiving the IAC assessment report did you implement this recommendation?
    a. 1 year or less
    b. 1-2 years
    c. 2 or more years
    d. I don't know
4. For the above recommendation, did your firm have plans to take this action prior to the IAC team's site visit in [*year of client assessment*]?
    a. Yes, specific plans and budgets were already in place
    b. No, but it was under consideration
    c. No
    d. I don't know

[*Questions 3 and 4 are repeated for each recommendation a respondent answered Question 1 with (a) or (b).*]

For each of the recommendations listed below, please indicate why the recommendation was not implemented.

5. [*Recommendation listed*]: Please choose the appropriate response for each item:
    a. Need more time (plan to implement in future)
    b. Technically not feasible
    c. Budget not available
    d. Payback insufficient / payback period too long
    e. Insufficient staff time
    f. Cost higher than estimated
    g. Alternative measure implemented
    h. Overlooked / forgotten
    i. Other
    j. I don't know

[*Question 5 is repeated for each recommendation a respondent answered Question 1 with (c).*]

The following questions are related to the Industrial Assessment Centers program and energy assessment initiatives at your company.

6. Did your company's other facilities implement any similar efficiency measures because you shared the IAC assessment report with them?
    a. Yes
    b. No
    c. We shared the report, but I do not know if anything was implemented.
    d. My company has no other facilities.
    e. I don't know
7. Is it likely that your facility WOULD HAVE sought an energy assessment in [*year of client assessment*] IF the IAC program HAD NOT been available to you?
    a. Yes
    b. No
    c. I was not involved in this decision-making process
8. [*If answered (a) to question 7*] How would your facility most likely have obtained an energy assessment in the absence of the IAC program?
    a. By hiring a private firm or consultant
    b. Through a utility rebate program
    c. Through a corporate program
    d. Local facility staff would have performed an assessment
    e. Through some other public or non-profit program
    f. Other
    g. I don't know
9. [*If answered (b) to question 7*] Why is it not likely that your facility would have sought an energy assessment from another source within one year of the IAC assessment date?
    a. Lack of a suitable service provider
    b. Budget not available
    c. Time not available
    d. Did not think it worthwhile (savings would not justify cost/effort)
    e. It was not a priority

    f. Did not think of it
    g. Other
    h. I don’t know
10. Overall, how satisfied were you with the Industrial Assessment Centers program?
    a. Very dissatisfied
    b. Dissatisfied
    c. Neither satisfied nor dissatisfied
    d. Satisfied
    e. Very satisfied
    f. Not applicable
11. Do you have any other comments or suggestions you would like to share with us? (optional)

Industrial Assessment Center Director Interview Script

I. Purpose of study

SRI International’s Center for Innovation Strategy and Policy (CISP) is working with the Department of Energy’s Advanced Manufacturing Office to conduct an evaluation of the Industrial Assessment Centers program. As part of this process, SRI is conducting stakeholder interviews with Directors of university IACs to get a better sense of the activities, processes, and impact of IACs.

This conversation is designed to take roughly 45 minutes. Your participation is entirely voluntary. **No information you share will be directly attributed to you in any published reports without your written permission.** By continuing with this interview, you are giving your verbal consent for SRI staff to take detailed notes on our conversation and include your (anonymized) answers in relevant analyses.

II. General Information

1. How long have you been involved with the IAC program at your school?
2. How long has your Center been funded by DOE?
3. What other forms of support, if any, does your Center receive (including in-kind support, other matching support)?
4. Do you partner with other organizations? (e.g., utility companies, state energy offices, etc.)
5. Where is the Center housed? (e.g., school, unit, degree program)
6. Of the different goals of your Center (training students, saving energy, raising productivity), is there one you think is more important and you focus on more?

III. Students

1. Are students trained entirely on the job or is there a course they are required to take as well?
2. How do students hear about the Center?
3. How do you choose which students are involved with the Center?
4. Do you turn students away?
5. What practices with students have been the most successful? (e.g., in engaging students, getting good work out of students)

IV. Clients/Potential clients

1. How do clients hear about your services?

2. Do you feel you reach all those that could benefit from your services?
3. Are most of your clients in a specific sector/sub-sector of the economy?
4. Do you think these clients are typical of your geography and their sector/sub-sector? If not, why not?
5. In your opinion, what are your most effective methods for informing potential clients of your services?
6. In your opinion, what are your most effective methods for getting clients to engage with you?
7. Is there a specific type of client that you devote a great deal of your time to? Why?
8. Are there firms that apply that you turn away due to lack of resources?
9. Are there firms that inquire about services but do not end up applying for services?

V. Outcomes

1. What do you consider to be the outcomes of your Center?
2. Do you track or assess these outcomes beyond required reporting by DOE? If so, how?
3. Do you think clients should be followed up with more than just at six to nine months?
4. In your opinion, what are your most effective methods for getting clients to act on your recommendations (and stick with them)?

VI. Big Picture

1. How do you think IACs fit into the broader energy conservation landscape? What role should they play?
2. How do you think the practices and methodologies at IACs align with those on a national and international scale?
3. [*For those who have been involved for multiple years*] How do you feel about the changes to priorities and technological adjustments made recently (e.g., smart manufacturing, cybersecurity)? Do you feel like these changes have mostly helped or hurt the program?
4. Have you identified any activities that you think your Center should do/could do (better/more of)? Are there any limitations to doing what you would ideally like to do?
5. Do you have any general comments about what, if anything, could be done to improve the impact of the IAC program?

VII. End

1. Do you have any other feedback or information you would like to share?
2. May we follow-up with you if we have any other questions?

Industrial Assessment Center Student Interview Script

1. How long have you been involved with the IAC program?

2. How many IAC assessments have you participated in thus far?

3. Have you been designated a “Lead Student” with the IAC program?

4. How did you learn about the IAC program? How do you think most of your fellow IAC students learned about it?

5. Why did you become involved with the IAC program? (E.g., participated as part of a class, interested in energy efficiency career, looking for real-world experience/skills)

    a. [If not specified] Was the ability to obtain a certificate a large factor in your decision to participate?

6. To the extent you’ve spoken to your fellow IAC students about their intentions, what do you think are the biggest motivating factors for students to participate in the IAC program?
7. What are your career goals? How relevant is your experience with the IAC program to your future career plans?
8. Has your participation in the IAC program made you more interested in a career in energy efficiency?
9. What skills, if any, do you feel you’ve gained by participating in the IAC program?
10. Which aspects of your IAC program experience have been most valuable/useful to you?
11. Is there anything that you think your Director has done particularly well to help train you and support students in this program?
12. Is there anything you hoped to get out of the IAC program that hasn’t actually come to fruition?
13. Do you have any thoughts on how the IAC program experience could be improved for students?

Appendix D: List of Industrial Assessment Centers Used in Analysis

University	IAC Participation Dates
1. Arizona State University	1990 – present
2. Boise State University	2012 – 2021
3. Bradley University	1994 – 2017
4. Case Western Reserve University	2020
5. Clemson University	2017 – 2021
6. Colorado State University	1984 – present
7. Georgia Institute of Technology	2017 – 2021
8. Indiana University-Purdue University	2012 – present
9. Iowa State University	1991 – 2017
10. Lehigh University	2001 – present
11. Louisiana State University	2017 – present
12. Louisiana Tech University	1984 – present
13. Mississippi State University	1994 – present
14. North Carolina State University	1993 – 2021
15. Oklahoma State University	1982 – present
16. Oregon State University	1987 – present
17. San Diego State University	1991 – 2021
18. San Francisco State University	1993 – present
19. Syracuse University	2001 – present
20. Tennessee Technological University	2007 – present
21. Texas A&M University	1987 – present
22. University of Alabama	2007 – present
23. University of Dayton	1981 – present
24. University of Delaware	2007 – present
25. University of Florida	1991 – present
26. University of Illinois at Chicago	2001 – present
27. University of Kentucky	2012 – 2021
28. University of Louisville	1994 – present
29. University of Massachusetts	1984 – present
30. University of Miami	2001 – present
31. University of Michigan	1994 – 2017
32. University of Missouri	2007 – present
33. University of Nebraska-Lincoln	2017 – present

34. University of Texas Rio Grande Valley[29]	2017 – present
35. University of Utah	2001 – present
36. University of Washington	2007 – present
37. University of Wisconsin-Milwaukee	1987 – 2006, 2012 – present
38. West Virginia University	1993 – present

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[29] In 2013, University of Texas at Brownsville and University of Texas-Pan American were consolidated into University of Texas Rio Grande Valley. For purposes of collecting profile data from the Emsi Burning Glass databases, the two defunct institutions were included in the search.

Appendix E: Supplemental Tables

Metric	z-test p-value
Average number of energy efficiency skills per profile: Alumni-*Cohort*	1.8e-15
Average number of energy efficiency skills per profile: Alumni-*Energy*	2.2e-16
Average number of skills per profile: Alumni-*Cohort*	0.0003
Average number of skills per profile: Alumni-*Energy*	2.2e-16
Total energy efficiency skill value of a profile: Alumni-*Cohort*	2.2e-13
Total energy efficiency skill value of a profile: Alumni-*Energy*	0.015
Average value of an energy efficiency profile skill: Alumni-*Cohort*	2.2e-16
Average value of an energy efficiency profile skill: Alumni-*Energy*	2.2e-16
Total skill value of a profile: Alumni-*Cohort*	0.022
Total skill value of a profile: Alumni-*Energy*	2.2e-16
Average value of a profile skill: Alumni-*Cohort*	2.2e-16
Average value of a profile skill: Alumni-*Energy*	2.2e-16
Average number of energy efficiency skills per profile: Male-Female	0.038
Average number of skills per profile: Male-Female	0.188

Table 28. Statistical testing of differences between groups for student impact metrics

O*NET Code	Occupation	Number of IAC Alumni in Occupation	Number of *Cohort* Comparison Group Members in Occupation
11-1011.03	Chief Sustainability Officers	0	1
11-9021.00	Construction Mangers	0	1
11-9199.10	Wind Energy Development Managers	0	1
13-2051.00	Financial and Investment Analysts	0	2
17-2112.00	Industrial Engineers	1	2
17-2141.00	Mechanical Engineers	1	18
17-2199.03	Energy Engineers, Except Wind and Solar	16	2
17-2199.11	Solar Energy Systems Engineers	3	0
19-2041.03	Industrial Ecologists	0	2
25-1194.00	Career/Technical Education Teachers, Postsecondary	0	1
37-3011.00	Landscaping and Groundskeeping Workers	0	1
41-4011.00	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	1	17
41-4011.07	Solar Sales Representatives and Assessors	1	0
47-1011.03	Solar Energy Installation Managers	2	2
47-4011.01	Energy Auditors	6	2

51-8012.00	Power Distributors and Dispatchers	1	1
51-9199.00	Production Workers, All Other	0	2
53-7063.00	Machine Feeders and Offbearers	0	1

Table 29. O*NET codes and their descriptors for the occupations identified as being in energy or “green” industries in which IAC alumni or members of the cohort comparison group are employed

O*NET Code	Occupation
11-3051.00	Industrial Production Managers
11-3051.02	Geothermal Production Managers
11-3051.06	Hydroelectric Production Managers
11-9131.00	Postmasters and Mail Superintendents
11-9199.09	Wind Energy Operations Managers
13-1041.06	Coroners
13-1161.01	Search Marketing Strategists
13-2081.00	Tax Examiners and Collectors, and Revenue Agents
15-1232.00	Computer User Support Specialists
15-1241.01	Telecommunications Engineering Specialists
15-1254.00	Web Developers
17-1021.00	Cartographers and Photogrammetrists
17-1022.00	Surveyors
17-3013.00	Mechanical Drafters
17-3021.00	Aerospace Engineering and Operations Technologists and Technicians
17-3022.00	Civil Engineering Technologists and Technicians
17-3024.00	Electro-Mechanical and Mechatronics Technologists and Technicians
17-3024.01	Robotics Technicians
17-3026.00	Industrial Engineering Technologists and Technicians
17-3027.01	Automotive Engineering Technicians
17-3029.08	Photonics Technicians
19-4031.00	Chemical Technicians
19-4099.01	Quality Control Analysts
27-1013.00	Fine Artists, Including Painters, Sculptors, and Illustrators
27-3042.00	Technical Writers
27-3092.00	Court Reporters and Simultaneous Captioners
27-4011.00	Audio and Video Technicians
27-4012.00	Broadcast Technicians
27-4014.00	Sound Engineering Technicians
27-4021.00	Photographers
29-1126.00	Respiratory Therapists
29-1141.01	Acute Care Nurses
29-2055.00	Surgical Technologists

29-2056.00	Veterinary Technologists and Technicians
29-2099.01	Neurodiagnostic Technologists
29-9093.00	Surgical Assistants
31-9091.00	Dental Assistants
35-1011.00	Chefs and Head Cooks
39-4011.00	Embalmers
43-4111.00	Interviewers, Except Eligibility and Loan
43-6014.00	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive
43-9031.00	Desktop Publishers
45-4022.00	Logging Equipment Operators
47-1011.00	First-Line Supervisors of Construction Trades and Extraction Workers
47-1011.03	Solar Energy Installation Managers
47-2011.00	Boilermakers
47-2021.00	Brickmasons and Blockmasons
47-2022.00	Stonemasons
47-2061.00	Construction Laborers
47-2071.00	Paving, Surfacing, and Tamping Equipment Operators
47-2072.00	Pile Driver Operators
47-2081.00	Drywall and Ceiling Tile Installers
47-2111.00	Electricians
47-2121.00	Glaziers
47-2151.00	Pipelayers
47-2152.04	Solar Thermal Installers and Technicians
47-2171.00	Reinforcing Iron and Rebar Workers
47-2181.00	Roofers
47-2221.00	Structural Iron and Steel Workers
47-2231.00	Solar Photovoltaic Installers
47-3011.00	Helpers--Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters
47-3012.00	Helpers--Carpenters
47-3013.00	Helpers--Electricians
47-3015.00	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters
47-4011.00	Construction and Building Inspectors
47-4011.01	Energy Auditors
47-4021.00	Elevator and Escalator Installers and Repairers
47-5011.00	Derrick Operators, Oil and Gas
47-5012.00	Rotary Drill Operators, Oil and Gas
47-5013.00	Service Unit Operators, Oil and Gas
47-5023.00	Earth Drillers, Except Oil and Gas
47-5041.00	Continuous Mining Machine Operators
47-5044.00	Loading and Moving Machine Operators, Underground Mining

49-1011.00	First-Line Supervisors of Mechanics, Installers, and Repairers
49-2011.00	Computer, Automated Teller, and Office Machine Repairers
49-2021.00	Radio, Cellular, and Tower Equipment Installers and Repairers
49-2022.00	Telecommunications Equipment Installers and Repairers, Except Line Installers
49-2091.00	Avionics Technicians
49-2092.00	Electric Motor, Power Tool, and Related Repairers
49-2093.00	Electrical and Electronics Installers and Repairers, Transportation Equipment
49-2094.00	Electrical and Electronics Repairers, Commercial and Industrial Equipment
49-2095.00	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay
49-2096.00	Electronic Equipment Installers and Repairers, Motor Vehicles
49-2097.00	Audiovisual Equipment Installers and Repairers
49-2098.00	Security and Fire Alarm Systems Installers
49-3011.00	Aircraft Mechanics and Service Technicians
49-3031.00	Bus and Truck Mechanics and Diesel Engine Specialists
49-3041.00	Farm Equipment Mechanics and Service Technicians
49-3042.00	Mobile Heavy Equipment Mechanics, Except Engines
49-3043.00	Rail Car Repairers
49-3051.00	Motorboat Mechanics and Service Technicians
49-3052.00	Motorcycle Mechanics
49-3053.00	Outdoor Power Equipment and Other Small Engine Mechanics
49-3091.00	Bicycle Repairers
49-3092.00	Recreational Vehicle Service Technicians
49-9011.00	Mechanical Door Repairers
49-9012.00	Control and Valve Installers and Repairers, Except Mechanical Door
49-9041.00	Industrial Machinery Mechanics
49-9043.00	Maintenance Workers, Machinery
49-9044.00	Millwrights
49-9052.00	Telecommunications Line Installers and Repairers
49-9061.00	Camera and Photographic Equipment Repairers
49-9062.00	Medical Equipment Repairers
49-9064.00	Watch and Clock Repairers
49-9081.00	Wind Turbine Service Technicians
49-9092.00	Commercial Divers
49-9094.00	Locksmiths and Safe Repairers
49-9095.00	Manufactured Building and Mobile Home Installers
49-9097.00	Signal and Track Switch Repairers
49-9098.00	Helpers--Installation, Maintenance, and Repair Workers
49-9099.01	Geothermal Technicians
51-1011.00	First-Line Supervisors of Production and Operating Workers
51-2031.00	Engine and Other Machine Assemblers

51-2041.00	Structural Metal Fabricators and Fitters
51-2061.00	Timing Device Assemblers and Adjusters
51-3022.00	Meat, Poultry, and Fish Cutters and Trimmers
51-3093.00	Food Cooking Machine Operators and Tenders
51-4023.00	Rolling Machine Setters, Operators, and Tenders, Metal and Plastic
51-4062.00	Patternmakers, Metal and Plastic
51-4111.00	Tool and Die Makers
51-4192.00	Layout Workers, Metal and Plastic
51-4193.00	Plating Machine Setters, Operators, and Tenders, Metal and Plastic
51-5111.00	Prepress Technicians and Workers
51-6064.00	Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders
51-7031.00	Model Makers, Wood
51-8011.00	Nuclear Power Reactor Operators
51-8013.04	Hydroelectric Plant Technicians
51-8021.00	Stationary Engineers and Boiler Operators
51-8031.00	Water and Wastewater Treatment Plant and System Operators
51-8092.00	Gas Plant Operators
51-9011.00	Chemical Equipment Operators and Tenders
51-9021.00	Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders
51-9081.00	Dental Laboratory Technicians
51-9161.00	Computer Numerically Controlled Tool Operators
51-9162.00	Computer Numerically Controlled Tool Programmers
51-9194.00	Etchers and Engravers
51-9195.04	Glass Blowers, Molders, Benders, and Finishers
53-5031.00	Ship Engineers
53-6041.00	Traffic Technicians
53-6051.01	Aviation Inspectors
53-6051.07	Transportation Vehicle, Equipment and Systems Inspectors, Except Aviation
53-7031.00	Dredge Operators
53-7062.04	Recycling and Reclamation Workers
53-7071.00	Gas Compressor and Gas Pumping Station Operators

Table 30. O*NET codes and their descriptors for the occupations identified as being a part of the STW based on education attained and skill level