Benefits of Multi-Day Industrial Center Assessments for Large Energy-Intensive Facilities[1]

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ABSTRACT

Multi-day Industrial Assessment Center (IAC) assessments are shown to be effective in serving the energy efficiency needs of large energy-intensive industrial facilities. Assessment results from two and three-day visits to eight large Industries of the Future (IOF) plants are discussed and compared to single day assessments. The effect on student employees and on program metrics for one IAC is shown. For the multi-day assessments of large plants, average annual cost savings per assessment recommendation (AR) increased by 43% and implemented savings increased by 34%. The average number of ARs per plant also increased and the ARs in the larger plants are generally more complex. Students are exposed to more complex plants, have more challenging projects and more time in the plant to study and gather data, and receive more attention from both plant personnel and faculty.

Introduction

DOE fosters the use of Best Practices in manufacturing plants, particularly IOF plants. Best Practices shows plants how to reduce energy consumption and save money through the use of information resources and tools, technical assistance, and by demonstrating new technologies (U.S. Department of Energy 2003A). The IAC program and showcase demonstrations are part of a suite of Best Practices available to plants.

The DOE-sponsored IAC program provides comprehensive industrial assessments for manufacturing plants at no cost to manufacturers (U.S. Department of Energy 2003B). Assessments are performed by teams of students supervised by faculty and staff at 26 universities around the nation. The assessments generally focus on energy efficiency projects, but also include pollution prevention, waste reduction and productivity improvement projects. Each assessment visit results in a formal, technical report prepared for the manufacturer. A major feature of each report is the assessment recommendations (ARs), which are projects recommended for implementation in the plant. In addition to an industrial assessment report, an assessment visit enhances management awareness of the plant's energy situation in general. Other plants owned by the same organization may benefit from replication of projects. Follow-up surveys show that plants implement more than half the recommended projects and achieve significant cost savings (Center for Advanced Energy Studies 2003). The plant visit phase of most assessments takes one day.

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A showcase is a public demonstration of emerging technologies and proven practices in the areas of energy efficiency, renewable energy, environmental benefits and productivity (U.S. Department of Energy 2003A). DOE sponsors showcases in partnership with industry and state IOF efforts, and the IAC at Texas A&M University (TAMU) has participated in several showcase events. Manufacturers are involved as sponsors and as sites for demonstration of technologies and energy efficiency programs. Showcases provide manufacturers with information about new and emerging technologies, software, publications, an information clearinghouse, research and development, and plant assessments. Assessments may be provided by an IAC or as a result of the competitive plant-wide assessment program sponsored by DOE (U.S. Department of Energy 2003A).

The IOF program supports nine major energy-intensive industries important to the United States economy with research and development to help them become more energy efficient. The nine Industries of the Future are agriculture, metal casting, aluminum, mining, chemicals, petroleum, forest products, steel and glass (U.S. Department of Energy 2003C).

Texas industry consumes about 20% of the energy used by U.S. industry, and the Texas chemical and refining industries combined use about 15% of the energy used by U.S. industry (Ferland 2001). Most of that energy use occurs along the Gulf Coast, near Houston, an area that can be served by the TAMU IAC. Area chemical plants and refineries typically are larger than the traditional one-day visits easily can serve, and so multi-day assessments of larger plants are effective in targeting some of Texas' most energy-intensive industry.

The IAC at Texas A&M University (TAMU)

The IAC at TAMU began in 1986 and has experimented with the assessment process. As early as 1993 energy consumption was monitored in small and medium sized industrial plants to support assessment reports (Dorhofer and Heffington 1994). Results from monitored assessments are reviewed briefly because, as in multi-day assessments, more time is spent in the plant than usual. In January 2000, the TAMU IAC made the first of eight multi-day visits to large IOF plants. These plants are larger than those normally visited and the results from these visits have interesting impacts on the IAC program, industry, and faculty and students.

TAMU is about 90 miles from the Houston-Gulf Coast area and travel can occupy several hours of each assessment day. A typical one-day assessment visit begins with arrival of the team at the plant about 8:00 a.m. A meeting with plant representatives follows for the purpose of discussing plant utilities consumption, plant processes, and any special safety issues. The first meeting occupies about two hours, and a plant tour and assignment of projects to individual students takes up the rest of the morning. Data gathering and analysis occupy the afternoon until about 4 p.m. An exit meeting with plant personnel completes the day. Multi-day (two or three days) assessments expand all phases of the visit.

A technical report in traditional energy audit report form is supplied within two months of the visit to the plant so that recommended projects can be implemented. A copy of the report is sent to the field manager for quality control purposes. Subsequent activities can include IAC follow-up on special projects and response to queries from plant personnel. Between six and nine months after the report is completed, the plant is surveyed to determine the implementation status of the recommended projects. Data, including implementation results, are entered into a U.S. Department of Energy database located at

http://caes.rutgers.edu (Center for Advanced Energy Studies 2003) for the use of the public involved in similar conservation efforts or other studies.

Review of Monitored Assessment Results

Monitored assessments are supported by monitoring instruments and require additional time in the plant for the installation and removal of the equipment. In one case 12 months of monitored data on selected equipment items were obtained to support plant demand and energy efficiency projects (Heffington, Dorhofer & Lewis 1996). Equipment in two other plants was monitored for one to two week periods to measure demand and duty factors (Dooley & Heffington 1998). These three plants were monitored using centrally located loggers and remote sensors installed after the IAC assessment visit and the monitored data did not affect assessment report results (Heffington & Eggebrecht 2001).

In later studies, monitoring was completed prior to the assessment visit in order to obtain demand and energy data to identify and support ARs. Three plants were monitored with centrally located loggers and sensors so that one week of data could be reviewed prior to the one-day assessment visit by the full team for insights into possible ARs. Installing and removing central loggers and sensors on the electrical leads to equipment is labor intensive and safety issues call for use of an electrician. To address labor and safety issues, four additional plants were monitored for one week prior to each assessment visit with more easily installed, self-contained, sensor-logger units needing neither wiring nor a central logger (Heffington & Eggebrecht 2001).

Monitoring is a well-documented method of verifying the savings resulting from energy projects (Lewis, Dorhofer & Heffington 1995; Claridge et al. 1991). However, in small and medium sized manufacturing plants, the TAMU IAC has found it to be unfruitful for supporting significant demand management and energy efficiency projects. In the plants monitored before the assessment visit to identify and support projects, only relatively small equipment turn off projects resulted. Project savings yielded a payback of more than four years for the cost of the monitoring installation. Assessments in these seven plants did result in about 25% more ARs, attributed to the additional time spent in the plants (Heffington & Eggebrecht 2001). On average, the ARs had annual cost savings that were about a third larger than average for the TAMU IAC.

The monitored assessments described above were all for small and medium-sized plants and met three of the four standard IAC program criteria: less than $100 million gross annual sales, under 500 employees, under $2 million in utility costs, and no in-house energy expertise. The seven plants above averaged $35 million ($4 million to $103 million) in gross annual sales, 165 (35 to 500) employees, and $350,000 ($58,000 to $940,000) in annual utility costs.

Multi-Day Assessments

Multi-day assessments span two or three days at larger plants using a team at full strength during the entire assessment visit. The TAMU IAC has supported DOE's Industries of the Future program with eight multi-day assessments of large plants, six to the chemical and petroleum refining industries and one each to the glass and mining industries. Four supported DOE showcase activities. In addition to these large plants, about two-thirds of

TAMU visits have been to smaller IOF plants, their clients or suppliers. The eight large IOF plants served with multi-day assessments averaged $320 million ($35 million to $1.2 billion) in gross annual sales, 280 (77 to 765) employees, and annual utility costs of $12 million ($3.3 million to $46 million).

Multi-Day Assessment Results

Table 1 shows results from TAMU multi-day and one-day assessment visits using information from the national IAC database (Center for Advanced Energy Studies 2003). An AR represents one project documented and recommended in an assessment report. In almost all cases an individual student gathers the data, performs the calculations, and completes the AR. Table 1 does not include any data for visits for which implementation survey has not been performed nor does it include data for visits for which implementation data are unavailable or excluded (implementation status K in the database). Pending ARs (implementation status P) are included. Pending ARs have implementation costs of $10,000 or more and capital barriers at the plant hold back implementation (Muller, Trabachino and Glaeser 2001).

Table 1. TAMU Assessment Visit Results

	One-Day (Small/ Medium Plants)	8 Multi-Day (Large Plants)	All
Number of Visits	409	8	417
Number of Days	409	20	429
Number of ARs	3,060	97	3,157
ARs per Visit	7.5	12.1	7.6
ARs per Visit Day	7.5	4.9	7.4
ARs Implemented, %	60	57	60
Annual Recommended Cost Savings, $/AR	7,224	108,830	10,346
Annual Recommended Cost Savings per Visit Day, $/day	54,000	528,000	78,300
Cost Savings Implemented, %	53	42	49
Implementation Cost, $/AR	7,355	108,378	10,459

The one-day visit column in Table 1 for TAMU removes the effect of the eight large, IOF plants, which represent 2% of TAMU assessments. The 409 visits in this column include the effect of the seven monitored assessments that resulted in an increased number of ARs and annual savings. Including the seven monitored assessments increases the average number of ARs per visit and the average AR cost savings per visit for TAMU by less than 1%. Thus, the 409 visits basically reflect data from standard one-day visits.

Inclusion of the multi-day assessments in the TAMU metrics increases the recommended savings per AR from $7,220 to $10,300 in Table 1, an increase of 43%.

Recommended savings per visit day are increased by over $24,000 or 45% to $78,300. The cost savings of the average AR completed by students at the eight large IOF plants was about 15 times larger than the AR savings for one-day visits. The average recommended savings are $528,000 per visit day, almost ten times as much as the TAMU one-day visits produced. Savings data for over 10,000 visits sponsored by the national IAC program yield recommended cost savings of $13,999 per AR and $100,000 per visit day (Center for Advanced Energy Studies 2003).[2] The cost savings data for the multi-day assessments made by TAMU are about eight times and five times greater, respectively, indicating enhancement of the national program metrics by the TAMU results at large plants.

Implemented savings can be calculated from the data in Table 1, and are $28,600 per visit for the 409 one-day visits and $38,400 per visit for all TAMU visits, an increase of 34%. Implemented savings are $222,000 per visit day, over seven times as great as one-day visits.

The number of ARs is 12.1 per plant, 61% greater than the 7.5 ARs per TAMU visit day for one-day visits. However, on a visit day basis, the average number of ARs is only 4.9 for the eight, large IOF plants. The significantly larger cost savings on both an AR and visit day basis, the higher implementation costs shown in Table 1 and the lower number of ARs per visit day indicate more complex projects completed by students for the multi-day visits. The larger number of ARs per plant can be due both to the additional time spent in the plant and the increased complexity of the larger plants. That more ARs result when more time is taken for the visit phase of the assessment has been demonstrated (Heffington & Eggebrecht 2001).

Benefits for Students

Sixty student employees were involved in these visits, an average of eight per visit. During the recent fall and spring semesters the average number of students on one-day visits was about five per visit. Large plants have significant advantages for more students. For example, one staff member usually leads one-day visits, but two have been present at these larger plants so that the attention given to individual students from university professionals is greater. Larger plants may have personnel with focused responsibilities in a single area and who are more knowledgeable when compared to the personnel at smaller plants who may have multiple responsibilities spanning many areas.

Students are able to spend more time learning about plant processes and procedures than is available in one day. Larger plants are usually more complex, but plant complexity does not necessarily scale with size, and so in spending more time in a larger plant students may actually become more familiar with the plant and its processes. Although plant complexity may not be as great as one might expect, project complexity may be increased because of the larger systems encountered, the greater need for energy, and the longer time available for the team to study systems and gather data. Faculty and staff are sometimes better able to use their expertise in complex plants, and enjoy the challenge.

U.S. DOE has sponsored a number of showcases around the nation (U.S. Department of Energy 2003A) and the TAMU IAC has provided assessment services for manufacturers considering or participating in four showcases. The multi-day assessment visits to these complex plants have provided attractive educational opportunities for students and staff alike.

[2] Based on 10,120 visits including 47 multi-day visits by TAMU and other IACs in the database as of 4/4/03. Visits with no implementation data or implementation status K for all ARs are excluded.

An added attraction is participation in the actual showcase public event. The Texas Technology 2003 Showcase held in March 2003 in Houston provided several IAC students with access to technical sessions, plenary addresses, tours, networking and exposure to manufacturers leading in energy efficiency and pollution prevention.

Technologies

The total of 97 recommended projects in Table 1 for the multi-day assessments does not include 17 additional ARs that were not recommended but that were fully completed and included as report appendices where they are termed Considered Assessment Recommendations or CARs. Most were not recommended because of long paybacks, and they include some challenging engineering work such as cogeneration studies. The more complicated ARs and CARs considered by students at the eight large, IOF plants served with multi-day visits are shown in the following list. (A number in parenthesis beside an entry shows the number of times a similar project appeared.)

1. Install variable frequency drives (3)
2. Install turbines for letdown or to use excess boiler capacity (3)
3. Install cogeneration (2)
4. Modify existing cogeneration system (2)
5. Replace pump seals (2)
6. Replace natural-gas fired internal combustion engines (2)
7. Install electric and natural gas IR heaters (2)
8. Modify conveyor system (2)
9. Install flare-gas compressor
10. Fire with oxy-fuel process
11. Replace field-erected boilers
12. Replace electric motors with natural gas engines
13. Reactivate abandoned recuperators on glass furnaces
14. Install natural gas pipeline
15. Install CO_2 vaporizer
16. Install cooling tower
17. Install roof
18. Replace steam ejectors with vacuum pumps
19. Eliminate pumping through large condensers
20. Pressurize condensate system

Many of these complex projects (e.g., those dealing with cogeneration, letdown turbines, oxy-fuel firing) usually would not be encountered at smaller plants. In addition to the complex projects in the list above, other projects more commonly encountered by students were recommended often at the larger plants, including such things as recycle or reduce waste, turn off equipment, and steam system maintenance projects.

Most projects were related to energy, but a few increased productivity or reduced waste or pollution. The natural gas engine replacement ARs (#6) were unique. The Houston area is an air quality non-attainment cap and trade zone facing stringent NO_x reduction requirements by 2007 (Texas Natural Resource Conservation Commission 2003). Plants

there are considering replacing natural gas fired equipment, including both engines and heaters, with electricity as a source of energy. Such replacements often represent large capital investments and have no energy cost savings. This is the case with the two natural gas engine replacement projects considered here where a number of internal combustion engines on the order of 500 hp must be replaced if air quality rules do not change. The boiler replacement AR (#11 in the list) is also driven by NO_x reduction considerations.

Pollution considerations such as those faced by these large plants in the Houston area have caused the TAMU IAC to include the pollution impact of ARs in reports. The NO_x and CO_2 or carbon equivalent reduction data are reported for each AR. Most of the time average emissions data are used for electricity generation and natural gas use, but in two cases where the plant either was self-generating or purchasing from a nearby cogenerator, data for the actual source were available (U.S. Environmental Protection Agency 2001). Also, larger plants often have measured emissions data available for such things as natural gas fired engines and fired heaters, and this data may not be available at smaller plants.

Present program guidelines published since the last TAMU visit to a large IOF plant provide multi-day assessments for important, complex recommendations, plants or processes, and energy costs in the $1 million to $2 million range annually (Office of Industrial Productivity and Energy Assessment 2002). This guideline does not exclude service to plants with larger energy costs, which may be served under the right conditions. However, the upper limit of $2 million is significantly smaller than the annual energy costs for the eight plants discussed here, which ranged from $3.3 million to $46 million. The $2 million per year upper limit for energy costs may perhaps focus multi-day assessments into a range between the small and medium-sized plants that are the mainstay of the program, and the larger plants described here. Approached correctly, assessments of such larger plants and their complex projects offer considerable energy-efficiency benefits to industrial participants, and to faculty and students, as well as increasing important program metrics.

Related Considerations

Other issues in the multi-day assessments have involved more stringent confidentiality and safety training, compared to smaller plants. Four of our eight large multi-day assessments have been to chemical plants and the chemical industry is highly competitive. Therefore, confidentiality has been a major issue and signing some of the confidentiality agreements routinely signed by visitors to these plants would call for violation of our contract to provide IAC assessments. Planning assessment visits in this climate has caused us before each visit to advise plant personnel about the disposition of their data and to ask if there are confidentiality issues that need resolution.

Similarly, large chemical plants and refineries usually have formal safety training requirements that require special training for IAC personnel. This can sometimes be met by spending extra time during the initial phases of the visit for training delivered by safety personnel of the plant.

Conclusions

The effect of eight, large IOF plants on the TAMU IAC has been studied and positive impacts on industry, program metrics, and the IAC students and staff are shown by

comparing TAMU visit results to those without the large plants. Including the eight, large IOF plants that represent only 2% of TAMU assessments increases TAMU IAC cost savings significantly. Recommended cost savings on both an AR and visit day basis each increase by over 40%. Implemented savings are up about one-third. The large plants considered here have annual utility costs varying from $3.3 million to $46 million and averaging $12 million, significantly higher than the upper limit of $2 million in present program guidelines. Thus, in spite of their advantages, such larger plants might not be considered as candidates for assessment visits, except in special circumstances.

Multi-day assessments to large, complex plants offer advantages in addition to improved program metrics. More time is available to study the plant and its subsystems in detail. More plant data, such as pollution data for important systems, may be available. Plant personnel with extensive systems knowledge may be available for discussions. Students accomplished 60% more projects, many of them more challenging and complex than usually encountered in smaller plants. This activity enhances student education and benefits both students and staff intellectually. Service to large, energy-intensive plants that would not be reached normally, such as the large IOF refineries and chemical plants in major energy using areas of the United States, can be provided by these multi-day assessments.

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References

Center for Advanced Energy Studies. *IAC Database,* Available: http://oipea-www.rutgers.edu/database, The State University of New Jersey—Rutgers. [Date visited: April 4, 2003].

Claridge, D.E., J. S. Haberl, D.L. O'Neal, W. M. Heffington, C. Tombari, M. Roberts, and S. Jaeger. 1991. "Improving Energy Conservation Retrofits with Measured Results." *ASHRAE Journal*, Volume 33, Number 10 October: 14-22.

Dooley, E.S. and W. M. Heffington. 1998. "Industrial Equipment Demand and Duty Factors." *In Proceedings of the Twentieth National Industrial Energy Technology Conference* April: 198-207. Houston, Texas.: Energy Systems Laboratory, Texas A&M University.

Dorhofer, F. J. and W. M. Heffington. 1994. "Electrical Energy Monitoring in an Industrial Plant." *In Proceedings of the Sixteenth National Industrial Energy Technology Conference* April: 269-274. Houston, Texas.: Energy Systems Laboratory, Texas A&M University.

Ferland, Kathey. 2001. "Texas Industries of the Future." Conference presentation to *Energy Efficiency Strategies and Emerging Technologies to Achieve NO_x Reductions* July 18, 2001. Houston, Texas. Texas Industries of the Future, Center for Energy Studies, Austin, Texas.

Heffington, W.M. and J.A. Eggebrecht. 2001. "Extended Energy Assessments Supported by Monitoring." *In Proceedings of 2001 ACEEE Summer Study on Energy Efficiency in Industry* July: Volume 2, 339-350. Tarrytown, New York.: American Council for an Energy-Efficient Economy, Washington, D.C.

Heffington, W.M., F.J. Dorhofer, and D.R. Lewis. 1996. "Electrical Monitoring in a Metal Fabrication Plant." *In Proceedings of the National Industrial Efficiency Expo '96 and the Competitive Power Congress '96* August (1): 1-7. Somerset, New Jersey.: Association of Energy Engineers, Atlanta, Georgia.

Lewis, D.R., F.J. Dorhofer, and W.M. Heffington. 1995. "Further Findings Concerning Electrical Energy Monitoring in an Industrial Plant." *In Proceedings of the 17th Annual Industrial Energy Technology Conference* April: 86-91. Houston, Texas.: Energy Systems Laboratory, Texas A&M University.

Muller, M. R., C. Trabachino, and F. J. Glaeser. "User Information, Version 8.1." *The DOE Industrial Assessment Database.* January: The State University of New Jersey—Rutgers. Piscataway, New Jersey.

Office of Industrial Productivity and Energy Assessment. 2002. "Program Guidelines—Clients" Communication to IAC Directors from Field Manager. November. The State University of New Jersey—Rutgers. Piscataway, New Jersey.

Texas Natural Resource Conservation Commission. 2003. *State Implementation Plan,* Available: http://www.tnrcc.state.tx.us/oprd/sips/, [Date visited: April 19, 2003]

U.S. Department of Energy (A). *Best Practices,* Available: http://www.oit.doe.gov/bestpractices, Office of Industrial Technologies. [Date visited: January 31, 2003].

U.S. Department of Energy (B). *Industrial Assessment Centers,* Available: http://www.oit.doe.gov/iac, Office of Industrial Technologies. [Date visited: May 9, 2003].

U.S. Department of Energy (C). *Industries of the Future,* Available: http://www.oit.doe.gov/industries, Office of Industrial Technologies. [Date visited: January 31, 2003].

U.S. Environmental Protection Agency, Office of Atmospheric Programs, "Emission and Generation Resource Integrated Database (E-GRID2000), v. 2.0, 2001. http://www.epa.gov/airmarkets/emissions/index.htm, [Date visited, July 30, 2002].