Study of Energy Savings Generated by Clients of the Industrial Assessment Center Program

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ABSTRACT

The U.S. Department of Energy's Industrial Assessment Center (IAC) Program provides funding to operate 26 assessment centers located at engineering colleges across the U.S. These Industrial Assessment Centers assess energy, waste, and productivity activities at client manufacturing plants and generate recommendations for saving energy and reducing operating costs. The centers serve about 600 U.S. manufacturers with assessments each year, making five to ten separate recommendations, on average, per client. Assessment data, including implementation information collected within a year following the assessment, are recorded and maintained in a database at Rutgers University.

The purpose of this study was to examine IAC Program benefits to clients, including benefits beyond those currently identified in the IAC database. These include benefits generated by IAC clients through replications, delayed implementations, and spin-offs of assessment recommendations. While long-term client follow-up is part of the IAC Program's activities, it is mainly conducted for marketing purposes, and until recently, the effort did not include updating savings data in the database. This study was conducted through telephone interviews with a random sample of IAC clients, stratified by assessment fiscal year (FY). Only clients assessed between FY 92 and FY 99 were interviewed. Ratio estimates were developed to use as a basis for computing current savings estimates by adjusting original database data for all FY 92–99 clients. First, for sampled IAC clients, ratios of current (at interview) to original (at assessment) savings estimates were computed. These ratios were computed for each assessment fiscal year. For each fiscal year, the ratios were then multiplied by the savings estimates from the total original database for the entire population of clients for that fiscal year. Annual savings were then totaled to estimate current savings for clients served over a ten-year period.

The client follow-up interviews revealed that a significant amount of energy savings is not identified in the original savings estimates recorded in the IAC database. Additional savings include source energy savings from replicated measures (7.5 % above original), spin-off measures (17% above original) and measures previously identified in the database as unimplemented (18% above original). Furthermore, 22% of the assessment recommendations originally identified in the IAC database as unimplemented were actually implemented by IAC clients.

The results of this study will be used to quantify long-term IAC savings and adjust database savings estimates to account for the missing benefits. They will also serve as a basis for recommendations about IAC follow-up efforts in the future.

Introduction

The U.S. Department of Energy's (DOE's) Industrial Assessment Center (IAC) Program provides funding to 26 engineering colleges across the United States to conduct energy, waste, and productivity assessments for manufacturing plants within the respective regions of the colleges. Annually, more than 600 assessments are conducted by assessment teams comprising engineering students (upper-level undergraduate and graduate) and led by engineering faculty and staff. Each assessment generates five to ten recommendations for energy, energy cost, and waste and productivity cost savings customized for the particular client. Detailed data about assessment recommendations, including energy and cost savings data and implementation status are maintained in an IAC database at Rutgers University.

The purpose of this study was to quantify comprehensive lifetime cost and energy savings attributable to IAC assessments, including benefits not currently recorded in the IAC database. Clients sometimes generate additional benefits through delayed implementation, spin-offs of the original assessment recommendations, and internal and external replication. Spin-off measures are defined as energy savings actions taken as a result of the IAC assessment, but not included in the list of recommendations listed in the report. Internal and external replication occurs when energy savings recommendations (originally identified in the IAC report) are implemented elsewhere in the plant (internal) or at a related plant (external). This work expands upon an earlier Oak Ridge National Laboratory (ORNL) study (Martin et al., 1999), and the analysis approach used here follows recommendations in that report. In both studies, follow-up interviews were conducted with clients who had received assessments several years earlier. In addition to developing initial estimates for savings generated by the program, the earlier ORNL study identified opportunities for critical improvements in database record keeping, which would support future quality assurance efforts as well as measurements of program benefits.

The IAC Program database documents information on IAC assessments and individual assessment recommendations (ARs). Each AR within the database is originally classified as either implemented or unimplemented, and original energy and cost savings estimates (based on engineering calculations) for it are recorded. For the purposes of this study, however, ARs and savings due to them are classified into five types: originally implemented, originally unimplemented, internal replication, external replication, and spin-off.

The AR implementation designations "originally implemented" and "originally unimplemented" are recorded in the database at assessment completion on the basis of a client's indications of whether they intend to implement recommendations. The implementation information in the database is based on follow-up calls conducted by the centers nine to twelve months after assessments. Sometimes, however, plans for implementation are not carried out, or clients change their minds and decide to implement ARs that were originally rejected. Furthermore, ARs that were originally implemented may later be decommissioned. Thus ARs classified as "originally unimplemented" may currently be implemented, and ARs classified as "originally implemented" may currently be unimplemented. IAC clients sometimes also implement ARs elsewhere besides the original AR locations, either at another location in the assessed plant (internal replication) or at another plant related to the original plant (external replication). Clients also sometimes implement efficiency measures related to but different from the original ARs. Clients identify these "spin-off measures" as being inspired by their IAC assessment. At the time of the study, entries for either replicated or spin-off ARs were not recorded in the IAC database,

nor were updates made to record recommendations that were implemented or rejected after the first year following an assessment.

Part of the 1999 study was a literature review that included various energy impact evaluations, mostly from the electric power industry. These studies ranged from simple telephone or mail surveys to billing and on-site metering analyses. (See, for example, Van Liere et al. (1987); Conant and Schutte (1993); Dohrman, Rittenhouse, and Schiazza (1995); and Jacobsen et al. (1992).) Megdal and Pedersen (1998) discuss persistence and spillover in energy efficiency programs. Statistical methods for analyzing energy program savings have involved regression (e.g., Buller et al. 1993), analysis of covariance (e.g., Megdal, Paquette, and Greer 1995), and variance components analysis (e.g., Fagan et al. 1995, Ozog, Davis and Conant 1995). Pigg (1992) discusses the selection and use of control groups in energy impact evaluations, self-selection bias, and difficulties in matching participants and nonparticipants. The approaches and results from these studies were considered, along with the IAC requirements that the study be within the scope of ordinary IAC client follow-up, meet budget restrictions, and minimize imposition on clients. The resulting approach satisfied our technical and budgetary priorities by using slightly different statistical methods, omitting a control group analysis, and placing a broad limitation on the analysis of non-responders.

This paper describes the approach used in the study for follow-up with IAC clients. Presented next are discussions of the statistical accounting and computation of savings estimates from the study data. Finally, savings estimates are summarized. The methods and estimates for savings also apply to long-term AR implementation rates; these are also discussed. The results of this study suggest that net IAC savings extend well beyond those savings originally documented in the database. Furthermore, measure retention occurs beyond the seven-year limit previously considered to be a bound on savings persistence.

Approach to Follow-Up Interviews

In April and May of 2002, the University of Tennessee conducted follow-up interviews. The study's main goal was to quantify comprehensive lifetime cost and energy savings attributable to IAC assessments. A secondary goal was to quantify implementation rates for ARs as a function of number of years post-assessment.

The approach for follow-up interviews was based on the results of an ORNL pilot client study conducted as part of the earlier IAC impact investigation (Martin et. al. 1999). The pilot study demonstrated that savings attributable to the original assessment ARs tend to change over the years as originally unimplemented ARs are implemented, implemented ARs are decommissioned, and ARs are replicated or spun off. The pilot study also suggested that savings due to ARs might persist[1] over time and that measure retention lasts beyond the seven-year limitation.

Both the 1999 and 2002 studies were of randomly sampled IAC clients. Whereas the 1999 pilot study was completely random, however, the 2002 study was stratified by assessment FY. Stratification ensured better representation over a longer period, which allowed for more comprehensive estimates of

[1] Persistence is typically defined as a combination of measure retention (in years) and changes in energy savings over time. While follow-up interviews addressed both components, the study was not designed to distinguish between the two. Instead, the savings results were simply integrated into the overall analysis. A detailed persistence study, including examination of savings degradation rates by measure technology, was beyond the scope of this study.

lifetime savings. The 1999 study resulted in follow-up discussions with 42 IAC clients. The 2002 study generated responses from 63 additional clients; these responses were combined with the original 42 for this analysis.

The questions posed in both studies were nearly the same: clients were asked whether each of their original ARs was still (at the time of the interview) or ever was implemented, whether it was internally or externally replicated, and whether savings measures were "spun off" from it. Clients were also asked if or by when they would have implemented savings measures had the IAC assessment not been performed, and they were asked to provide current energy and cost savings estimates for still-implemented, original ARs, and for replicated and spin-off savings measures. Current savings were generally estimated as percentages of original engineering savings estimates, as documented in the AR database. Several questions about client satisfaction with the assessment program were also posed.

An engineer reviewed client-provided savings estimates, and all of the data were quality checked as part of the data analysis. In situations where measures were implemented via replication or spin-off, engineering estimates for savings were developed using client input regarding project scope. Savings for originally implemented but subsequently decommissioned measures were not counted towards IAC Program benefits. For the 2002 study, savings from measures that clients said they would have implemented anyway without the IAC assessment were not counted. The frequency of such measures was low, however. Of 269 originally implemented ARs, only 15 (or 5.6%) were discounted this way. Clients in the 1999 study were not asked to identify savings that would have been implemented anyway, therefore savings from the 1999 data may be overestimated by 5% to 6%, the rate found in the 2002 study data.

The response rate for the 2002 study was 20% (320 sampled, 63 interviews). Of the 257 non-responses from the client sample, however, only 50 (19%) were outright refusals, and only 16 (6%) were because of plant closures. The remaining 191 (74%) of the non-responses were due to inadequate contact information (e.g., out-dated telephone numbers, business names/addresses never properly recorded in documentation). Non-response can lead to biased estimates, because it may be associated with smaller savings at the time of the study—for example, because of poor client economic health or client dissatisfaction with the original IAC assessment. However, resources were not available for pursuing non-responders. Therefore, with 74% of non-response occurring simply from the lack of adequate contact information (which is not likely to be strongly influenced by savings potential), non-response bias is ignored, as an approximation, in the analysis presented here.

The 2002 client study was performed three years after the 1999 pilot study. In order to incorporate results from both studies into one analysis, the results were combined according to the number of years between client assessments and follow-up interviews. For example, clients in the 2002 study who received assessments in FY 98 were grouped with pilot (1999) study clients whose assessments were conducted in FY 95.

The combined numbers of clients sampled, for each assessment year, are shown in the third column of Table 1. Data from the two studies were combined to develop estimates based on all available data of site and source energy savings and energy and total cost savings attributable to IAC ARs.

Savings Estimates

Statistical analyses were performed for site and source energy savings, energy and total cost savings, and implementation rates. "Energy cost savings" refers to the dollar value of site energy savings. "Total cost savings" refers to the site energy cost savings plus dollar savings due to productivity and waste measures. Separate analyses were performed for each savings type, for each of the five AR types, and for each assessment FY (or number of years post-assessment at time of interview). Various savings summaries were then computed by totaling savings estimates over assessment FYs, AR types, or both. These savings summaries always refer to unique (i.e., mutually exclusive) classes, so no type of savings is ever counted more than once.

The basic approach in all of these analyses is to estimate the ratio of current savings to original savings for the sampled clients. This ratio can then be used to compute savings estimates for **any** client (not just a sampled client) by using the ratio to scale up or down the client's original savings estimate:

Estimate of Annual Savings *y* Years Out for Assessments Performed in *fy* =
(Original Savings Estimate for *fy* Assessments) × (Savings Ratio Estimate for *y* Years Out),

where *y* denotes a number of years, and *fy*, a particular FY. This method of estimation using ratios is a standard statistical technique (Cochran 1977, Chap. 6), for which valid standard errors, significance levels, etc., can be computed. (Standard errors were computed for the ratio estimates and used to interpret the results, but are not discussed further here.) Figure 1 illustrates the entire process of data collection and ratio estimate calculation.

Because only one year had elapsed between FY 01 assessments and the 2002 study, and because little follow-up information was available in the database on FY 01 AR implementations, FY 01 savings were assumed to be as reported in the database, and the savings ratios for FY 01 were assumed to be 1. The FY 01 original savings estimates listed in the tables are small because many of the FY 01 ARs that will in fact be implemented are not yet classified that way in the IAC database.

Table 1 shows site and source energy savings estimates computed for the "originally implemented" AR class. The last column of the last row of the table shows the ratio-adjusted total source energy savings estimate for originally implemented ARs from assessments performed FY 92–FY 01. This is 15,231,999 MMBtu, which is 82% of the 18,562,675 MMBtu total original source energy savings estimate (from the IAC database). Table 2 is like Table 1, except that it is for spin-off savings. Table 2 shows that 3,233,783 MMBtu is the ratio-adjusted total of spin-off savings estimates, which is 17.4% of the originally implemented total. Tables similar to Table 1 were also computed for energy and total cost savings, for all five AR types, and for implementation rates (originally implemented and unimplemented AR types only).

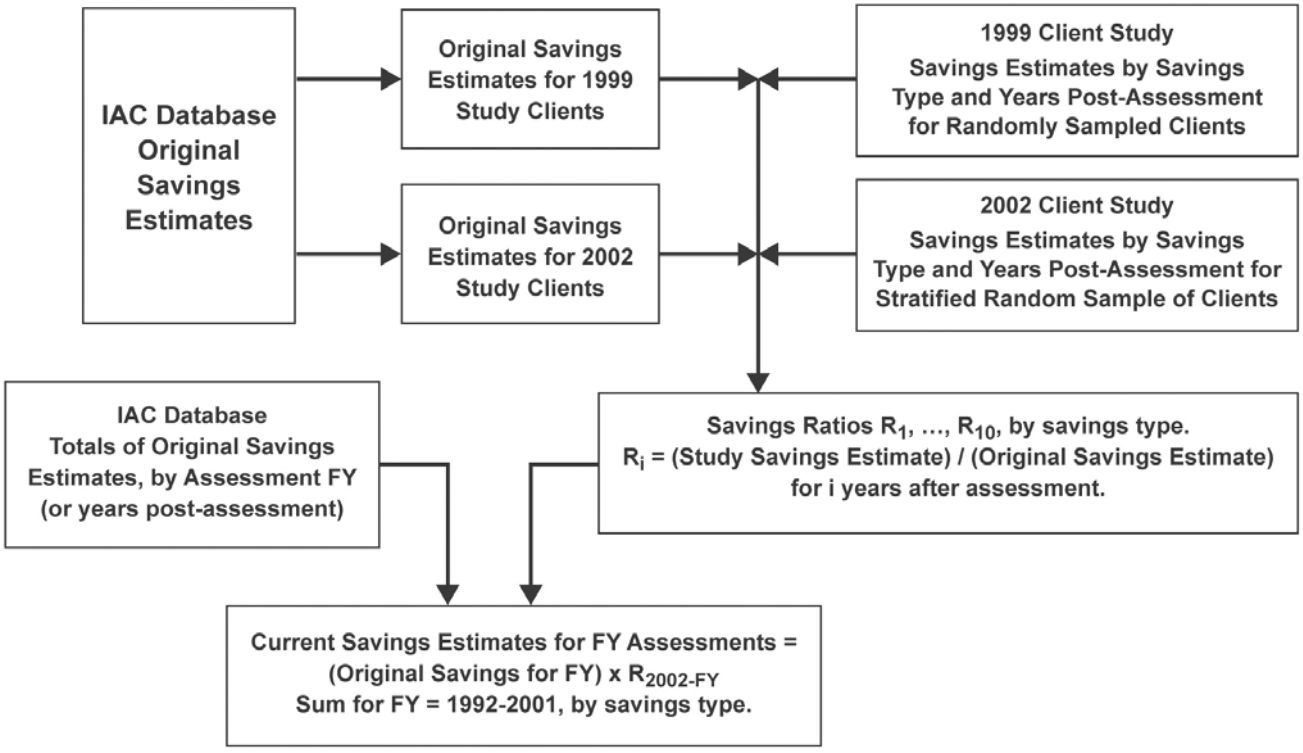

Figure 1. Schematic for data collection and calculation of ratio estimates.

Table 1. Originally Implemented Site and Source Energy Savings

Assess-ment FY	Years After Assess. (FY 02)	Combined Number of Clients Sampled	Site Energy Ratio, Present-to-Original	Original Site Energy Savings (MMBtu)	FY 02 Annual Site Energy Savings (MMBtu, Estimate)	Source Energy Ratio, Present-to-Original	Original Source Energy Savings (MMBtu)	FY 02 Annual Source Energy Savings (MMBtu, Estimate)
2001	1	0	1.00	113,560	113,560	1.00	165,008	165,008
2000	2	3	0.82	1,017,856	839,469	0.91	1,757,992	1,604,127
1999	3	18	1.00	1,305,239	1,304,768	0.91	2,080,526	1,901,300
1998	4	30	0.65	783,778	505,690	0.77	1,529,464	1,171,349
1997	5	20	0.79	957,608	761,283	0.81	1,746,334	1,421,345
1996	6	15	0.66	1,213,857	804,768	0.63	2,514,211	1,574,080
1995	7	5	0.77	1,263,115	976,043	0.77	2,531,500	1,959,920
1994	8	7	0.84	1,260,136	1,063,214	0.85	2,313,932	1,958,921
1993	9	3	0.98	1,153,213	1,132,491	0.98	1,888,848	1,854,908
1992	10	4	0.76	1,173,963	893,862	0.80	2,034,860	1,621,041
Total		**105**		**10,242,326**	**8,395,148**		**18,562,675**	**15,231,999**

Table 2. Spin-off Site and Source Energy Savings

Assess-ment FY	Years After Assess. (FY 02)	Combined Number of Clients Sampled	Site Energy Ratio, Present-to-Original	Original Site Energy Savings (MMBtu)	FY 02 Annual Site Energy Savings (MMBtu, Estimate)	Source Energy Ratio, Present-to-Original	Original Source Energy Savings (MMBtu)	FY 02 Annual Source Energy Savings (MMBtu, Estimate)
2001	1	0	0.00	113,560	0	0.00	165,008	0
2000	2	3	0.00	1,017,856	0	0.00	1,757,992	0
1999	3	18	0.02	1,305,239	25,866	0.03	2,080,526	67,631
1998	4	30	0.01	783,778	9,178	0.02	1,529,464	29,888
1997	5	20	0.20	957,608	192,609	0.30	1,746,334	529,411
1996	6	15	0.14	1,213,857	169,057	0.14	2,514,211	362,936
1995	7	5	0.04	1,263,115	48,340	0.05	2,531,500	116,131
1994	8	7	0.00	1,260,136	2,450	0.00	2,313,932	11,546
1993	9	3	0.76	1,153,213	872,428	0.78	1,888,848	1,475,663
1992	10	4	0.13	1,173,963	150,758	0.31	2,034,860	640,577
Total		**105**		**10,242,326**	**1,470,685**		**18,562,675**	**3,233,783**

Cumulative Savings over Assessment Years and AR Types

The results shown in Tables 1 and 2 were combined with the site and source energy savings estimates from the corresponding tables (not shown) for originally unimplemented ARs and for internally and externally replicated ARs. The combined ratio-adjusted totals are shown in Table 3. Similar tables were also compiled for energy cost savings, total cost savings, and quantities of implemented ARs. Table 3 shows that savings persist over time. The savings ratios for site and source energy (as well as energy and total costs) all remain close to 1, considering statistical error, for years five through ten from the assessment date. This indicates that savings are persisting, as measures are being retained beyond the previous program estimates of seven years, up to ten years following assessments.

Table 3. Total Site and Source Energy Savings by Assessment FY[a]

Assess-ment FY (*fy*)[b]	Years (*y*) After Assess. (FY 02)	Combined Number of Clients Sampled	Site Energy Ratio, Present-to-Original	Original Site Energy Savings (MMBtu)	FY 02 Annual Site Energy Savings (MMBtu, Estimate)	Source Energy Ratio, Present-to-Original	Original Source Energy Savings (MMBtu)	FY 02 Annual Source Energy Savings (MMBtu, Estimate)
2001	1	0	1.00	113,560	113,560	1.00	165,008	165,008
2000	2	3	1.01	1,017,856	1,027,084	1.12	1,757,992	1,975,695
1999	3	18	1.12	1,305,239	1,464,132	1.10	2,080,526	2,289,574
1998	4	30	0.79	783,778	621,703	0.89	1,529,464	1,365,619
1997	5	20	1.48	957,608	1,413,846	1.54	1,746,334	2,686,377
1996	6	15	1.15	1,213,857	1,399,562	1.05	2,514,211	2,636,929
1995	7	5	1.03	1,263,115	1,302,616	1.02	2,531,500	2,589,784
1994	8	7	0.88	1,260,136	1,108,497	0.94	2,313,932	2,166,910
1993	9	3	2.37	1,153,213	2,730,845	2.24	1,888,848	4,230,724
1992	10	4	1.07	1,173,963	1,252,128	1.51	2,034,860	3,077,347
Total		**105**		**10,242,326**	**12,433,973**		**18,562,675**	**23,183,968**

[a]Data combined from 1999 and 2002 studies. 1999 data not adjusted for "implemented anyway" status.
[b]Implementation data for 2001 assessments were incomplete at the writing of this report; ratios were assumed to be 1.

Table 4 contains components of ratio-adjusted site and source energy totals, computed by summing across FYs (or years after assessments) in Table 3. The last two columns of Table 4 also show corresponding totals for energy and total cost savings, and the second column of Table 4 shows implementation count estimates. These totals estimate savings for all of the unique savings types, for assessments performed up to ten years prior to the 2002 study.

From Table 4, based on the combined 1999 and 2002 studies, 22,460 ARs recommended in FY 92–FY 01 assessments are estimated to be implemented by FY 02. This is 98.7% of the 22,756 ARs (including FY 01) that were originally classified as implemented in the IAC database. Thus, although the mixture of implemented and unimplemented ARs changed, the overall implementation rate was about the same.

Of 4,655 ARs made in FY 01, only 245 were recorded as implemented at the time of this study, the remainder still pending follow-up and entry into the database. Ignoring the 4,665 FY 01 ARs, 48,513 ARs were recommended, of which 22,511 were originally recorded as implemented. This gives a combined original implementation rate of 46%. Of the 22,511, 17,260 (17,505–245) or 77% are estimated as still implemented. Many originally implemented ARs were decommissioned or later rejected by clients. On the other hand, among originally unimplemented ARs, 4,955 are estimated to have been subsequently implemented. This represents an increase of 22% above the 22,511 that were originally implemented.

Table 4. Ratio-Adjusted Estimates of Cumulative Cost and Energy Savings by Savings Type—FY 92-01[a]

Savings Type	Total Number of Implemented ARs (Estimate)	Annual Site Energy Savings (MMBtu, Estimate)	Annual Source Energy Savings (MMBtu, Estimate)	Annual Energy Cost Savings ($, Estimate)	Annual Total Cost Savings ($, Estimate)
Originally Implemented	17,505	8,395,148	15,231,999	91,959,420	188,137,751
Originally Unimplemented	4,955	1,732,862	3,328,704	19,288,544	42,226,630
Internal Replication		379,212	709,370	5,258,403	9,062,899
External Replication		456,065	680,113	2,451,109	6,378,968
Spin-off		1,470,685	3,233,783	24,547,845	29,178,947
Total	**22,460**	**12,433,972**	**23,183,969**	**$143,505,321**	**$274,985,195**

[a] Estimates from results of 2002 and 1999 Pilot Client Studies (105 Clients).

Figure 2 shows the composition of currently implemented ARs in terms of their original implementation statuses. This reflects the Table 3 estimates of the numbers of implemented ARs as percentages of the total (22,460) currently implemented. Figure 2 illustrates that a substantial number (22.1%) of ARs originally classified as unimplemented do in fact become implemented in the long term. Conversely, 77.9% of ARs identified in the database as originally implemented were actually implemented at the time of the follow-up contact. This shift away from implementation was due to measure decommissioning or delayed AR rejection after the initial follow-up call conducted by centers.

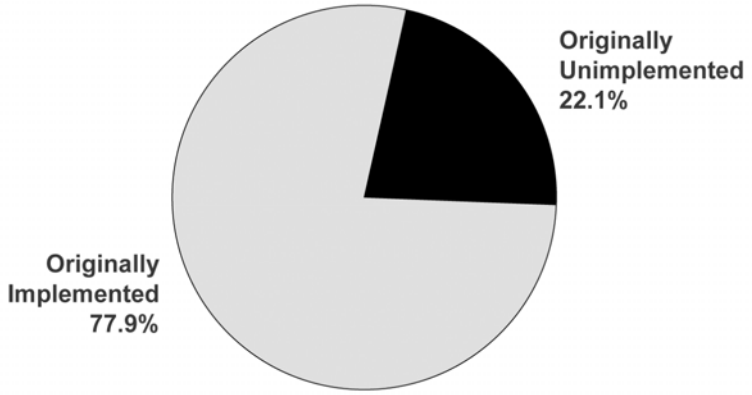

Figure 2. Percentages of currently implemented ARs by original implementation status.

For the ten-year cumulative ratio-adjusted estimates of energy savings, Figure 3 shows the composition of source energy savings in terms of the five savings types, that is, the estimates of ratio-adjusted source energy savings as percentages of the total (23,183,969 MMBtu) by savings type. Although most of the adjusted source energy savings are from originally implemented ARs, substantial contributions are also from spin-offs, replications, and implementations of originally unimplemented ARs.

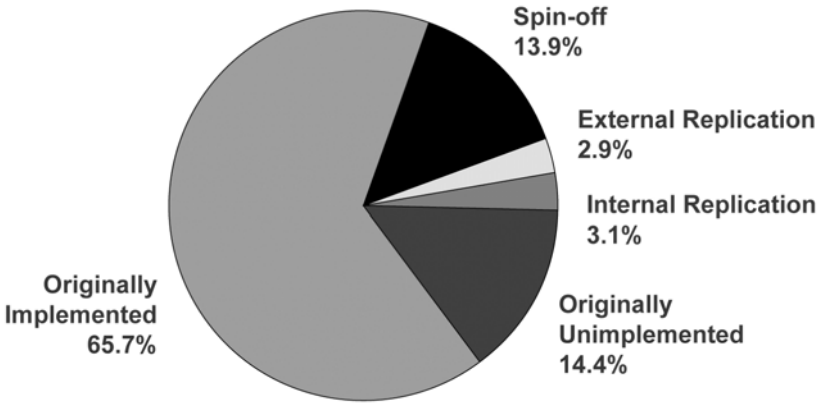

Figure 3. Components of ratio-adjusted estimates of total implemented source energy savings.

Site energy, energy cost, and total cost savings occur in about the same relative proportions, by savings type, as source energy savings. For example, 66% of adjusted source energy savings and 64% of adjusted energy cost savings are due to originally implemented ARs; 14% of adjusted source energy savings and 13% of the adjusted energy cost savings are due to originally unimplemented ARs that were subsequently implemented; 6% of adjusted source energy savings and 5% of adjusted energy cost savings are due to either internally or externally replicated ARs; and about 14% of the adjusted source energy savings and 17% of the adjusted energy cost savings are due to spin-off measures.

The purpose of the ratio approach is to adjust savings identified in the database to include benefits of replication, spin off and delayed implementation (or delayed rejection).[2] Originally implemented source energy savings from 1992 through 2001, documented in the database, were 18,562,675 MMBtu. Using adjustment ratios to account for other benefits raises the cumulative source energy savings to 23,183,969 MMBtu, an increase of 25%. The breakdown of the 25% increase is as follows: 17.4% increase from spin-off ARs, 3.8% increase from internally replicated ARs, 3.7% increase from externally replicated ARs, 17.9% increase from delayed AR implementation, and an 18% decrease from ARs that were decommissioned or rejected after the initial follow-up call.

Conclusions

Long-term follow-up with 105 IAC clients who received assessments from 1992 through 1999 identified additional source energy savings, energy cost savings, and total cost savings beyond those recorded in the IAC Program's database. Until recently, follow-up information in the program database was limited to that collected within a year after an assessment, despite the occurrence of continued, long-term relationships between the centers and their clients. The study identified additional benefits resulting from delayed, replicated, and spin-off implementation of IAC ARs as well as penalties from delayed rejection and decommissioning of ARs. The results of the follow-up discussions with the

[2] These adjustment factors will be used temporarily until more robust follow-up information on replication, spin-off, and delayed implementation is directly entered into the database, by centers, over time.

sample of clients were used to generate current-to-original savings ratios, which were then used to adjust database savings to account for the additional benefits and penalties.

The study identified an increase of 25% of source energy savings over savings documented in the database over a ten-year period. Of this 25%, 17.9% of annual source energy savings were generated by measures implemented well after the initial IAC 12-month follow-up, spin-off measures generated a 17.4% increase, replicated measures (internal and external to the plant) generated a 7.5% increase, and rejected or decommissioned measures decreased savings by 18%. Also, current-to-original savings ratio estimates calculated as part of the statistical analysis suggest that savings from implemented ARs tend to persist for at least ten years from their original implementation date, and that savings therefore tend to accumulate, on a relatively constant basis, over that time.

The IAC Program has already addressed several recommendations based on the findings of the study. (1) Client contact information will be better recorded initially, and kept current for improved follow-up. A major reason for non-response in the two IAC client studies was inadequate client contact information (e.g., changes in area codes). (2) Because the implementation status of recommended measures may change over time, client follow-up will be encouraged for reasons beyond marketing relationships (e.g., efforts to improve implementation rates are being undertaken) and any new implementation information culled from long-term interaction from clients will be included in the IAC Program database. Notice that this, together with better maintenance of client contact information, will largely address the problem of non-response. (3) Clients will be asked about replicated and spin-off implementation of measures during all follow-up discussions. If a client identifies such measures, savings will be estimated and entered directly into the IAC database.

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